ECONOMIC ANALYSIS OF ALTERNATIVE CATTLE BREEDING SYSTEMS WITH RETAINED OWNERSHIP THROUGH THE STOCKER AND FEEDER PHASES

By

RANDALL DEAN LITTLE

Bachelor of Science in Agriculture
New Mexico State University
Las Cruces, New Mexico
1982

Master of Science
University of Illinois
Urbana, Illinois
1985

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
December, 1990

ECONOMIC ANALYSIS OF ALTERNATIVE CATTLE
BREEDING SYSTEMS WITH RETAINED
OWNERSHIP THROUGH THE
STOCKER AND FEEDER
PHASES

Thesis Approved:

Odell L. Walker
Thesis Adviser

James N. Trapp

Harry P. Mapp

Keith S. Lusby

David J. Bernardo

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

My first thanks go to Dr. Odell L. Walker, my major adviser. Dr. Walker provided valuable advice, guidance, and encouragement that helped not only in my graduate program, but in other aspects of life as well. I count it an honor to have been his advisee.

I also appreciate the contributions made by the members of my advisory committee: Dr. James N. Trapp, Dr. Harry P. Mapp, Jr., and Dr. Daniel J. Bernardo of the Department of Agricultural Economics and Dr. Keith S. Lusby of the Department of Animal Science. Their helpful suggestions and constructive criticism kept me on the right track. I would also like to thank Dr. James E. Osborn and the Department of Agricultural Economics for the financial assistance provided during my graduate study.

I am especially indebted to Dr. David S. Buchanan of the Department of Animal Science. He devoted much time to my cause, helping me understand the method used to develop animal performance estimates for the crossbreeding systems.

Several other individuals deserve recognition for their contributions to this project. Fred Schmedt of the Noble Research Foundation and A. L. Hutson, Area Extension Economist, in Duncan, helped me design the representative ranch. They provided useful suggestions and ideas during the planning of this project. Michael Ray, formerly a feedlot consultant with Purina Mills, reviewed my feedlot performance assumptions to verify their realism. Janet Barnett also deserves thanks for her efforts preparing the final draft. Her contributions have been invaluable.

My deepest appreciation goes to my family. My wife, Dulcy, and children, Jonathan and Christi, are the true champions. Dulcy was a main source of strength and encouragement. Her support way undying, even in the worst of times. I am glad she is my life partner. Jonathan and Christi helped me keep a proper perspective throughout this whole process. A man could not ask for better. My Dad, Howard Little, and my sisters, Gayle, Paula, Vannetta, and Rayna, also were loyal sources of encouragement, always ready to lend an ear (or whatever I needed) to help me through.

I would be terribly remiss if I failed to thank God for His help, guidance, and provision during my graduate program. My objective has been to glorify Him through my attitude and performance. Mostly, I thank Him for His free gift of salvation, offered through His Son, Jesus Christ.

Finally, I dedicate this dissertation, with all the effort it required and the accomplishment it represents, to the memory of Christine J. Little, March 6, 1932 to July 4, 1987. By word, but mostly by example, she challenged me to reach high and she helped instill in me the tenacity and will to keep reaching, until the goal was attained. This one's for you, Mom. I miss you.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table		Page

Table | Page

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Cattle producers are frequently exhorted to increase productive efficiency to remain competitive (Trapp 1985; Johnson et al. 1989). A key to increasing efficiency is the adoption and use of the most efficient, yet economically feasible, production technology available. Perhaps the most critical technology-related decisions a cow-calf producer makes regard the cow herd. The producer must select the best breed or breed combination and breeding system for his or her operation, within limitations imposed by available resources.

The producer must identify product characteristics that offer the greatest economic potential for his or her production situation. Numerous possibilities exist from breeds and breed combinations available. What type of product (the calf) is needed? Should a producer selling weaned calves use different product criteria than one retaining ownership through finishing? Desired calf type influences decisions regarding cow size and milk production, bull type, and breeding system.

Calf performance is strongly influenced by the genetics contributed by parental breeds and by the dam's milk production potential. However, breed selection must be performed within the confines of the resources available to the operation. Thus, desired product characteristics are also constrained by the operation's resource base and production potential. Is it economical for a producer to maximize production by selecting the largest beef breeds available? The producer must select an optimal cow size and milk production potential for the nature and amount of resources.

Added to these production decisions are the marketing decisions the producer faces. When is the best time to sell the calves? Producers have the opportunity to retain ownership of calves as stockers or feeders. Is retained ownership a viable production and marketing alternative? Will plans involving retained ownership, which require more capital than selling weaned calves, cash flow? Do alternative crossbreeding systems producing calves of differing frame size have different optimal production and marketing plans? These decisions have a direct influence on the productivity, efficiency, and ultimately, the profitability of the operation.

Objectives

A rich pool of breed performance data on a variety of beef breeds, along with animal science research on beef production potential using those breed data, has been developed over the past 20 years. Research evaluating the ranch-level economic implications is needed.

Producers need factual information about breeding programs and alternative production and marketing plans to assist their decision making, rather than a neighbor's off-the-cuff recommendations or conversation overheard in the sale barn. Livestock producers operate in an environment characterized by much price and production uncertainty. Because of the volatile nature of returns from cattle production, producers also need information about the entire range of possible returns. The goal of this research is to provide that information. The research effort focuses on cattle producers in

Oklahoma, but has general application to most producers in the Southern Plains.

The objectives of the research are to:

1. Estimate animal performance for alternative cattle breeding systems using existing breed performance data.

2. Compare profitability of alternative breeds and breeding systems in a whole ranch setting.

3. Identify the potential impact of retained ownership on the ranch plan and profitability.

4. Determine the influence of the firm's financial position on the decision to retain ownership.

5. Generate a distribution of returns for selected breeding systems with retained ownership options in a risky environment.

The objectives will be addressed in two phases. First, a static analysis, assuming perfect knowledge, of each breeding system considered will be conducted. The first four objectives will be addressed in the static analysis. The second phase is the risk analysis, in which a simulation modeling approach will be used to generate a distribution of returns for select breeding systems and ranch plans.

The Live Beef Production Process

The production of live animals for beef can be divided into three phases, the cow-calf phase, stocker phase, and feeder phase. Commercial cow-calf operations comprise the first segment of the beef production process. These operations maintain breeding herds for the purpose of producing weaned calves weighing between 300 and 600 pounds. The importance of cow-calf operations rests chiefly upon the conversion of coarse forage and grass into palatable and nutritious food for human consumption. Cow-calf operations are especially adapted to regions where pasture is plentiful and land is cheap (Ensminger 1987).

The second phase in producing live animals for beef is the stocker phase. Stocker operations typically involve weaned calves which are fed and managed for growth prior to feedlot finishing. Stocker operations produce feeder steers and heifers, most of which are 12 to 20 months old, weighing 500 to 900 pounds. The key traits of economic importance to a stocker operation are rate of gain and adaptability (Taylor 1984).

Three typical stocker programs are considered in this study. The first two involve grazing winter wheat pasture through the winter. In the first program, wheat pasture stockers graze wheat from weaning in the fall to mid-March. The stockers are removed prior to the jointing stage in the wheat plants' developmental process so the wheat can be harvested for grain without significantly affecting wheat yields. In the second stocker program, grazeout wheat pasture stockers graze wheat pasture through mid-May. Stockers graze an average of 114 days on wheat pasture to be harvested for grain and 171 days on grazeout wheat pasture in Western Oklahoma (Walker et al. 1988).

In the third stocker program considered, year-round stockers are fed a high roughage ration (including pasture if available), sufficient for maintenance through the winter, then placed on summer pasture during the following summer. Calves fed in such a manner through the winter have a high compensatory gain; their capacity for growth on summer pasture is greater than calves fed a high energy ration in the winter. This stocker program lasts about 330 days.

The third segment is feedlot finishing. In this phase, the cattle are fed high concentrate rations in a confined feedlot to attain rapid weight gain and increase market desirability. The cattle are fed to slaughter weight and then sold to packers who slaughter and process the beef. The key traits of economic importance in the feeder phase include the rate of gain and feed conversion efficiency.

Retained Ownership

Retained ownership is defined as maintaining ownership of calves beyond weaning into subsequent phases of the live beef production process. A large number of opportunities for retained ownership exist. The retained ownership alternatives available to a spring calving operation in this study are illustrated in Figure 1. The producer can sell at weaning in the fall or retain ownership of stockers or feeders. The producer has the option to place his calves directly into the feedlot at weaning. The stocker retention alternatives were discussed in the previous section. At the end of a stocker program, the producer can sell the stockers or place them in a feedlot for finishing.

Cattle producers have several incentives to retain ownership. They attempt to capture profits that may be realized in subsequent phases of the live beef production process. Retained ownership may allow producers to capture more benefits of a progressive breeding program, improved performance, for example. It also provides valuable animal performance information, which can be used to better plan a breeding program.

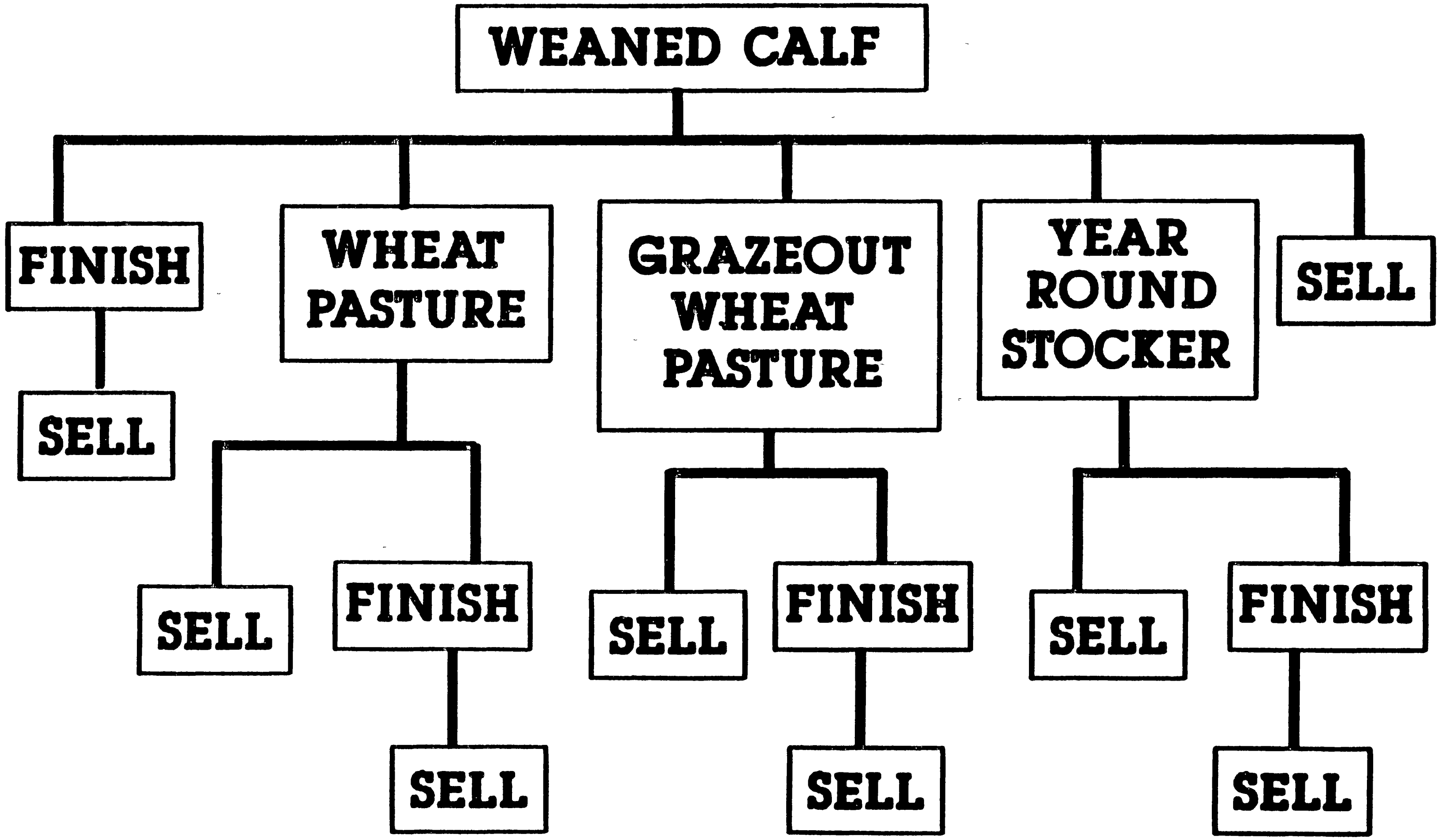


Figure 1. Retained Ownership Alternatives Available to a Spring Calving Operation in this Study

Justification of Research

Beef production is a critical component of the agricultural industry in Oklahoma. Historically, the value of cattle and calves has dominated the total value of production of all commodities and livestock in Oklahoma (Figure 2); 1989 was no exception. The value of production of cattle and calves was over $1,843 million, far above winter wheat, which ranked second (Oklahoma Agricultural Statistical Service 1990).

Cattle and calves on Oklahoma farms and ranches totaled 5.2 million head on January 1, 1989. The average inventory value of $545 per head gave a total value of all cattle and calves in the state of $2.83 billion. There were two million cows in Oklahoma on January 1, 1989, of which 94.65 percent were beef cows (1.9 million head) and the remainder dairy cows (Oklahoma Agricultural Statistical Service 1990).

These statistics demonstrate the importance of cattle production and specifically cow-calf operations to the agricultural sector and ultimately Oklahoma's economy. The monetary importance, coupled with the need to increase the competitiveness of the beef sector, emphasize the need for research evaluating alternative production and marketing strategies available to producers.

Organization of Remaining Chapters

Theoretical considerations underlying the study and a review of pertinent literature are presented in Chapter II. Data for the base situation and the base linear programming model are presented in Chapter III.

A brief review of crossbreeding and the development of the alternative breeding systems and their performance and resource requirement

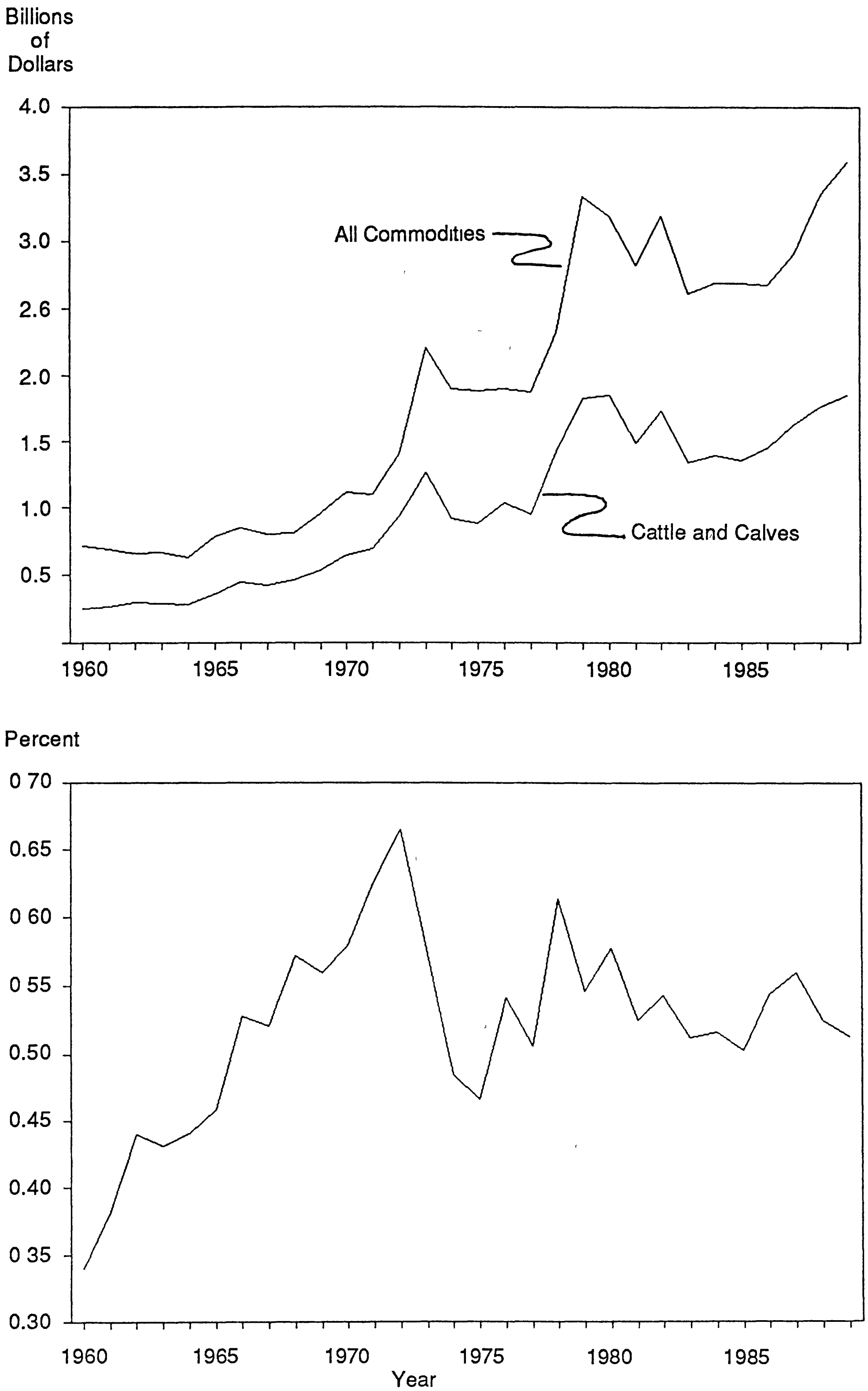


Figure 2. Value of Production of Cattle and Calves in Oklahoma, in Dollars and as a Percent of the Total Value of All Commodities and Livestock

assumptions are presented in Chapter IV. Chapter V contains discussion of the results of the static analysis.

The risk analysis, its justification, method, and results are discussed in Chapter VI. Finally, the summary, conclusions, and suggestions for further research are presented in Chapter VII.

CHAPTER II

THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW

The primary objective of this study is to provide information to cattle producers about the economic performance of alternative cattle breeding systems with retained ownership. Theoretical considerations underlying the selection of the optimal breeding system and the optimal retained ownership strategy are discussed in this chapter. Also, a review of the literature pertinent to these broad topics is presented.

The Multiproduct Problem

Selection of the best cattle breeding system from a number of alternative systems is a type of multiproduct problem. In this case, the products are different calf types produced in alternative breeding systems. Differing characteristics include frame size, muscling, and condition (body fat). These traits are heavily influenced by the genetics contributed by the parental breeds. Frame size and muscling are especially influenced by the sire breed in crossbreeding systems. Condition is markedly influenced by the milk production potential of the cow.

The following theoretical presentation draws heavily on Beattie and Taylor (1985, p. 206-209). The multiproduct problem formulation which best describes the choice among breeding systems facing livestock producers is one in which the producer maximizes profit. The producer's objective is to maximize profits, Π,

$$\Pi = \sum_{j=1}^{m} P_j Y_j - \sum_{i=1}^{n} r_i x_i \tag{1}$$

where P_j is the output price of the jth output, Y_j, and r_i is the input price of the ith input, x_i; subject to a set of constraints on the amount of resources available,

$$X_i^o - \sum_{j=1}^{m} X_{ij} = 0 \qquad \text{for } i=1, \ldots, n \tag{2}$$

which for all X and Y is contained in the implicit production function

$$F(X_1, \ldots, X_n, Y_1, \ldots, Y_m) = 0 \tag{3}$$

The Lagrangean to the problem is

$$L = \sum_{j=1}^{m} P_j Y_j - \sum_{i=1}^{n} r_i x_i + \lambda F(X_1, \ldots, X_n, Y_1, \ldots, Y_m) \tag{4}$$

The first order partials set equal to zero yield

$$\frac{\partial L}{\partial Y_j} = P_j + \lambda \frac{\partial F}{\partial Y_j} = 0 \qquad \text{for } j=1, \ldots, m \tag{5}$$

$$\frac{\partial L}{\partial X_i} = -r_i + \lambda \frac{\partial F}{\partial X_i} = 0 \qquad \text{for } i=1, \ldots, n \tag{6}$$

$$\frac{\partial L}{\partial \lambda} = F(X_1, \ldots, X_n, Y_1, \ldots, Y_m) \tag{7}$$

The product-product first order conditions can be obtained from the m equations in (5),

$$\frac{P_j}{P_k} = \frac{\partial F/\partial Y_j}{\partial F/\partial Y_k} \qquad \text{for } j, k = 1, \ldots, m \qquad (8)$$

which, by the implicit function rule, gives

$$\frac{P_j}{P_k} = -\frac{\partial Y_k}{\partial Y_j} \equiv \frac{MR_j}{MR_k} = RPT_{jk} \qquad \text{for } j, k = 1, \ldots, m \qquad (9)$$

where MR_j is the marginal revenue from selling output Y_j and RPT_{jk} is the rate of product transformation between the two outputs, Y_j and Y_k. RPT_{jk} is the slope of the product transformation curve, which represents all possible output combinations that can be obtained from a given amount of resources.

The factor-factor first-order conditions can be obtained from the n equations in (6),

$$\frac{r_i}{r_l} = \frac{\partial F/\partial X_i}{\partial F/\partial X_l} \qquad \text{for } i, l=1, \ldots, n \qquad (10)$$

which, by the implicit function rule, gives

$$\frac{r_i}{r_l} = -\frac{\partial X_l}{\partial X_i} \equiv \frac{MFC_i}{MFC_l} = RTS_{il} \qquad \text{for } i, l=1, \ldots, n \qquad (11)$$

where MFC_i is the marginal factor cost, the cost of a unit of input X_i and RTS_{il} is the rate of technical substitution between inputs X_i and X_l, which is the rate at which one input must be substituted for the other to keep output constant.

The factor-product first-order conditions can be obtained by combining the jth equation in (5) and the ith equation in (6),

$$-P_j \left[\frac{\partial F/\partial X_i}{\partial F/\partial Y_j}\right] = r_i \qquad \text{for } i=1, \ldots, n \quad j=1, \ldots, m \qquad (12)$$

which, by the implicit function rule, gives

$$-P_j\left(\frac{\partial Y_j}{\partial X_i}\right) = r_i \equiv MVP_{ij} = MFC_i \qquad \text{for} \quad i=1, \ldots, n \quad j=1, \ldots, m \tag{13}$$

where MVP_{ij} is the marginal value product of using input X_i to produce Y_j. Thus, (13) implies that, at the point of profit maximization, no matter where used, the increase in returns from using the last unit of input X_i must exactly equal its cost.

The second-order conditions for profit maximization require that the relevant principal minors of the bordered Hessian alternate in sign, beginning with positive (Beattie and Taylor, 1985, p.209). Additionally, at the point of profit maximization, profit must be greater than zero.

The cattle producer in this study is assumed to maximize profit, subject to the operation's resource constraints. The resource constraints include land, labor, capital, and management. Land constrains a cattle operation not only by its availability, but also by its forage or feed production capabilities. Land varies in quality, thus forage production potential differs across land types. Forage production also varies within land types, due to managerial practices.

The profit-maximizing level of production is achieved with the least cost combination of inputs. For example, a cow must receive adequate nutrition to be productive. A producer can meet those needs in a number of ways. However, to maximize profit, the least cost combination of feedstuffs must be used to meet the cow's requirement.

At the point of profit maximization, the returns from using the last unit of an input (marginal revenue) just equal the cost of that unit (marginal costs). For example, when profits are maximized, the cost of producing the last unit of forage will equal the additional returns gained from increased production by employing the last unit of forage. Enterprises with higher returns can support the use of more intensive (and expensive) forage production.

Linear Programming

Linear Programming (LP) is the most common and widely used whole farm planning technique. It is an appropriate tool for solving the multiproduct problem described above and the intermediate-product problem, where one output can either be sold or used as an input in the production of another product. LP solves the product-product problem, the factor-factor problem, and the factor-product problem.

LP typically deals with the problem of allocating limited resources among competing activities in the best possible or optimal way. This problem of allocation can arise whenever one must select the level of certain activities that compete for scarce resources necessary to perform those activities (Hillier and Lieberman, 1980). In its simplest form applied to agriculture, LP is a method of determining a profit maximizing combination of farm enterprises that is feasible with respect to a set of fixed farm constraints (Hazell and Norton, 1986).

The mathematical formulation of the LP problem is

$$\text{Maximize } Z = \sum_j c_j X_j \tag{14}$$

subject to

$$\sum_j a_{ij} X_j \leq b_i, \quad \text{for } i=1, \ldots, n \tag{15}$$

and

$$X_j \geq 0, \quad \text{for } j=1, \ldots, m \tag{16}$$

where X_j is the level of the jth activity, c_j is the expected gross margin or profit of a unit of the jth activity, a_{ij} is the quantity of the ith resource required to produce one unit of the jth activity, and b_i is the amount of the ith resource available. The LP problem is to find the farm plan (defined by a set of activity levels, X_j, j=1,...,m) that has the largest possible profit, Z, but which does not violate any of the fixed resource constraints, or involve any negative activity levels (Hazell and Norton, 1986).

Data needs for an LP model can be extensive. For the problem addressed in this study, the c_j's include output prices for each sex and weight class of cattle to be sold, the per head or per acre expense involved in each production activity, and other per unit costs, such as for hired labor and borrowed capital. The b_i's reflect the maximum amount of the resources the firm has available to use in production.

Data necessary for the a_{ij}'s can be divided into two broad categories, resource requirements and production. The resource requirements include forage, labor, and capital.

The production a_{ij}'s include sale weights of each class of livestock to be sold in the livestock activities and the forage produced in the forage activities. Production in the animal activities is influenced by rate of gain, death loss, and shrink. Forage production is influenced by season of the year.

Studies of Alternative Breeding Systems/Cow Types

Several studies have considered alternative breeding systems or cow types. In related studies, Stokes et al. (1981 and 1986) developed a method for incorporating biological simulation results into an economic model to evaluate performance of spring calving cow herds that differ in terms of potential cow size and milk production. In the earlier study, the producer had the option to retain ownership of all or part of the calves. In the latter study, the calves were sold in one of two weaning policies, wean all on November 1 or part on October 1 and the remainder on December 1.

Both Stokes studies concluded that economic performance was improved during the study periods by decreasing milk production and increasing mature cow size in the herd. They cited several factors which contribute to these results. Conception rates increased slightly as mature size increased and milking potential decreased. Price discounts were associated with improved calf condition which resulted from increased milk production. Heavier milking cow types had increased feed costs, so that benefits of higher production were offset by the higher cost of milk production.

Wilton et al. (1974) developed a linear programming (LP) model to investigate the effect of changing management and biological parameters in purebred herds of three mature cow sizes. Their primary purpose in the study was to develop a method for applying the LP technique to a vertically integrated cow-calf operation. Given their assumptions, their results indicated that enterprise returns ranked in the same order as cow size. Returns per unit of output or per unit of animal resource were, however, almost constant.

Using the method and assumptions developed by Wilton et al. (1974), Morris and Wilton (1975) evaluated the influence of mature cow weight on the economic returns from various beef cattle operations under different management and input/output price scenarios. Their results indicated that with average and lower feed prices, returns increase as cow size increases, but at high feed prices, small cows are optimal for smaller operations, while intermediate-sized cows are optimal for larger operations. They also found that with average or high beef prices, returns increase as cow weight increases. However, the inverse occurs when low beef prices prevail in the marketplace.

Wilton and Morris (1976) used Wilton et al.'s (1974) basic methodology to compare crossbreeding systems at different reproductive rates, heterosis estimates, cow weights, beef-to-feed price ratios, and resource availability levels. They concluded that terminal sire systems generated higher returns at the farm level than straight breeding or rotational crossing, due to better use of farm resources. In general, larger cows yielded higher returns in the crossing systems examined.

McMorris et al. (1986a and 1986b) evaluated in a deterministic framework, biological and economic performance of herds of different cow weights and milk yields. The breeding systems included two purebred systems, a four-breed large rotational beef system, a four-breed small rotational dual purpose system, and a three-breed small rotational beef system. They found that at average or high beef-to-feed price ratios (B:F), systems that yielded high output generated higher returns, while at low B:F, systems producing smaller calves were slightly more profitable. They also found the effect of cow weight highly dependent on B:F. At low B:F, cow weight had a negative effect on returns. However, the effect became positive and increased as B:F increased. The effect of milk yield was also highly dependent on B:F, changing from negative to positive as B:F increased. As feed costs decreased, it became economically beneficial to increase calf weight gain through increased milk yield.

Notter et al. (1979) used a deterministic simulation model to study the effects of crossbreeding on the biological and economic efficiency of beef production for a Midwestern cow-calf-feedlot management system. The systems simulated included two- and three-breed specific crossing, two- and three-breed rotational crossing, and two- and three-breed combined rotational-terminal sire crossing. They concluded that economic efficiency, as measured by total production costs per 100 kilograms of ending body weight, increases in systems that utilize individual and maternal heterosis. Systems which used large terminal sire breeds coupled with attempts to minimize calving problems also were more economically efficient than systems which did not. However, cost of production alone is a poor economic performance measure.

Cartwright et al. (1975) used simulation modeling to evaluate the net effects of heterosis, complementarity, and size on production efficiency in closed, self-contained herds employing two-breed, rotational, and three-breed crossing systems. They found rotational systems with breeds of similar size more profitable than purebred systems of those breeds. They also found that terminal sire systems have the greatest profit potential, both in terms of net income and return on investment. Cartwright et al. concluded that heterosis and complementarity consistently added to net efficiency, but the cow size effect varied, depending on the nutritional management system. When cow herd nutrition was relatively more expensive, smaller cows were less efficient due to less efficient maintenance per unit of body weight.

Risk

Livestock producers, like other agricultural producers, operate in an environment characterized by extreme production and price uncertainty. Recognition of the risks producers face is important in research since the presence of risk may alter producers' decisions relative to what is defined as optimal by static production theory under perfect knowledge.

Robison and Barry (1987) distinguish between risk and uncertainty as follows. Uncertainty exists when alternative actions have multiple possible outcomes, depending on the occurrence of random events. Risk exists when those uncertain events have the potential to alter the decision maker's material or social well-being. This definition implies that risky events form a subset of uncertain events. The decision maker's response to nonrisky outcomes is indifference. Only risky events have significance. Farmers face two broad types of risk on economic outcomes, business and financial (Gabriel and Baker 1980).

Business Risk

Business risk is defined to be the risk inherent in the firm, independent of the way it is financed. Business risk, generally reflected in the variability of net operating income or net cash flows, includes those sources that would be present with 100 percent equity financing (Boehlje and Eidman 1984).

Two major external sources of business risk trouble the agricultural firm (Gabriel and Baker 1980). One is market or price risk, which results from price variability for both outputs and inputs and uncertain availability and quality of the latter. Price movements of a seasonal, cyclical, and trend nature are predictable to some extent, but the inability of the decision maker to predict these prices accurately in making decisions represents a source of business risk (Eidman 1985).

The second major source of business risk is production risk. Production risk results from the biophysical environment, beyond producer control. Production risk is reflected in variability of yields per acre, weaning weights, rates of gain, death loss, and other variables used to measure physical production.

Financial Risk

Financial risk is the added variability of net cash flows or of owner's equity that results from the fixed financial obligation associated with debt financing and cash leasing (Gabriel and Baker 1980). Financial risk results from leverage. Leverage multiplies potential financial return or loss generated by different production and price levels.

Financial risk, which deals primarily with the firms' ability to meet total creditor claims, increases as leverage increases. The effects of farm business risks are magnified considerably by the increase in financial risk when leverage increases (Barry, Hopkins, and Baker 1988). Financial risk also includes uncertain loan availability, and fluctuating interest rates, which reflect the price of debt capital.

Potential sources of risk facing a farmer or rancher are summarized in Figure 3.

Risk Management

Halter and Dean (1971, p.9) specify seven components of a decision model under uncertainty: (1) alternative actions that can be taken; (2) states of nature which could occur; (3) consequences (payoffs) of each combination of action and state of nature; (4) probability of each action; (5) available strategies telling the decision maker which action to take, given (4); (6) consequences of each strategy for each state of nature; and (7) a decision rule or criterion for evaluating alternatives and making the final choice.

In contrast to the perfect knowledge case, explicit specification of uncertain events, those beyond decision maker control, is a major addition to

Potential Sources of Risk:

An uncertain final product price
An uncertain intermediate product price
An uncertain future price for its stored intermediate product
Storage costs
Uncertain input prices
The price of borrowed funds used by the firm, and implicitly the return on unused borrowed funds or credit
The input-output relationship between the final product and the intermediate product
The input-output relationship between the intermediate product and the inputs
The input-output relationship between its debt capital plus borrowing capacity and its internal equity capital
Input availability

Potential Responses to Risk:

Adjusting input and output levels
Holding output reserves
Holding credit reserves
Holding input reserves
Integrate vertically
Gathering information
Postponing decisions
Forward contracting
Hedging
Integrate horizontally
Aquiring risk-reducing inputs
Buying flexible inputs
Buying insurance
Specializing
Adjusting financial leverage
Diversifying operations spatially
Spreading transactions over time
Participating in public programs designed to reduce risk
Utilizing share leasing of resources

Source: Robison, Lindon J. and Peter J. Barry. The Competitive Firm's Response to Risk. New York: Macmillan Publishing Co. 1987, p. 65.

Figure 3. Potential Sources of and Responses to Risks Faced by an Agricultural Firm

the decision process. With uncertainty, the entire range of outcomes for each alternative is considered.

Decisions are intended to yield acceptable outcomes, viewed ex ante. A good decision is one consistent with the decision maker's expectations and preferences, not just a decision that works out well. Good decisions, however, do not ensure good outcomes due to the effects of risk. Unfortunately, good decisions sometimes have undesirable outcomes, while poor decisions can yield favorable outcomes (Sonka and Patrick 1984).

Choosing a decision rule in a risky environment first requires a systematic analysis of: a) the risk involved in a particular activity; and b) the ability of the firm and manager to handle that amount of risk (Boehlje and Trede 1977). An assessment must be made of the farmer's willingness to take risk and ability to manage under the pressures of risk. An assessment should also be made of the financial risk that the firm can assume. Then, a choice rule to accommodate or reduce the potential risk must be developed.

Strategies (alternative actions or responses) to reduce risk can be divided into three categories: marketing, financial, and production (Boehlje and Trede 1977). Marketing strategies are used to minimize price risks. Financial strategies are used to reduce financial risk or the consequences of other business risks. Production strategies are used to minimize production, technological, and some forms of business and legal risk. Potential responses to risk are summarized in Figure 3.

Vertical integration as a form of diversification in a cow-calf operation is the risk response considered in this study. (Vertical integration for non-risk response purposes is discussed in a later section.)

Diversification

Diversification, a production strategy involved in enterprise selection, combines enterprises to reduce the variability of returns (Sonka and Patrick 1984). The adage, "Don't put your eggs in one basket," sums up diversification well.

For example, let P_A and P_B be the proportion of resources used for the production of enterprises A and B, and σ_A^2 and σ_B^2 be their income variances. The variance of total returns, σ_T^2 is given by

$$\sigma_T^2 = P_A^2\sigma_A^2 + P_B^2\sigma_B^2 + 2P_AP_B\rho\sigma_A\sigma_B \tag{17}$$

where $P_A + P_B = 1$ and ρ is the correlation coefficient for the incomes of A and B. The correlation coefficient varies between plus and minus one. Positive values of ρ indicate returns that vary in the same direction and negative values indicate variation in opposite directions. Although the greatest reduction in total variability occurs if ρ is negative, reduction in risk will occur from diversification if

$$\sigma_A^2 - P_A^2\sigma_A^2 > P_B^2\sigma_B^2 + 2P_AP_B\rho\sigma_A\sigma_B \tag{18}$$

In general, risk is further reduced by diversification as the correlation between enterprises takes on lower values. However, diversification is subject to the law of diminishing returns. Adding more enterprises would generally further reduce risk, but the marginal risk reduction becomes smaller as the number of enterprises increases (Sonka and Patrick 1984). Some diversification reduces exposure to risk, but too much may preclude gains from learning or from economies of scale (Robison and Barry 1987).

Pope and Prescott (1980) examined diversification using detailed microdata. The purpose of their study was to examine the relationship between farm size and other socioeconomic variables and diversification in a large cross-section of California crop farms. They concluded that larger farms are more specialized, as are wealthier and less experienced farmers. There was also evidence that corporations are more specialized than farms with other organizational forms such as sole proprietorships and partnerships. Pope and Prescott further conclude that, in general, their results are consistent with risk theories. That is, a firm diversifies to spread risk and wealthier farmers have fewer incentives to spread risk.

Heady (1952) conducted several studies to evaluate potential benefits of diversification and its effect on income and income variability. He concluded that, given the crop enterprises he was considering, diversifying with limited resources lowered absolute variance. Heady also concluded that enterprise combinations which result in little or no sacrifice in income, raise the minimum income received in one year, and lessen both absolute and relative variances, are most efficient diversification systems.

Mapp et al. (1979), using Hazell's (1971) approach which minimizes total absolute deviation (MOTAD), analyzed a typical farm situation in southwestern Oklahoma. They used the MOTAD model to derive risk efficient farm plans. The MOTAD model, they concluded, demonstrated the possibility of reducing relative variability through diversification. Mapp et al. found that in their base plan, where risk was assumed of no importance, the profit maximizing organization of production is very specialized. However, when the total negative deviations from the gross margin expectations were minimized subject to receiving a minimum level of revenue, a considerably more diversified farm plan resulted. By diversifying, the producer could substantially lower risk while only slightly lowering gross margins.

Scott and Baker (1972) used a quadratic programming-risk aversion model to select farm plans for a typical central Illinois cash grain farm. The alternate production activities included corn, soybeans, wheat, and idle land to be used for conservation purposes or to meet the 1972 government feed-grain program. They found that a risk neutral producer would specialize in corn, which had the highest mean income, even though it also had the highest variance. A risk averse producer, however, would diversify into soybeans, which resulted in substantial reductions in income variability.

Vertical Integration

Vertical integration is part of the larger spectrum of coordination of the various levels of production and processing between the initial producer and the final consumer (Logan 1969). Following Mighell and Jones (1963), Logan defines integration as the combination of two or more levels of activity into one firm. Thus integration is the extension of a firm's administrative decisions into areas of market coordination typically allocated to the free market mechanism. Failure of the external market creates profit and risk incentives for the firm to integrate vertically (Kilmer 1986).

When a firm vertically integrates, it internalizes the conversion of an intermediate product to a final product at some conversion cost. If the firm's conversion cost is less than the market's conversion cost, then the integrated firm can outperform the nonintegrated firm and increase its expected return. One reason the conversion cost may be cheaper for the firm than for the industry is the cost of information. The firm knows first-hand the quality and quantity of its product. In contrast, the nonintegrated firm may view the quality and quantity of the intermediate product as stochastic (Robison and Barry, 1987).

A key to vertical integration is to maintain ownership through as many profitable pricing points as possible. It may not require ownership of additional facilities. For example, a cow-calf producer can integrate into the feeder phase by custom feeding his cattle, rather than invest in the machinery and equipment necessary to feed the cattle himself. A primary goal of vertical integration is to increase firm profits and efficiency of operation, including increasing output relative to inputs and achieving economies of production (Black and Haskell 1977).

Logan (1969) used a lexicographic utility function approach to analyze the value of vertical integration at the firm level. He postulated that two variables in a firm's utility function, maximization of return on investment and short run risk reduction, might logically apply to integration. While each variable will assume different importance from firm to firm, risk reduction undoubtedly plays an important part in decisions to integrate.

Logan (1969) concludes that a firm must consider more than just return on investment resulting from the profits of the new level to be integrated, it must also know the change in profits of its current operation after integration. The firm must also analyze the risk associated with the quantity and quality of the supply of inputs (or outputs) before and after integration. Logan also concludes that the change in the distribution of these risk factors after integration and the effect on return on investment must be considered jointly.

The Intermediate-Product Problem

The intermediate-product problem is a variation of the multiproduct problem. One or more outputs produced by a firm are used as inputs in producing other outputs. The intermediate-product model provides the theoretical basis for vertical integration. A vertically integrated firm has the option to sell the intermediate product or use it in the production of other outputs.

To illustrate, a one input, two product model, with one product an input to the other, assuming perfect competition, is discussed. Let Y_{1s} be the amount of Y_1 produced for sale and Y_{12} be the amount of Y_1 produced for use in producing Y_2, according to the production functions,

$$Y_1 = f_1 (X_{11}) \tag{19}$$

$$Y_2 = f_2 (X_{12}, Y_{12}) \tag{20}$$

Let $X_{11\text{-}s}$ be the amount of X_1 used to produce Y_1 for sale, $X_{11\text{-}Y2}$ be the amount of X_1 used to produce Y_1 for subsequent use in producing Y_2, and X_{12} be the amount of X_1 used directly in producing Y_2.

The firm's objective is to maximize profit

$$\Pi = P_1 Y_{1\text{-}s} + P_2 Y_2 - r_1 X_1^o \tag{21}$$

subject to the resource constraint,

$$X_1^o = X_{11\text{-}s} + X_{11\text{-}Y2} + X_{12} \tag{22}$$

The Lagrangean to the problem is

$$L = P_1 Y_{1\text{-}s} + P_2 Y_2 - r_1 X_1^o + \lambda (X_1^o - X_{11\text{-}s} - X_{11\text{-}Y2} - X_{12}) \tag{23}$$

The first order partials set equal to zero yield

$$\frac{\partial L}{\partial X_{11\text{-}s}} = P_1 \frac{\partial Y_1}{\partial X_{11\text{-}s}} - r_1 - \lambda = 0 \tag{24}$$

$$\frac{\partial L}{\partial X_{12}} = P_2 \frac{\partial Y_2}{\partial X_{12}} - r_1 - \lambda = 0 \tag{25}$$

$$\frac{\partial L}{\partial X_{11\text{-}Y2}} = P_2 \frac{\partial Y_2}{\partial Y_1} \frac{\partial Y_1}{\partial X_{11\text{-}Y2}} - r_1 - \lambda = 0 \tag{26}$$

$$\frac{\partial L}{\partial \lambda} = X_1^o - X_{11\text{-}s} - X_{11\text{-}Y2} - X_{12} = 0 \tag{27}$$

The product-product first order conditions can be obtained from (24) and (25)

$$P_1 \frac{\partial Y_1}{\partial X_{11\text{-}s}} = P_1 \, MPP_{X_1Y_{1\text{-}s}} = P_2 \frac{\partial Y_2}{\partial X_{12}} = P_2 \, MPP_{X_1Y_2} \tag{28}$$

which, by rearranging, yields

$$\frac{P_1}{P_2} = \frac{MPP_{X_1Y_2}}{MPP_{X_1Y_{11\text{-}s}}} = RPT_{12} \tag{29}$$

where $MPP_{X_1Y_{1\text{-}s}}$ is the marginal physical product of using X_1 to produce Y_1 for sale, $MPP_{X_1Y_2}$ is the marginal physical product of using X_1 to produce Y_2, and RPT_{12} is the rate of product transformation between outputs Y_1 and Y_2.

The factor-product first order conditions can be obtained from (24), (25), and (26)

$$P_1 \, MPP_{X_{1\text{-}s}} = r_1 + \lambda \equiv MVP_{X_1Y_{1\text{-}s}} = MFC_1 + \lambda \tag{30}$$

$$P_2 \, MPP_{X_2} = r_1 + \lambda \equiv MVP_{X_1Y_2} = MFC_1 + \lambda \tag{31}$$

$$P_2 \, MPP_{Y_1Y_2} \, MPP_{X_1Y_1} = r_1 + \lambda \equiv IMVP_{X_{11}Y_2} = MFC_1 + \lambda \tag{32}$$

where $MVP_{X_1Y_{1\text{-}s}}$ is the marginal value product of using X_1 to produce Y_1 for sale; $MVP_{X_1Y_2}$ is the marginal value product of using X_1 to produce Y_2; $IMVP_{X_{11}Y_2}$ is the intermediate marginal value product of using X_1 to produce Y_1, which, in turn, is used to produce Y_2; and MFC_1 is the marginal factor cost of input X_1.

Thus, at the point where profit is maximized, assuming the second order conditions are met, the increase in returns from using the last unit of X_1 must exactly equal its cost, no matter if it was used to produce Y_1 or Y_2 for sale, or to produce Y_1 to be used to produce Y_2 for sale.

Retained ownership by a cow-calf producer is an intermediate-product problem. Produced calves could be sold at weaning or used as an input in subsequent stocker and/or feeder activities. To maximize profit, the producer must consider the costs and returns involved in available production and marketing alternatives. The producer must produce cattle using the least cost combination of inputs. Also, the marginal revenue of using an additional unit of an input, protein supplement, for example, must equal the marginal cost of that input. That unit of protein supplement could be used in the production of weaned calves, which could be sold or retained, stocker calves, which also could be sold or retained, or feeder cattle. Regardless of where used, the marginal revenue gained from using that last unit must equal the cost of that unit to maximize profit.

Vertical Integration in Beef Production

The traditional marketing practice for many producers is selling weaned calves. Retained ownership, defined as maintaining ownership of calves beyond weaning, is a form of vertical integration specific to livestock production. By retaining ownership, a producer is integrating into subsequent phases of the live beef production process.

Henderson and Schwart (1977) estimated that 40 to 50 percent of the feeder calves produced are involved in operations integrated through the cow-calf and stocker phases. About 20 to 30 percent of the cattle placed on feed are involved in stocker-feeder integrated firms. Integration of all three stages involves fewer than ten percent of the feeder cattle produced.

Producers retain ownership for a number of reasons. They attempt to capture profits that may be realized in the stocker and feeder phases of the live beef production process. Through retained ownership, producers have the opportunity to expand their businesses and increase the number of marketing alternatives available (Araji 1976). Producers who retain ownership, especially through finishing, may capture more benefits of a progressive breeding program. Producers also gain valuable animal performance information, which can help them better plan the future of their breeding programs.

The producer with a progressive breeding program will likely have incentives to retain ownership based on market phenomena. Purcell (1973) concluded there are significant differences of opinion between feeder and producer groups as to what characteristics give value to a feeder animal. He further concluded that the feeder animal is not described and priced in a manner which transmits clear and discernable price signals to producers. Retained ownership, then, may provide the means by which cow-calf producers can capture price premiums cattle feeders (or the pricing mechanisms) have been unwilling to offer for higher performance cattle.

Custom feeding (grazing) can be defined as maintaining ownership and the right to major management decisions on cattle that have been relocated to someone else's lot (pasture) for growing and/or finishing where daily supervision is the responsibility of a second party.

One key to successful feeding lies in the makeup of the cattle which constitute a pen. The cattle should be as uniform as possible in weight, body type, age, breeding, and in previous nutritional background. When these conditions are met, the cattle feeder can manage the cattle to achieve optimum feed efficiency and market worth of the cattle (Gill et al. 1986).

A number of studies have concluded that retaining ownership is a profitable alternative to the typical practice of selling weaned calves. Ford et al. (1985) used simulation modeling to determine the most desirable development and marketing strategy for calves coming out of a cow-calf operation. They identified seven alternatives, ranging from sale at weaning to retained ownership to slaughter. Ford et al. concluded that retained ownership through the feedlot finishing phase produced the highest profitability of the strategies studied. Selling calves at weaning was least profitable.

Lambert and Sands (1984), using actual data from the Kansas Steer Futurities and Kansas Farm Management Association cost of production data, concluded that retained ownership through slaughter was profitable in six of nine years studied, while selling the same calves at weaning would have been profitable in only three years. They also concluded that because seasonal price tendencies for calves and fed cattle generally favor retained ownership, the cattle feeder can improve his odds of both avoiding seasonally low calf prices and achieving seasonally high fed cattle prices.

Watt et al. (1987) estimated potential benefits of retained ownership by a typical cow-calf operation in North Dakota. They concluded that beef producers, especially cow-calf producers, are exposed to significant price risk and that retained ownership is a viable production and marketing alternative which may reduce price risk inherent to cow-calf operations selling weaned calves. However, they also noted that all production alternatives considered were subject to considerable price risk and that increased returns in the retained ownership alternatives should be expected, in order to compensate for the higher level of management required.

Lambert (1989) used discrete stochastic programming to model the situation faced by Nevada cow-calf producers. Weaned calves could be marketed in the fall or fed over the winter and either marketed the following spring or placed on grass for summer grazing. Production decisions were based on animal performance, cost and availability of different feeds, and price expectations. Lambert concluded that calves should be retained through the winter, fed to gain about one kilogram per day, and then sold in the spring.

Aderogba et al. (1985) examined production and marketing strategies for winter forage-grain beef production systems in southwest Alabama. Forage availability, animal weights, and market prices were analyzed in a simulation model to select the optimum number and sex of cattle to be raised on a representative farm in southwest Alabama to gain the greatest net return based on costs and prices during 1961-1983. Their results show that carrying calves to slaughter weights can be an economical alternative to selling calves at weaning. Aderogba et al. concluded that vertical integration is economically sound for producers and has potential for reducing marketing and production risks.

Gebremeskel and Shumway (1979) adapted Hazell's (1971) "Minimization of Total Absolute Deviations" (MOTAD) model to handle intermediate and final products for a cow-calf producer on the Texas Gulf Coast. They integrated statistical decision theory with the MOTAD model to derive annual calf-marketing strategies based on observable information relevant for predicting subsequent calf prices and forage yields. Gebremeskel and Shumway found that the highest net return system was very risky while the lowest risk system attained by proper forage diversification, integration level, and herd size resulted in substantial reductions in risk with little impact on expected returns. They also found that retaining calves to be sold later as stockers greatly increases risk.

Whitson et al. (1976) evaluated risk return effects of selling produced calves, or holding them through subsequent stages of the production process. They used multiperiod quadratic programming (QP) to model the vertical sequence of decision choices and to evaluate risk and returns in a value-added sense. The QP model was used to derive a set of E-V efficient growth plans. Vertical production alternatives were utilized in all growth plans to increase income as well as to reduce variation. They concluded that using vertical production alternatives in ranch planning appears an effective response to risk. They noted, however, that vertical production alternatives should not be evaluated independently of other risk responses.

Saez et al. (1980) used a MOTAD model for a typical self-sufficient East Texas farm to explore a number of questions managers face. With regard to retained ownership, they concluded that there is more incentive for the risk-averting producer to diversify by retaining calves beyond weaning than for the profit-maximizing producer. Regardless of the degree of risk aversion, however, the cow-calf and cow-feeder options are close economic alternatives. A minor change in relative prices could induce a switch in the recommended marketing strategy.

Stokes et al. (1981) used results of a biological simulation model in an economic model to evaluate retained ownership alternatives faced by a Central Texas rancher. They found that, during the study period, placing weaned calves directly in a feedlot for finishing had the highest average net returns (lowest losses) compared to selling weaned calves, wheat pasture stockers, or finished wheat pasture stockers.

Angirasa et al. (1981) used a systems approach to determine the effects on beef production of different marketing plans. They found that cow-calf enterprises dominated the profit-maximizing solutions, but only within a narrow price range. Moderately risk averse producers tended to partially integrate through the stocker phase.

Contributions of This Research

Many of the retained ownership studies considered few retained ownership alternatives. Some focused primarily on stocker activities (Gebremeskel and Shumway 1979; Saez et al. 1980, Angirasa et al. 1981; Lambert 1989). Lambert and Sands (1984) compared only selling weaned calves with selling fed weaned calves. Several have considered stocker and finishing retention activities (Whitson et al. 1976; Aderogba et al. 1985; Ford et al. 1985; Watt et al. 1987). However, the scope of production alternatives was limited in most of these. A goal of this research is to investigate a broad range of stocker and feeder alternatives available to beef producers in Oklahoma.

The scope of the studies evaluating alternative cow types or breeding systems was, in general, limited. Exceptions include Cartwright et al. (1975), Notter et al. (1979), and Stokes et al. (1981 and 1986). However, the primary focus of the Cartwright and Notter studies was on physical productivity. The present study considers the economic performance of eleven crossbreeding systems.

Only Stokes et al. (1981) conducted a joint evaluation of alternative cow types and retained ownership. This study uses an approach to deriving animal performance estimates and conducting the analysis which differs from that of Stokes. Animal performance estimates used in this study are derived, based on relationships established by the theory of animal breeding, using data from ongoing beef breed research at the Roman L. Hruska Meat Animal Research Center in Clay Center, Nebraska.

Finally, distributions of returns for alternative production and marketing plans in selected breeding systems generated in the risk analysis in Chapter VI are a primary additional contribution of this research. Most of the other studies yielded expected values for the retained ownership alternatives and/or breeding systems. The stochastic returns generated in this research provide the basis for a risk analysis of alternative breeding systems with retained ownership.

CHAPTER III

MODEL AND DATA DEVELOPMENT - BASE SITUATION

One objective of this study is to evaluate alternative cattle breeding systems with the option to retain ownership of calves beyond weaning. To address the objective, a comparative static analysis of each system in a whole farm framework will be conducted using linear programming. The purpose of this chapter is to describe the base situation and its underlying assumptions and to present the development of the analytical model employed in the static analysis. The base situation, a two-breed rotation with medium frame, medium milk potential breeds, will provide the basis of comparison among the alternative breeding systems.

Area of Study

The representative ranch used as a basis for comparison of the alternative breeding systems is assumed located in South-Central Oklahoma (Figure 4). Ten of Oklahoma's 77 counties are included in the study area. According to the Census of Agriculture (U.S. Department of Commerce 1989), 14 percent of the State's beef cattle operations (6,123) were in the ten county study area in 1987 (Table I). Total market value of cattle and calves sold in 1987 in the study area was $144,236,000, eight percent of the State's total.

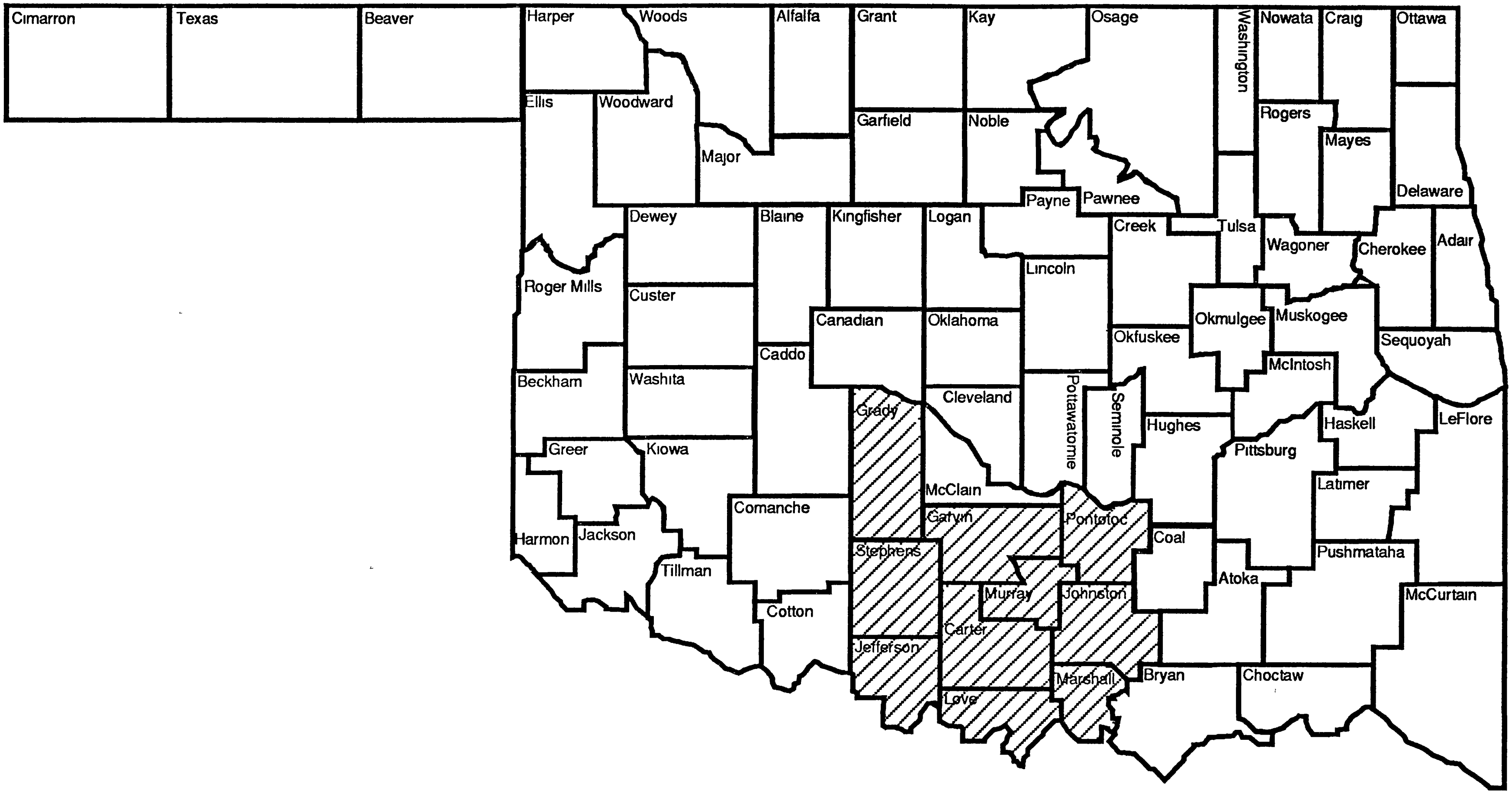


Figure 4. Ten County Study Area in South-Central Oklahoma

TABLE I

CATTLE AND CALVES AND BEEF COW INVENTORIES, JANUARY 1, 1989, MARKET VALUE OF CATTLE AND CALVES, AND NUMBER OF BEEF CATTLE OPERATIONS IN 1987 IN THE TEN COUNTY STUDY AREA

County	Inventory of all Cattle and Calves	Inventory of Beef Cows	Market Value of Cattle and Calves Sold	Total Number of Beef Cattle Operations
	Head	Head	$1,000	
Carter	60000	22500	$14,391	827
Garvin	94000	38000	14352	960
Grady	135000	45500	29562	954
Jefferson	72000	23000	27672	382
Johnston	55000	19500	9699	417
Love	33000	17000	9075	435
Marshall	27000	10000	5788	281
Murray	38000	16000	6088	323
Pontotoc	66000	34000	13119	752
Stephens	69000	23500	14490	792
TOTAL	649000	249000	$144,236	6123
Percent of State Total	12	13	8	14

Sources: U.S. Department of Commerce, 1989.
Oklahoma Department of Agriculture, 1989.

The total inventory of cattle and calves on January 1, 1989 was 649,000 head; 12 percent of the State's total. The study area had 13 percent of the State's total beef cow herd, 249,000 head, on January 1, 1989 (Oklahoma Department of Agriculture 1989).

Average annual precipitation in the study area is about 37 inches. The normal average annual temperature for the study area is 62.9 degrees Fahrenheit, ranging from a monthly average low in January of 40.6 degrees to a high of 83.2 degrees in July.

Land Resources

A land base sufficient to support a herd size of about 300 cows in a normal forage-yielding year is assumed for the representative operation. Decisions regarding the land base were made with the assistance of agricultural specialists from the Noble Foundation and an area agricultural economics extension specialist. The operator has managerial control over 2,800 acres of native pasture, 1,260 acres of which are owned, and 350 acres of improved pasture, 158 acres of which are owned (Table II). Rental rates for improved pasture and native range are $10.00 and $8.00 per acre, respectively.

The soil types on the ranch are in the Darnell-Stephenville association of the Cross Timbers land resource area and in the Renfrow-Zaneis-Vernon association of the Central Reddish Prairie land resource area.

The Cross Timbers is a large wooded area of rolling to hilly sandstone uplands extending from the Kansas line to Texas. The Darnell are shallow, light-colored soils on slopes and narrow ridge tops. Locally they are covered with sandstone rocks on steeper areas, with ledge rock outcrops common. The main uses of Darnell soils include forested pasture and a little cropland. The

TABLE II

SUMMARY OF LAND RESOURCES

	Improved Pasture	Native Pasture
Acres Owned	158	1260
Acres Rented	192	1540
TOTAL	350	2800
Rental Rates	$10.00	$8.00

Stephenville are moderately deep soils with developed subsoils that occupy the ridges and gentle slopes. The main uses of Stephenville soils include cropland and wooded pasture (Gray and Galloway 1959, p.30, 32, 60).

The Reddish Prairie is an area of smooth to rolling lands which gets its name from the dominantly red sedimentary rocks of the "Red Beds" formation. The area is mixed prairie. It occupies a continuous body from north to south across Oklahoma in about the center of the State. It borders the Cross Timbers on the east. The Renfrow-Zaneis-Vernon association occupies gently rolling plains underlain by interbedded sandstones and clay beds. Renfrow are brown to reddish brown silt loam surface soils with reddish blocky clay, slowly permeable subsoils. Cropland is the main use of Renfrow soils, with pasture on steeper areas. Zaneis are brown loam soils with granular, reddish, heavy clay loam subsoils. Pasture and cropland are the main uses of Zaneis soils. Vernon are limy red clay soils of steep slopes, very little changed from the red clays themselves. The main uses of Vernon soils include pasture and rangeland (Gray and Galloway 1959, p.36, 38, 62).

Management

The ranch operator is assumed to be an efficient manager. For the static analysis, the operator's major objective is to maximize profits. Thus, ranch organization adapts as profitability of activities changes.

Forage yields on improved pasture assumed in this study require timely fertilizer application. It must be applied at the appropriate times and at specified levels to achieve the desired yields. Livestock are distributed to the pasture activities to optimize livestock yield and to utilize the available forage, regardless of the per cow requirements, which are influenced by frame size and milk potential.

The cow-calf activities also require above-average management. Rotational crossbreeding systems require at least one breeding pasture per breed used in the rotation. Females in the breeding herd must be identified by the breed of their sires to maintain the proper breed sequence in the next generation. This is critical to maximize heterosis levels in a rotational crossbreeding program. For a combined rotational-terminal system, an additional breeding pasture is required for that portion of the herd involved in the terminal cross. Management is assumed to be at a level sufficient to handle the intricacies of the crossbreeding systems considered in the study.

High variability in weights within a pen of finished cattle results in price discounts when those cattle are sold. As a result, placing a pen of calves of similar weight and condition in a feedlot for finishing is important. The breeding season and consequently the calving season are assumed managed in a way to minimize variability in weaning weight.

Vertical integration, achieved by retaining ownership, requires knowledge of a broad spectrum of cattle production. Additional management decisions must be made at each marketing level. The ranch manager is assumed capable and willing to make these decisions. The manager is also assumed capable of managing the operation at all levels of integration considered.

Labor

Labor needed for cattle enterprises derives from machinery and equipment operation, feeding, marketing, and other animal care tasks. Pasture labor includes equipment and fence repair. Components of cow herd labor include breeding period labor, dry cow-preparturition care, calving care, calf care to weaning, feeding, and local hauling. Stocker labor includes feeding and care, local hauling, and marketing (Walker et al. 1987).

The 2,700 hours of operator and family labor assumed available per year are distributed equally by month (225 per month) throughout the year. Additional labor is available for hire in each period for $5.00 per hour.

Machinery and Equipment

The base operation has adequate machinery and equipment complements to perform the duties associated with the livestock and pasture activities considered in the model (Tables III and IV). The machinery and equipment complements are representative of an above average level of management. All machinery and equipment is assumed well maintained, with repairs done as necessary. Machinery and equipment are assumed replaced annually at a rate equal to the average annual depreciation.

Overhead

The firm has certain fixed costs which must be paid each year, regardless of the enterprise mix (Table V). These include land rent, family living expenses, real estate taxes, and insurance. A miscellaneous category is added to the overhead charge to cover such items as publications, farm organization membership fees, and travel expenses. The machinery and equipment replacement charge and a fence replacement charge are also included in the overhead.

TABLE III

MACHINERY COMPLEMENT ASSUMED FOR THE BASE OPERATION

Item	Size	List Price	Salvage Value	Annual Years Owned	Depr. Hours Used	Insur Cost/ Hour	Tax Cost/ Hour	Total Ownership Cost/ Hour	Total Annual Cost/ Hour	Ownership Cost	Average Value	Depreciation
Tractor	110 HP	43500	12849	10	600	5.11	0.28	0.72	6.11	3665.08	15325.39	3065.08
Offset Disc	14 ft	9000	1247	12	150	4.31	0.20	0.60	5.11	766.12	3876.72	646.12
Rotary Mower	6 ft	2900	479	10	100	2.42	0.21	0.55	3.18	318.13	1210.67	242.13
Sprayer	12 ft	1300	68	20	50	1.23	0.19	0.53	1.95	97.61	616.12	61.61
Dry Fert Spreader	25 ft	4000	195	20	50	3.81	0.25	0.80	4.86	242.77	1902.71	190.27
Pickup	.75 ton	14500	5274	5	800	2.31	0.07	0.17	2.55	2037.15	4612.88	1845.15
Stock Trailer	21 ft	4000	838	10	50	6.32	0.25	0.68	7.25	362.73	1581.17	316.23
Total Investment		79200								7489.61	29125.68	6366.61

TABLE IV

EQUIPMENT COMPLEMENT ASSUMED FOR THE BASE OPERATION

Item	Number Units	List Price	Salvage Value	Years Owned	Insur.	Taxes	Total Ownership Cost/Unit	Total Ann. Ownership Cost	Average Value	Depreciation
Livestock Handling Equipment	1	9865	986.5	20	32.5545	54.26	530.74	530.74	4439.25	443.93
Livestock Feeding Equipment	1	3610	361	10	11.913	19.86	356.67	356.67	1624.50	324.90
Horse with Tack	4	850	595	10	0	0.00	25.50	102.00	510.00	25.50
Total Invesment		14325						989.41	6573.75	794.33

TABLE V

COMPONENTS OF THE OVERHEAD CHARGE FOR THE BASE OPERATION

Family Living Expenses			$16,000
Real Estate Taxes			1,000
Insurance			2,000
Publications, Travel, Farm Organization Fees, etc.			2,500
Pasture Rent	Acres	$/Acre	
Improved Pasture	192	10	1,920
Native Pasture	1540	8	12,320
Annual Machinery and Equipment Replacement Charge			7,161
Fence Replacement			1,083
Total Overhead			$43,984

Financial Situation

A firm's financial position has a strong influence on the enterprises it can realistically incorporate into its farm plan. The beginning balance sheet for the base operation is presented in Table VI. The base operation is assumed to have an initial debt/asset ratio of 0.3. This value is consistent with the average debt/asset ratio for producers in Oklahoma (Plaxico et al. 1988; Oklahoma Agricultural Statistics Service 1990). Although the LP analysis is conducted in a long-run framework, the initial financial situation is depicted in the model. It is difficult to normalize financial constraints since the financial situation changes across time.

The firm is assumed to have $2,000 in cash, initially. The machinery and equipment have values assumed at $29,126 and $6,574, respectively. The house is assumed worth $65,000 and owned land worth $334,950. Improved pasture is assumed valued at $525 per acre and native pasture, $200 per acre. Total assets equal $610,227.

Given a debt/asset ratio of 0.3, total debt for the firm is $183,068. Long term debt is assumed 75 percent of total debt ($137,301), intermediate term debt, 20 percent ($36,614), and short term debt, 5 percent of total debt ($9,153).

The firm's initial equity is $427,159. The beginning leverage ratio, debt/equity, is 0.43.

Input Costs

Input prices were obtained from Oklahoma State University agricultural economists, merchants and dealers, and Agricultural Prices (USDA). Input prices, with the exception of protein supplement, are estimates of current prices

TABLE VI

BEGINNING BALANCE SHEET FOR THE BASE OPERATION

BALANCE SHEET				
ASSETS				
Short Term				
Cash on Hand		2,000		
	Total		2,000	
Intermediate Term				
Breeding Livestock		172,577		
Equipment		6,574		
Machinery		29,126		
	Total		208,277	
Long Term				
Home		65,000		
Land		334,950		
	Total		399,950	
TOTAL ASSETS				$610,227
LIABILITIES				
Short Term		9,153		
Intermediate Term		36,614		
Long Term		137,301		
TOTAL LIABILITIES				$183,068
NET WORTH				$427,159

paid by livestock producers in Oklahoma. The price of protein supplement is a five year average price (1985-1988) for 41 percent protein cottonseed meal.

The price of protein supplement has been subject to price fluctuations recently. A current price could result in a supplement cost atypically low or high. Using an average price circumvents this problem. The five year average price in constant 1989 dollars for protein supplement was used due to the relative magnitude of the cost of protein supplement to the cost of other inputs in the budget. Other input price levels have been relatively flat over the last five years, so the current price is assumed sufficient. The other inputs include salt and minerals, 20 percent protein cubes, veterinarian services and supplies, and non-legume hay.

Livestock Prices

Prices received for livestock were obtained from the Agricultural Marketing Service (USDA). Prices for feeder cattle and cull breeding stock are from the Oklahoma City livestock market, while slaughter cattle prices are from the Amarillo market. The prices received for livestock are ten-year averages, 1979-1988. A ten-year average price minimizes the influence of cyclical effects inherent in cattle prices. All market prices are inflated to 1989 dollars using the GNP deflator.

Monthly prices used are based on the 1989-based ten-year average 400-500 pound steer price, P_B, and adjusted to other classes of cattle and for seasonality,

$$P_{im} = P_B * R_{iB} * SI_{im} \tag{33}$$

where P_{im} is an average market price for cattle class i in month m, R_{iB} is the ratio of the ten-year average market price of cattle class i to the ten-year average price for 400-500 pound steers, and SI_{im} is the seasonal index for cattle class i in month m. P_B equals $96.00. The ten-year average seasonal price indexes for selected classes of cattle are presented in Table VII. The ratios of ten-year average market prices for selected classes of cattle to the ten-year average 400-500 pound steer price are also presented in Table VII.

The prices reported by the Agricultural Marketing Service are given for 100 pound intervals, i.e. 400-500 pound steers, 500-600 pound steers, and so forth. However, lighter animals typically sell for more per pound than do heavier animals. Thus, using the same price for all animals within the weight range biases the profitability in favor of enterprises producing heavier calves within the same weight interval.

Linear interpolation is used in the model to generate more realistic market prices. The reported price for a given weight interval is assumed to be the price for the midpoint weight in that interval. Linear interpolation assumes weights and prices are linearly related between two midpoint weights. This assumption is not viewed as detrimental since the weights are reported in 100 pounds intervals.

A marketing charge of $1.72 per cwt and a custom hauling charge of $.35 per cwt are subtracted from the calculated market price for all weaned calves, stockers, and cull breeding stock (Walker et al. 1987).

Pasture Activities

The ranch is assumed to have two types of land available for grazing, rangeland, which has no alternative use, and improved pasture, which could be used as marginal cropland, but is not. Since the model is designed to generate the optimal long-run plan, activities reflecting the alternative grazing uses of the

TABLE VII

SEASONAL INDEXES FOR CATTLE CLASSES SOLD IN THIS STUDY, 1979-1988, OKLAHOMA CITY AND AMARILLO PRICES

Class	Index of Ann. Ave. Price, 1979-1988 4-500 lb Str = 1.0	Seasonal Indexes - 10 Yr Ave., 1979-1988 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Price 1979-1988
3-400# Strs	1 0627	98 60	103 10	104 90	105 30	103 10	97 80	96 50	100 60	100 10	96 10	96 90	97 00	102 02
4-500# Strs	1 0000	99 40	103 40	103 50	105 50	102 70	97 70	96 40	99 00	99 40	97 10	98 10	98 00	96 00
5-600# Strs	0 9257	99 90	103 70	104 40	104 00	100 50	97 60	96 70	98 90	98 80	97 30	99 10	99 00	88 87
6-700# Strs	0 8782	101 40	104 10	103 40	101 30	98 60	96 20	97 50	99 70	99 30	98 10	100 00	100 40	84 31
7-800# Strs	0 8525	103 60	104 70	103 20	100 20	97 10	95 60	97 50	99 70	99 20	98 10	100 00	101 10	81 84
8-900# Strs	0 8261	103 60	104 70	103 20	100 20	97 10	95 60	97 50	99 70	99 20	98 10	100 00	101 10	79 31
9-1000# Strs	0 7999	103 60	104 70	103 20	100 20	97 10	95 60	97 50	99 7.0	99 20	98 10	100 00	101 10	76 79
10-1100# Strs	0 7424	103 60	104 70	103 20	100 20	97 10	95 60	97 50	99 70	99 20	98 10	100 00	101 10	71 27
8-1000# Strs	0 8130	103 60	106 00	102 90	99 80	96 90	95 30	97 90	100 80	99 00	98 00	100 10	99 60	78 05
900-1100# Ch Strs	0 8192	101 00	101 10	101 30	102 30	102 60	99 90	95 90	96 00	95 70	99 20	102 90	102 20	78 64
1100-1300# Ch Strs	0 8188	98 70	99 70	101 10	104 00	104 80	101 40	98 80	97 50	96 80	97 40	99 70	100 10	78 60
900-1100# Sel Strs	0 7565	101 00	101 10	101 30	102 30	102 60	99 90	95 90	96 00	95 70	99 20	102 90	102 20	72 62
1100-1300# Sel Strs	0 7560	98 70	99 70	101 10	104 00	104 80	101 40	98 80	97 50	96 80	97 40	99 70	100 10	72 58
3-400# Hfrs	0 8942	99 00	104 00	105 20	105 50	102 10	98 10	96 60	98 60	98 90	95 90	98 20	97 90	85 84
4-500# Hfrs	0 8414	99 00	104 00	105 20	105 50	102 10	98 10	96 60	98 60	98 90	95 90	98 20	97.90	80 78
5-600# Hfrs	0 8009	100 70	104 20	104 10	102 90	99 50	97 80	97 90	99 40	99 20	96 80	98 60	98 80	76 88
6-700# Hfrs	0 7856	100 70	104 20	104 10	102 90	99 50	97 80	97 90	99 40	99 20	96 80	98 60	98 80	75 42
7-800# Hfrs	0 7174	100 70	104 20	104 10	102 90	99 50	97 80	97 90	99 40	99 20	96 80	98 60	98 80	68 87
8-900# Hfrs	0 6951	100 70	104 20	104 10	102 90	99 50	97 80	97 90	99 40	99 20	96 80	98 60	98 80	66 73
9-1000# Hfrs	0 6731	100 70	104 20	104 10	102 90	99 50	97 80	97 90	99 40	99 20	96 80	98 60	98 80	64 61
900-1000# Ch Hfrs	0 7936	99 10	100 10	101 20	103 80	104 30	101 10	98 40	97 10	96 90	97 70	99 90	100 40	76 19
900-1000# Sel Hfrs	0 7318	99 10	100 10	101 20	103 80	104 30	101 10	98 40	97 10	96 90	97 70	99.90	100 40	70 25
Cows-Utility 2-3	0 5182	98 50	106 40	107 30	106 40	102 50	100 10	98 20	98 50	97 50	94 70	93 40	96 30	49 75
1000-1500# Bulls	0 6456	100 70	105 50	105 70	104 80	102 50	100 80	99 40	98 00	97 30	95 40	93 70	96.10	61 98

Sources Blakely, Leo V "Seasonal Price Index Update for Oklahoma Agricultural Commodities" Current Farm Economics Selected December Issues 1979 to 1987
Trapp, James N "Seasonal Price Index Update for Oklahoma Agricultural Commodities, 1978-1987" Current Farm Economics 61(1-4) 31-46 1988

improved pasture were included. Two types of improved pasture were considered, lovegrass and bermudagrass, at three fertilization levels each. Lovegrass activities include nitrogen fertilization rates of zero, 60, and 150 pounds per acre. Bermudagrass activities include nitrogen fertilization rates of zero, 50, and 100 pounds per acre. Forage production, production costs, labor requirements, and machinery and equipment requirements for the pasture activities are adapted from budgets developed using the O.S.U. Budget Generator (Walker et al. 1987).

For modeling purposes, the grazing year is broken into three periods: SUM1, April-June; SUM2, July-October; and WINT, November-March (Table VIII). Dividing the year into periods increases the realism of the modeling effort by allowing a delineation among periods of the year with similar production and quality. The first period includes those months with rapid forage growth and high quality forage. The second period includes the late summer months when forage production and quality are moderate but declining. The last period includes the winter months when production is minimal and quality is low.

The values in Table VIII reflect the pounds of dry matter of forage available for consumption in each forage activity. These values were obtained from enterprise budgets developed at Oklahoma State University. The producer is assumed to manage cattle grazing patterns in a manner consistent with the distribution of available forage over the three periods. This ensures forage availability, even though of a lesser quality, in the winter period, when minimal growth occurs.

The model can transfer excess dry matter produced but not utilized in the SUM1 period to the SUM2 period. Likewise, excess forage in the SUM2 period is transferred to the WINT period. With each transfer, an appropriate decrease in forage quality occurs.

TABLE VIII

AVAILABLE FORAGE IN THE NATIVE PASTURE AND IMPROVED PASTURE ACTIVITIES BY PERIOD, POUNDS OF DRY MATTER PER ACRE

Pasture Activity	SUM1 Period	SUM2 Period	WINT Period
	---------- (Lbs DM/Acre) ----------		
Native Range	153.3	306.6	251.9
Improved Pasture			
Lovegrass			
0 Lbs N per Acre	153.3	306.6	251.9
60 Lbs N per Acre	1533.0	474.5	438.0
150 Lbs N per Acre	1752.0	1022.0	657.0
Bermudagrass			
0 Lbs N per Acre	153.3	306.6	251.9
50 Lbs N per Acre	1095.0	1095.0	0.0
100 Lbs N per Acre	1149.0	1917.0	219.0

The model has winter wheat pasture and grazeout wheat pasture rental activities. Grazing on winter wheat pasture is assumed to begin on October 31 and terminate March 15. The grazeout option is an extension of the grazing period on wheat pasture, from March 15 to May 14. Wheat pasture and grazeout wheat pasture are assumed available for rent at $1.89 per hundredweight of dry matter consumed. For the base situation, this is equivalent to a rental rate of $43.79 and $42.49 per head for steers and heifers, respectively, on wheat pasture and an additional $25.08 and $24.48 per head for steers and heifers on grazeout wheat pasture.

Beef Cow Herd

Breed Composition

The beef cow herd assumed for the base operation is a two breed cross with medium frame, medium milk potential breeds (Hereford and Angus). Hereford-Angus cross, or "black baldy," cows are used as base because of their predominance and popularity as brood cows.

The base breeding herd is maintained through a rotational crossbreeding system. In a two breed rotation involving breeds A and B, cows of breed A are bred to bulls of breed B. Heifers from these matings are bred to bulls of breed A. Next generation heifers by breed A are mated to bulls of breed B and so forth. A minimum of two breeding pastures is required and heifers must be identified by the breed of their sire (Cundiff and Gregory 1977).

Calving Season

The timing of the calving season is a decision the producer must make. Generally, producers time the calving season to concur with favorable weather conditions and forage availability, either in the spring or in the fall.

The length of the calving season is determined by the length of the breeding season. Breeding seasons vary in length from 45 days to leaving the bulls with the cows year-round. However, management of year-round calving programs is difficult. Cows and calves must be gathered several times to administer vaccinations, wean, and work older calves. Coordinated and consistent marketing plans are difficult to maintain due to the wide variation in calf weights. Also, efficient supplementation programs are difficult to manage, since the cow herd consists of cows in various stages of lactation and/or gestation, each with different nutritional requirements (Selk and Lusby 1989).

Short breeding and calving seasons facilitate employment of proper nutritional programs since cows will generally be in similar stages of gestation or lactation. Observation of calving, health programs, castration, and weaning are easier to manage. Achieving high pregnancy rates is difficult with very short breeding seasons; however most cows capable of conceiving should do so in a 90-day period (Selk and Lusby 1989).

According to Gilliam (1984), most cow-calf operations in the United States are spring calving operations. The goal of spring calving is to time calving after harsh winter weather, but before the heat of summer and subsequent insect problems. An advantage of spring calving is the onset of fresh forage production, which minimizes the need for supplementation during lactation. However, calving occurs after several months of poor nutritional conditions during winter. Spring calving cows usually calve in lower body condition than fall calving cows and require careful attention to their nutritional status both before and after calving (Selk and Lusby 1989).

The goal of fall calving is to complete calving before winter begins. Cows usually calve in very good body condition because calving occurs at the end of the forage growing season. Fall calving cows require additional feed supplementation during the fall and early winter. Cows are highly sensitive to nutritional levels before calving and should not be allowed to lose weight before breeding. However, the additional supplement required in the fall and early winter can be partially offset by reducing supplemental feeding in the late winter (Selk and Lusby 1989). The availability of wheat pasture makes fall calving a possibility in Oklahoma. However, the option of fall calving cows grazing wheat pasture is not considered in this study.

Calving in both the spring and fall is feasible in South-central Oklahoma. Both spring calving and fall calving activities are included in the model. Spring calving cows are assumed to calve, on average, on March 1. The average calving date for fall calving cows is assumed to be October 1.

Cow Herd Dynamics

A cow herd's productive efficiency is greatly influenced by the composition of the cow herd. The make-up of the cow herd determines the quantity and timing of feed and forage requirements. Herd composition is influenced primarily by conception rate, cow death loss, and culling practices, factors which reflect the management level of the operation. It is assumed the operation produces its own replacement heifers. A group of heifers is retained to provide a pool from which replacements are selected. For the rotational systems, 14 heifers are retained for every 100 cows in the herd. Of these, two are culled. The remaining twelve are bred at 15 months to calve as two-year olds (Walker et al. 1987).

Under the culling and replacement assumptions used, for every 100 cows, there are 66 to 71 cows four years old or older, 11 three-year old cows, and 12 two-year old cows. Cows exit the herd by culling (three percent after breeding season and seven at weaning) and by death loss (two percent). A 90 percent calving rate is assumed per 100 cows. Since some cows fail to conceive, more than 100 cows must be bred to have a 100 cow herd. Thus, calves born per cows and heifers bred is 86.5 percent (90/104). Two calves per 100 cows in the herd are assumed to die prior to weaning, giving an 88 percent weaning rate for the 100 cow herd. Assuming an equal number of steers and heifers are calved, 44 steers and 44 heifers are weaned per 100 cows in the herd. All steer calves are available for sale or for retention. Only 30 of the heifers are available for sale or retention because of the replacement heifer requirement (Walker et al. 1987).

During breeding season, one bull is kept for every 25 cows. When the breeding season is over, 25 percent of the bulls are culled and replaced prior to the next breeding season. One-year-old bulls replace four-year-old bulls each year.

Resource Requirements

The resource requirements for a cow unit in the base herd are adapted from budgets developed by Walker et al. (1987). Labor requirements per cow are included by month in the model (Appendix A). The objective function values for the cow activities reflect those operating costs not explicitly considered in the model (Table IX).

TABLE IX

ITEMS COMPRISING OPERATING COSTS OF THE SPRING AND FALL COW ACTIVITIES IN THE BASE SITUATION

Item	Unit	Cost/Unit	Quantity	Total $/Cow
Spring Calving Operation				
Hay	Lbs	$0.03	146.4	$4.39
Protein Supplement	Lbs	0.09	308	27.72
20% Protein Cube	Lbs	0.05	545.7	27.29
Salt and Mineral	Lbs	0.09	30	2.70
Veterinarian-Medicine	Hd	14.65	1	14.65
Vet-Med Supplies	Hd	1.78	1	1.78
Personal Taxes	Hd	5.28	1	5.28
Herd Bulls	Cwt	150.00	0.12	18.00
Machinery and Equipment Expenses	Dol			29.00
			Total	$130.81
Fall Calving Operation				
Hay	Lbs	$0.03	146.1	$4.38
Protein Supplement	Lbs	0.09	485.8	43.72
20% Protein Cube	Lbs	0.05	907	45.35
Salt and Mineral	Lbs	0.09	30	2.70
Veterinarian-Medicine	Hd	14.65	1	14.65
Vet-Med Supplies	Hd	1.78	1	1.78
Personal Taxes	Hd	5.28	1	5.28
Herd Bulls	Cwt	150.00	0.12	18.00
Machinery and Equipment Expenses	Dol			29.00
			Total	$164.87

Forage requirements in pounds of dry matter for one cow in the spring and fall calving activities are presented in Table X (Walker et al. 1987). These values reflect the forage requirements of the cow, her calf, and her portion of the forage requirements of the replacement heifers and herd bulls. The per period dry matter requirements also take into account the quality of forage available in each period of the year. This implicitly satisfies the requirement that the cow not consume more forage than she is able. Adequate supplementation to meet protein and other nutrient needs of the cow is assumed.

Forage requirements for each cow type in each alternative breeding system are adjusted to compensate for changes in frame size and milk production potential. The method for estimating forage requirements for the alternative cow types is discussed in Chapter V.

Production

Spring-born calves are weaned at 210 days and fall-born calves at 285 days. Weaning weights in the base spring calving activity are assumed to be 500 pounds for steers and 483 pounds for heifers (Table XI). In the base fall calving activity, weaned steers are assumed to weigh 580 pounds and heifers, 547 pounds. Given the assumed weaning rate (88 percent), replacement heifer retention rate (14 percent), and weaning weights, there are 2.20 hundredweights (cwt) of a steer calf and 1.449 cwt of a heifer calf available for sale per cow in the spring calving operation. Likewise, in the fall calving operation, there are 2.552 cwt of a steer calf and 1.641 cwt of a heifer calf available for sale per cow. A three percent shrink is assumed at the time of sale of calves and cull breeding stock.

TABLE X

FORAGE REQUIREMENTS FOR COW AND STOCKER ACTIVITIES, POUNDS OF DRY MATTER PER HEAD

Period	SUM1	SUM2	WINT
Period		(Lbs/Head)	
Cow Activities			
Spring Calving	2789	3559	2589
Fall Calving	2792	3288	3692
Stocker Activities			
Year-Round Stocker Steers	1334	1381	1385
Year-Round Stocker Heifers	1252	1359	1312
		Wheat Pasture	
Wheat Pasture Stocker Steers		2317	
Wheat Pasture Stocker Heifers		2248	
Grazeout Wheat Pasture Stocker Steers		1327	
Grazeout Wheat Pasture Stocker Heifers		1295	

TABLE XI

ESTIMATED PRODUCTION FOR THE BASE SPRING AND FALL CALVING OPERATIONS

	Spring Calving Operation	Fall Calving Operation
	---------- (Lbs) ----------	
Production		
Weaned Steers	500	580
Weaned Heifers	483	547
Cull Breeding Stock		
Cull Cows	989	989
Cull Bulls	1725	1725
Cull Replacement Heifers	672	672

A cow-calf operation also "produces" cull breeding stock. A certain number of cull cows, bulls, and replacement heifers are put on the market each year. The average mature weight of a cow in the base herd is assumed to be 1125 pounds and her cull weight, 989 pounds. In the spring (fall) calving operation, three cull cows, .245 cwt per cow, are assumed sold in July (March) and seven, .688 cwt per cow, in October (July). Cull replacement heifers weighing 672 pounds (.1344 cwt per cow) are sold in May in the spring calving operation and January in the fall calving operation. Cull bulls weighing 1725 pounds (.1725 cwt per cow) are sold in July.

Stocker Activities

Three stocker activities are included in the model to represent available opportunities to retain ownership through the stocker phase. Only stocker activities involving spring-born calves are included. The stocker activities are: (1) placing the calves on wheat pasture on October 31 and removing them March 15 (wheat pasture stockers); (2) extending the grazing period on wheat pasture from March 15 to May 14 (grazeout stockers); and (3) roughing the calves through the winter, then placing them on summer pasture in the spring and removing them September 26 (year-round stockers). Heifers and steers are treated as separate entities in the model.

Fall-born calves are weaned at 285 days. They are old enough and big enough to go directly into a feedlot at weaning. A fall calving activity with weaning at 210 days was considered initially. However, a preliminary analysis revealed that it was least profitable, so it was dropped from the model.

Some shrink is to be expected when transferring calves from the cow herd to a stocker operation, due to the stress of weaning and working.

However, the level of stress is less for retained calves than for purchased calves. A 1.5 percent shrink on retained weaned calves is assumed during the transfer from the cow herd to any of the stocker activities. In contrast, a three percent shrink is assumed if the weaned calves or stockers are sold. A two percent death loss is assumed for all stocker activities.

Resource Requirements

Forage is the primary need of the stocker activities. Stocker dry matter forage requirements were derived from enterprise budgets developed by Walker et al. (1987). Wheat pasture is assumed available for rent to meet the needs of the wheat pasture and grazeout stocker activities. Base wheat pasture stocker steers and heifers are assumed to require 2,317 and 2,248 pounds of wheat pasture dry matter, respectively (Table X). Base grazeout stocker steers and heifers are assumed to require an additional 1,327 and 1,295 pounds of wheat pasture dry matter, respectively.

In the year-round stocker program, calves are fed a high roughage maintenance diet through the winter then grazed on summer pasture. In the model, year-round stockers compete for forage with the cow activities. Base year-round steers require 1,334, 1,381, 1,385 pounds of dry matter in the SUM1, SUM2, and WINT periods, respectively. Base year-round heifers require 1,252, 1,359, 1,312 pounds of dry matter in the SUM1, SUM2, and WINT periods, respectively.

Monthly labor requirements for the stocker activities are presented in Appendix A.

Production

Assumptions regarding animal performance and transfer and sale weights and dates are summarized in Table XII. After a three percent shrink, base wheat pasture steers and heifers have pay (transfer) weights of 736 and 695 pounds, respectively. Assumed pay (transfer) weights for grazeout steers and heifers are 838 and 786 pounds, respectively. Base year-round stocker steers and heifers are assumed to weigh 766 and 724 pounds when sold or transferred, respectively.

Feedlot Activities

Five feedlot finishing activities are considered: feeding weaned spring and fall calves, feeding wheat pasture stockers, feeding grazeout stockers, and feeding year-round stockers. Operating costs for the feeding activities are adapted from budgets developed by the O.S.U. Budget Generator.

Estimating Animal Performance

The average daily gains, feed conversions, and finishing weights for the base steer feeding activities in Table XII are obtained from results of Oltjen et al.'s (1984) feedlot growth simulation model. The simulation model uses a description of a pen of cattle with a set of equations to predict feed intake, beef cattle growth, and carcass composition resulting from the net energy content of specified rations (Oltjen et al. 1984). The finishing ration has a net energy for maintenance of .94 Mcal per pound and a net energy for gain of .63 Mcal per pound. The model is designed to simulate British-cross steers.

To run the model, a pen of cattle to be simulated must be described using a set of specified input parameters. The user must specify purchase and selling

TABLE XII

BASE ASSUMPTIONS REGARDING SALE OR TRANSFER DATES AND WEIGHTS, GAIN RATES, AND FEED EFFICIENCY FOR RETAINED OWNERSHIP OPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		(Lbs)						
Weaned Steers, Spring-Calving					500	485	210	31-Oct
Weaned Heifers, Spring-Calving					483	469	210	31-Oct
Weaned Steers, Fall-Calving					580	563	285	15-Jul
Weaned Heifers, Fall-Calving					547	531	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	493	1.80		758	736	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	476	1 62		716	695	135	15-Mar
Grazeout Stocker Steers	31-Oct	493	1 77		864	838	195	14-May
Grazeout Stocker Heifers	31-Oct	476	1.59		810	786	195	14-May
Year-Round Stocker Steers	31-Oct	493	0 83		790	766	330	26-Sep
Year-Round Stocker Heifers	31-Oct	476	0 75		746	724	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	485	2 79	6.23		1060	206	25-May
1 Feeding Weaned Spring Heifers	31-Oct	469	2 45	6 50		927	187	05-May
2 Feeding Stocker Steers	15-Mar	736	3 28	6 15		1085	107	29-Jun
2 Feeding Stocker Heifers	15-Mar	695	2 88	6.41		949	88	11-Jun
3 Feeding Grazeout Steers	14-May	838	3 49	6 23		1140	87	08-Aug
3 Feeding Grazeout Heifers	14-May	786	3 07	6 50		997	69	21-Jul
4 Feeding Year-Round Steers	26-Sep	766	3 20	6 67		1103	105	09-Jan
4 Feeding Year-Round Heifers	26-Sep	724	2 81	6 95		965	86	20-Dec
5 Feeding Weaned Fall Steers	15-Jul	563	3 03	5 93		1050	161	22-Dec
5 Feeding Weaned Fall Heifers	15-Jul	531	2 66	6 18		919	146	07-Dec

weights, a starting factor, efficiency factor, feed intake factor, shrinkage, starting date, death loss, implant usage, frame size and condition score (Table XIII).

The purchase weight is simply the pre-shrunk weight at the end of the previous program. For example, the purchase weight of a weaned spring steer is entered at 500 pounds. A three percent shrink is subtracted from the purchase weight to yield the weight at which animals start on feed. The selling weight implies a four percent pencil shrink. The selling weight entered is that weight which results in final body fat of about 30 percent and an estimated low choice grade.

The starting date is the date the steers entered the feedlot. The starting date drives the model's internal consumption and maintenance factors, which reflect the influence of environmental conditions, namely weather.

The starting factor adjustment reflects stress-induced subpar feed intake during the first ten days on feed. The efficiency factor is a multiplier on the ration NEm and NEg to account for cattle performance better or worse than expected, using a given set of input ration energy values. Likewise, the feed intake factor is a multiplier on the equation generated feed intake to account for observed consumption greater or less than predicted (Oltjen et al. 1984).

The equations used in the simulation program were developed with cattle fed oral stilbesterol, which is no longer legal to feed. Cattle not implanted will have gains about nine percent lower than predicted. The implant factor takes this into consideration. A value of zero indicates no implant use, while a nine indicates that cattle are implanted to achieve maximum implant response (Oltjen et al. 1984). All cattle fed are assumed implanted to achieve maximum implant response.

Cattle of different mature sizes gain at different rates with differing body composition. The simulation model accounts for this by allowing frame size to

TABLE XIII

INPUT ASSUMPTIONS USED IN THE FEEDLOT GROWTH SIMULATION MODEL TO DESCRIBE BASE STEER FEEDLOT ACTIVITIES

Item	Feeding Weaned Spring Steers	Feeding Weaned Fall Steers	Feeding Wheat Pasture Steers	Feeding Grazeout Steers	Feeding Year-Round Steers
Purchase Weight (Lbs)	500	580	748	853	778
Selling Weight (Lbs)	1060	1050	1085	1140	1103
Starting Date	10-31	7-15	3-15	5-14	9-26
Efficiency Factor (%)	100	100	100	100	100
Starting Factor (%)	75	75	75	75	75
Feed Intake Factor (%)	100	100	100	100	100
Shrinkage (%)	3	3	3	3	3
Implant Usage	9	9	9	9	9
Frame Size	2	2	2	2	2
Condition Score	5	5	6	6	5

be specified on a scale of one to three. The base steers are assumed medium frame. Previous nutritional treatment also affects subsequent feedlot performance. The model's condition score accounts for this, where cattle are rated between one and nine for body fatness. Cattle in moderate condition are set at five, very thin at two, or very fat at 9.

Heifer feedlot performance (average daily gain, feed conversion, and finishing weights) is assumed to be a fixed percentage of steer performance. The ratios used to estimate heifer performance from steer performance are adapted from studies by Hicks et al. (1990a and 1990b). Heifer average daily gains are assumed to be 87.89 percent of steer average daily gains. Heifer feed conversions are assumed to be 104.26 percent of steer feed conversion. Finishing weights for heifers are assumed to be 87.48 percent of steer weights. The average daily gains, feed conversions, and finishing weights for the base heifer feeding activities are presented in Table XII.

Representing Financial Statements in Linear Programming

Retained ownership is a capital intensive production strategy. As a result, the linear programming model needs to represent key financial statements: the cash flow statement and the balance sheet. Breaking the year into periods ensures the optimal ranch plan will cash flow, including family living, and that borrowing is contained within realistic limits.

The financial constraint submatrix used in the LP model is presented in Figure 5. The constraints are divided into two categories, capital constraints and credit limits.

		RHS	Cow Activity	Wht Pasture Strs	G O Strs	Sell Cow	W Str Tr.	Sell W. Str	St. Str Tr	Sell Str Str	Sell G O Str.	BOPCAPJF	BOPCAPSO	BOPCAPND	BLSCAP	CASHTR12	CASHTR56
OPCAPJF	L	BC	COE_1	WOE_1	GOE_1							-1 0				1	
OPCAPMA	L	O	COE_2	WOE_2	GOE_2					-SP		$1+\frac{i}{6}$				-1	
OPCAPMJ	L	O	COE_3	WOE_3	GOE_3						-GP						
OPCAPJA	L	O	COE_4	WOE_4	GOE_4	-CP											
OPCAPSO	L	O	COE_5	WOE_5	GOE_5			-WP					-1 0				1
OPCAPND	L	O	COE_6	WOE_6	GOE_6								$1+\frac{i}{6}$	-1 0			-1
LVSTCAP	L	O	CV	O	O										-1 0		
CRLIMJF	L	Z·A	$X\left[CV+\sum_{i=1}^{1} COE_i\right]$	$X\left[\sum_{i=1}^{1} WOE_i\right]$	$X\left[\sum_{i=1}^{1} GOE_i\right]$												
CRLIMMA	L	Z·A	$X\left[CV+\sum_{i=1}^{2} COE_i\right]$	$X\left[\sum_{i=1}^{2} WOE_i\right]$	$X\left[\sum_{i=1}^{2} GOE_i\right]$				-V·Z	-V·X							
CRLIMMJ	L	Z·A	$X\left[CV+\sum_{i=1}^{3} COE_i\right]$	$X\left[\sum_{i=1}^{3} WOE_i\right]$	$X\left[\sum_{i=1}^{3} GOE_i\right]$				-V·Z	-V·X	-W						
CRLIMJA	L	Z·A	$X\left[CV+\sum_{i=1}^{4} COE_i\right]$	$X\left[\sum_{i=1}^{4} WOE_i\right]$	$X\left[\sum_{i=1}^{4} GOE_i\right]$	-CP			-V·Z	-V·X	-W						
CRLIMSO	L	Z·A	$X\left[CV+\sum_{i=1}^{5} COE_i\right]$	$X\left[\sum_{i=1}^{5} WOE_i\right]$	$X\left[\sum_{i=1}^{5} GOE_i\right]$	-CP	-Z·WP	X·WP	-V·Z	-V·X	-W						
CRLIMND	L	Z·A	$X\left[CV+\sum_{i=1}^{6} COE_i\right]$	$X\left[\sum_{i=1}^{6} WOE_i\right]$	$X\left[\sum_{i=1}^{6} GOE_i\right]$	-CP	-Z·WP	X·WP	-V·Z	-V·X	-W						

Figure 5. The Financial Constraint Submatrix

$$Z = \frac{LR}{1+LR} \qquad X = \left(1 - \frac{LR}{1+LR}\right) \qquad V = \frac{(\text{St Str Value} - \text{W Str Value})}{\text{St Str Wt}} \qquad W = \frac{(\text{Go Str Value} - \text{St Str Value})}{\text{Go Str Wt}}$$

BC	=	Beginning Cash
A	=	Beginning Assets
COE_i	=	Cow Operating Expenses in period i
WOE_i	=	Wheat Pasture Stocker Steer Operating Expenses in period i
GOE_i	=	Grazeout Stocker Steer Operating Expenses in period i
CP	=	Cow Price ($/cwt)
WP	=	Weaned Steer Price ($/cwt)
SP	=	Wheat Pasture Stocker Steer Price ($/cwt)
GP	=	Grazeout Stocker Steer Price ($/cwt)
i	=	Annual interest rate

Figure 5. (Continued)

Capital Constraints

Two types of capital constraints are represented, short-term (operating capital) and intermediate-term (livestock capital). The operating capital constraints are considered in two-month periods, OPCAPJF,..., OPCAPND, in the model. Using two-month periods results in an underestimation of the interest charges in some periods. This occurs in periods when livestock are sold at the end of the period, offsetting the operating expenses incurred during that period. Interest should be charged on the operating capital borrowed to cover expenses early in the period, a task the model does not accomplish with bimonthly periods. Using monthly periods would increase precision, however use of two-month periods is not considered a handicap. The intermediate capital row, LVSTCAP, reflects financing of the cow herd on an annual basis.

The right-hand side (RHS) values for all short- and intermediate-term capital constraints equal zero, except for OPCAPJF, the first short-term borrowing period. The RHS for this period equals the firm's cash on hand at the beginning of the year, obtained from the beginning balance sheet.

The short-term operating capital rows force operating capital requirements for enterprise activities to be met in each period. Operating capital requirements can be met with funds from three sources, cash on hand at the beginning of the period, receipts from the sale of output during the period, or borrowing.

The operating capital requirements by period for three production activities with different types of operating capital requirements are illustrated in Figure 5. First, the cow-calf activity represents one in which capital is required continuously throughout the year. The entry in the ith operating capital row, COE_i, is the amount of operating expenses per cow incurred in the ith period.

The second production activity included in Figure 5 is wheat pasture stocker steers. The wheat pasture stocker activity requires weaned calves as inputs, which are transferred from the cow activity. The wheat pasture stocker activity is initiated after weaning in the fall and terminated in mid-March. The third production activity is grazeout steers. Grazeout steers are wheat pasture stockers that, instead of being sold in March, are kept on wheat pasture through May, then sold. The grazeout stocker activity is initiated and completed within the year. The operating capital entry in the ith period is the amount of operating expenses incurred in that period.

Entries in the operating capital rows for the sell livestock activities occur only in the period of sale. The entry is equal to the market price in dollars per hundredweight (cwt) for a given class of livestock. For example, the July sell cull cow activity is illustrated in Figure 5. The entry for the sell cow activity in the July-August operating capital row is the market price of July cull cows. The livestock sale entries in the operating capital rows reflect cash inflow from the sale of livestock, which is used to cover operating expenses in that period, and in subsequent periods via the cash transfer activities, should a cash surplus result.

Six operating capital borrow activities corresponding to two-month periods are included in the model. Borrowing a dollar provides a dollar of operating capital, but with an interest charge. The objective function entry for the borrowing activities is the two-month interest rate, which is the annual interest rate divided by six. The interest charge in the first five periods is also included as a use of cash in the following period. This reflects the cash outlay required to make the interest payment on short-term debt, which would occur in the period following that in which the operating capital was borrowed.

Cash transfer activities transfer any surplus cash from one period to the next. Thus, any excess cash in one period, from the sale of livestock, for example, can be used to cover operating expenses in the following period.

The Credit Limit Constraints

Certain limits to borrowing capacity exist. These can be internal, a producer's unwillingness to over-extend, or external, due to limits lenders place on the amount of credit they are willing to extend. These limits are based primarily on the financial condition of the producer and his or her collateral situation. Producer borrowing capacity is portrayed in the LP model in a set of six, independent, two-month, credit limit constraints, CRLIMJF,..., CRLIMND (Figure 5).

The RHS values for the credit limit constraints equal the producer's beginning assets adjusted to reflect lender-imposed limits. The adjustment factor is derived as follows. Given

$$LR = D/E = D/(A-D) \tag{34}$$

where LR is maximum allowed leverage ratio, D is debt, E is equity, and A is assets, Equation (34) is solved for D. This yields

$$D = L/(1+L) * A = Z * A \tag{35}$$

where Z, the adjustment factor, is the maximum leverage ratio assumed allowed by the lender divided by one plus the maximum leverage ratio. Total allowed debt is equal to total assets multiplied by Z. A maximum allowed leverage ratio of 2 is assumed in this study. Thus Z equals 2/3. The lender is assumed willing to extend credit up to a level equal to 2/3 of the producer's assets.

The production activity capital requirements in the credit limit rows reflect the total operating expenses incurred up to and including any given period.

The cow activity entries also include the cow value. For example, the entry in the first credit limit row for the cow activity equals the sum of the cow value and the per cow operating expenses incurred in the first period. In the second credit limit row, the entry equals the first period entry plus expenses incurred in period two, and so forth. All production activity entries in the credit limit rows are adjusted by the factor X, where

$$X = 1 - (LR/(1+LR)) = 1 - Z \qquad (36)$$

This reflects the fact that capital capacity does not diminish, dollar-for-dollar, as capital is extended to cover operating expenses or to purchase livestock. Instead, the capital capacity decreases by a fraction (in this case, 1/3) of the total, an amount determined by the maximum leverage ratio allowed.

The livestock transfer and sale activities increase capital capacity because assets also increase. The cull breeding livestock sale activities increase capital capacity directly by the value of the cull breeding stock sold, in the period of sale. The sale transaction is a source of capital in the period of sale and in every period following because each period is independent of the others in the model.

The transfer of weaned calves from the cow activity to subsequent activities (production or sell) results in a capital capacity increase since the producer can borrow against the value of the animals. However, the increase in capital capacity is limited by the maximum leverage ratio the producer's lender will allow. Thus, the increase in capital capacity is equal to the value of the weaned calf adjusted by the factor Z, defined earlier.

Weaned calves can be transferred and sold or transferred to subsequent production activities, stocker activities, for example. Should the calf be sold at weaning, the rest of its cash value is added to the available capital. Stocker value is greater than weaned calf value, thus when calves are retained the producer's capital capacity increases since he can borrow against the stocker's value. The amount of the increase is equal to the difference between the stocker and weaned calf values, divided by stocker sale weight and adjusted by the maximum leverage ratio adjustment factor, Z. If wheat pasture stockers are sold, their remaining cash value is added to the credit capacity. Changes in capital capacity as a result of retaining wheat pasture stockers into the grazeout activity or the feedlot activities and their subsequent sale accrue in the same manner as described for retaining weaned calves into the wheat pasture stocker activity.

The base situation and the construction of the base linear programming model were described in this chapter. The base situation, a two breed rotation with medium frame, medium milk potential breeds, will provide the basis of comparison among the alternative breeding systems. The method for deriving animal performance estimates for the alternative breeding systems is presented in the next chapter.

CHAPTER IV

DEVELOPMENT OF ALTERNATIVE BREEDING SYSTEMS

The development and derivation of the animal performance estimates and resource requirements for each frame size and milking potential combination used in the study are presented in this chapter. A brief overview of crossbreeding is included. The overview draws heavily on Willham (1970), Cundiff and Gregory (1977), Gregory and Cundiff (1980), Lasley (1987), and Buchanan and Clutter (1989). Following the general discussion, the method used to derive animal performance estimates is presented.

Crossbreeding

Long (1980) identifies two primary procedures by which the efficiency of beef production systems may be increased genetically: (1) selection within breeds to enhance critical characters, and (2) selection and combination of breeds to produce individuals that better fit production conditions and resources. Cundiff and Gregory (1977) identify the first procedure as being primarily the responsibility of purebred or seedstock producers. Improvement through the second procedure, which is accomplished by crossbreeding, is the responsibility of the commercial producer.

Crossbreeding is the mating of animals of two or more different breeds. It offers opportunities to improve upon performance of straightbred populations

(MacNeil et al. 1986). When appropriate breeds are used, systematic crossbreeding can result in significant improvement in productive efficiency and product desirability. The basic objective of crossbreeding systems is to optimize simultaneously the use of both nonadditive and additive gene effects. The nonadditive gene effects are the basis of heterosis (hybrid vigor), while the additive gene effects determine breed differences.

Consequences of Crossbreeding

The optimum effect of crossbreeding would be realized by systematic crossing of breeds that express maximum heterosis and excel in their breeding value for net merit, which is determined by average gene effects for the breeds (Cundiff 1970). Willham (1970) identifies several desirable consequences of crossbreeding, especially in the production of market livestock. These consequences are the utilization of heterosis, the opportunity to incorporate desirable genetic material quickly, and the chance to combine several desirable traits in the market animal.

Heterosis. Heterosis, or hybrid vigor, is defined as the average superiority of a crossbred individual over the average of the breeds in the cross. Heterosis levels are determined by breed choice and the crossbreeding system used. According to Willham (1970, p. 691), breeds crossed should be as genetically divergent as possible and the favorable gene must exhibit some dominance to maximize heterosis in the offspring of a cross between two breeds. The Brahman breed is somewhat unique in that when crossed with European breeds, high levels of heterosis for growth, maternal ability, and reproductive performance result (Koger 1980; Franke 1980; Crockett et al. 1978a and 1978b).

Three mating situations result in heterosis. Individual heterosis is the advantage of the crossbred individual relative to the purebred individuals (Table XIV). Maternal heterosis is the advantage of the crossbred mother over the average of purebred mothers. Paternal heterosis, which is the advantage of a crossbred male over the average of purebred males, generally only affects conception rate. Only individual and maternal heterosis are considered in this study.

The effects of heterosis are illustrated in the following example. Assume the purebred average weaning weight of two breeds is 465 pounds. The crossbred average weaning weight, which involves only individual heterosis since both parents are purebred, is 465 (1 + .047), which equals 486.9 pounds. Similarly, for a three-breed cross, a crossbred dam mated to a purebred sire, assume a purebred average weaning weight of 545 pounds. The crossbred average weaning weight, which considers both individual and maternal heterosis is 545 (1 + .047) (1 + .042), which equals 594.6 pounds.

Within a breed, parents cannot consistently transmit heterotic effects to their offspring because only half of their genes, one of each pair, are passed on to the next generation. Thus, systematic mating procedures involving different breeds are required to maintain heterotic effects from one generation to the next.

Incorporating Desirable Genetic Material. By crossbreeding, desired genes can be incorporated into a market animal faster than by conventional straightbred selection procedures. Success depends on the gene frequency difference between populations relative to the gene frequency change by selection. According to Willham (1970, p.692), the introduction of new genes or

TABLE XIV

HETEROSIS IN BEEF CATTLE

Trait	Heterosis	
	Individual	Maternal
	-------- (Percent) --------	
Calving Percent	3.4	6.6
Calf survival	1.7	2.0
Birth weight	2.7	1.6
Weaning weight	4.7	4.2
Postweaning ADG (feedlot)	3.9	-1.4
Postweaning ADG (pasture)	6.4	
Yearling weight (feedlot)	3.8	2.9
Yearling weight (pasture)	4.5	
Mature Weight	3.5	
Loin eye area	2.8	
Fat thickness	2.3	
Quality grade	.7	
Dressing Percent	.6	
Cutability Percent	.6	

Sources: Marlowe, T.J., A.L. Eller, Jr., J.A. Gaines, and D.R. Notter. "Guidelines on Crossbreeding for Beef Production." 1978-1979 Livestock Research Report. Research Div. Report No. 175. Blacksburg: Virginia Polytechnic Institute and Sate University. 1979.

Long, Charles R. "Crossbreeding for Beef Production: Experimental Results." Journal of Animal Science. 51:1197-1223. 1980.

Buchanan, D.C. and A.C. Clutter. Animal Breeding: Principles and Applications. 2nd Ed. Stillwater: Oklahoma State University. 1989.

the rapid increase in the frequency of desired genes is often more important than the improved performance achieved by heterosis.

Combining Breed Characteristics. Crossbreeding allows desired trait combinations to be incorporated into the phenotype of animals. Success at combining desirable traits depends on the degree of dominance and the gene frequency difference.

Cartwright (1970) refers to results of the discriminate matching necessary to combine breed characteristics as complementarity between dam and sire breeds with different traits. Complementarity refers to the advantage of a cross over a purebred or another cross resulting from the manner in which two or more characters combine or complement each other. The degree of complementarity depends on the extent of interaction between reciprocal crosses or among crosses of different breeds for an aggregate character.

Resource availability, especially in terms of quantity and quality of forage and feed production, is extremely variable among different regions of the country. Likewise, resource requirements, such as feed and labor, vary greatly among breeds. A primary benefit of combining breed characteristics lies in the ability to better align genetic resources, the cow herd, with feed and other production resources available to the producer and the climatic environment. This enables the producer to increase productive efficiency.

Effective Breed Combinations

In contrast to the dairy industry in the United States, beef producers have not substituted breeds that excel in red meat output for those with low output potential. About 90 percent of the cows used for milk production in the U.S. are Holsteins (Cundiff et al. 1986a). By replacing breeds with lower milk producing potential with Holsteins, dairy producers have capitalized on the Holstein breed's superior genetic potential for milk production. However, such movements in beef industry may be inappropriate. Cundiff et al. (1986a p. 279) state "The breeds that excel in retail product growth should not necessarily be substituted for breeds with less genetic potential for output because of trade-offs that result from antagonistic genetic relationships among traits."

For example, breeds which excel in retail product growth rate and efficiency also: (1) sire progeny with heavier birth weights, which increase dystocia, decrease calf survival, and decrease rebreeding in dams; (2) produce carcasses with lower marbling, which makes it difficult to meet grading requirements; (3) are older at puberty; and (4) have heavier mature weights and increased nutrient requirements per cow for maintenance.

Cundiff et al. (1986a, p. 279) conclude "No one breed excels in all characteristics of economic importance in the beef industry, nor is it possible to expect simultaneous improvement in all characteristics from intrapopulation selection since similar genetic relationships often exist within breeds." This points to the importance of crossbreeding systems that exploit complementarity and heterosis and align genetic resources with feed resources and climatic environment as a means of increasing productive efficiency, given the existence of trade-offs from genetic antagonisms (Cundiff et al. 1986a; Gregory and Cundiff 1980).

Crossbreeding Systems

Maintaining the level of heterosis is difficult in cattle because of their low reproductive rate and long generation interval. However, this does not prevent commercial beef operations from utilizing a high level of heterosis. The commercial producer must follow an organized crossbreeding plan, not just use breeds selected randomly, to capitalize on the benefits. Crossbreeding systems can be designed to restore significant levels of heterosis from one generation to the next.

Crossbreeding systems can be divided into two broad categories, rotational systems and terminal systems. Both types have associated advantages and disadvantages.

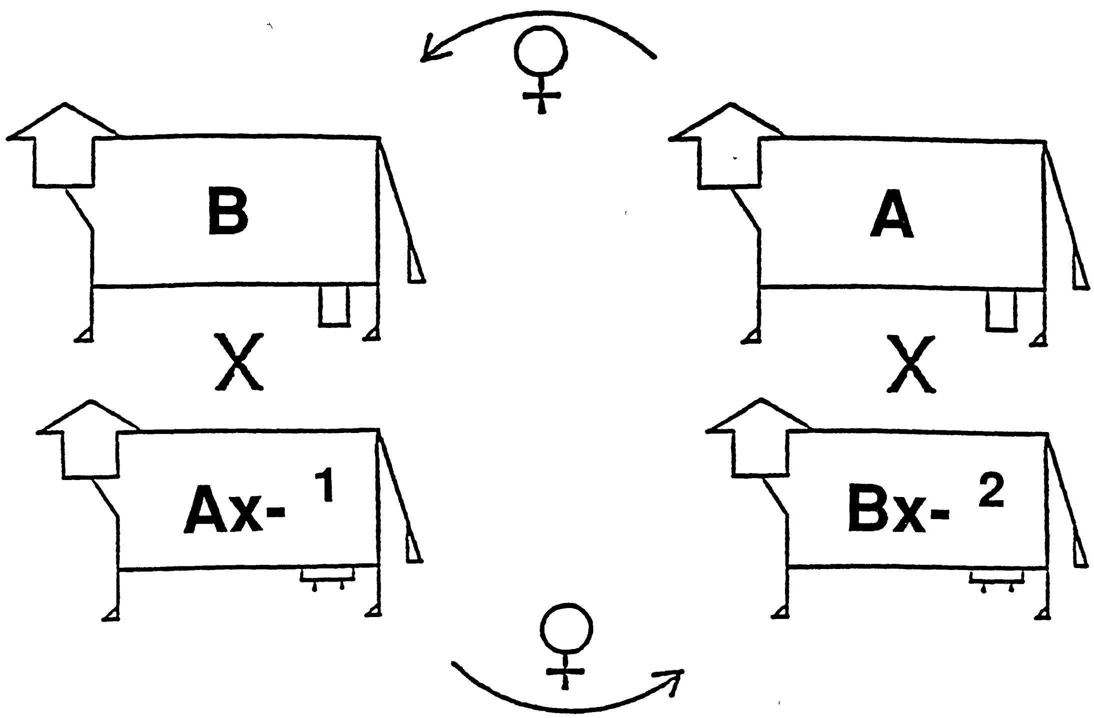
Rotational Crossbreeding Systems

Rotational systems are those that use a sire breed on the crossbred females produced in the previous generation (Bennett 1987a). The sire breed used in a given generation is of a different breed from the sire used in the previous generation.

Replacement heifers are selected from the offspring in each generation. Replacement heifers must be identified according to the breed of their sires. Rotational crossbreeding can involve any number of breeds. The number of breeds used in the rotation dictate the minimum number of separate breeding pastures required.

In the two breed rotation, the program is initiated by mating cows of breed A to bulls of breed B (Figure 6). The F1 (half breed A and half breed B) heifers of these matings are bred to bulls of breed A. The heifers from the breed A and F1 matings are then bred to sires from breed B, and the process continues generation after generation.

The three breed rotation is similar in design, except three breeds are used (Figure 7). The program is initiated by mating cows of breed C to bulls of breed A. The F1 replacement heifers of this mating are bred to bulls of breed B.



1 Denotes A-sired female.
2 Denotes B-sired female.

Figure 6. Schematic of a Two-Breed Rotational System

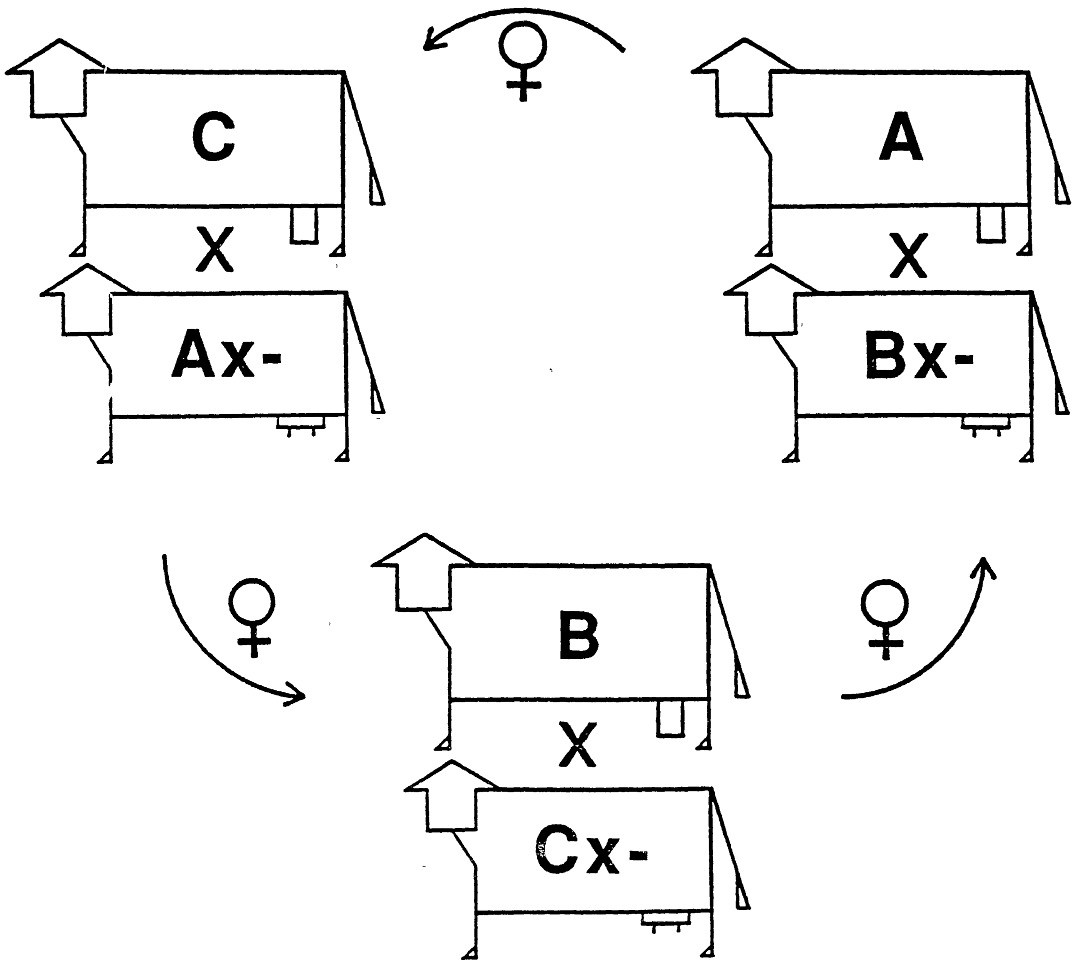


Figure 7. Schematic of a Three-Breed Rotational System

Replacement heifers from these matings are bred to bulls of breed C. The resulting generation of replacement heifers are bred to bulls of breed A, and the process continues.

Potential exists for wide fluctuation between generations in additive genetic composition in rotational crossbreeding systems. Thus the breeds selected for use in the rotational system should be reasonably comparable in characters such as birth weight to minimize calving difficulty. They should also be compatible in performance characteristics such as mature size and lactation potential to facilitate common management of all breed-of-sire groups.

The breed of sire changes in each generation. After the first rotation is complete, there is always some element of backcrossing involved which results in a loss of heterosis. Individual and maternal heterosis levels fluctuate in a rotational system's initial generations. Once crossbred cows enter the system, the fluctuations become less noticeable since low levels of one type of heterosis are offset by higher levels of the other. After several generations, the amount of both individual and maternal heterosis retained will stabilize at an equilibrium level, depending on the number of breeds used in the rotation.

Additive breed effects and average heterosis utilization of conventional rotations are uniquely determined by the number of breeds because each of n breeds is used a single time in each cycle of n generations (Bennett 1987a, p.1471). As the number of breeds in the rotation increases, the level of heterosis retained increases (Carmon, et al. 1956). For a two-breed rotation in equilibrium, 66.67 percent of the individual and maternal heterosis is retained; in a three-breed rotation, 86 percent (Dickerson 1969, 1973).

Rotational systems exploit breed and heterosis differences through the selection of breeds to include in the rotation (Bennett 1987a). A primary advantage of rotational crossbreeding systems is that the system generates its own replacement heifers. This allows the producer to apply selection pressure when selecting replacements and minimizes the opportunity for disease transmission into the herd.

The primary disadvantage associated with rotational systems is the failure to utilize breed complementarity (Cartwright 1970). Each breed in the rotation needs to be somewhat adapted as both a sire and dam breed. The producer is unable to capitalize on desirable characteristics of specific breeds, such as superior reproductive performance, since over time, each breed contributes equally to the sires and the dams. The maintenance of at least one breeding pasture per breed in the rotation can also be a disadvantage, especially for smaller producers.

Terminal Sire Crossbreeding Systems

Terminal breeding systems are designed such that a specific breed(s) of sire is mated to a specific breed(s) of dam to maximize the use of heterosis. Two breed terminal crosses use 100 percent of the individual heterosis, while three and four breed terminal crosses use 100 percent of the maternal heterosis as well.

The object of the terminal system is to maximize productive efficiency by selecting breeds used in the sequence of matings that complement each other to the greatest extent. Breed complementarity is the primary advantage of terminal systems since male and female breeds can be chosen for specific roles. Any terminal cross should have a sire breed(s) characterized by superior growth and carcass merit and a dam breed(s) characterized by superior reproductive performance and mothering ability.

In the three breed terminal system, straightbred cows of breed A are bred to bulls of breed B to produce F1 crossbred females (BA). The F1 females are mated to breed T and all the progeny, both male and female, are sold. Breeds A and B, the first two in the sequence, should be selected to synchronize cow size and maternal performance with available feed resources. The terminal breed, breed T, should be selected with an emphasis given to rate and efficiency of gain and carcass composition, to maximize these characteristics in as many of the progeny marketed as possible.

A major disadvantage of a terminal crossbreeding system is that it requires replacements to be imported from sources outside the herd, unless a portion of the herd is used to produce replacements. Importing animals from outside sources increases the risk of disease and eliminates control over selection practices.

Combining Breeding Systems

Conventional rotational crossbreeding systems that use breeds equally maintain the maximal heterosis possible in a rotation but do not maximize utilization of differences among breeds in the cross (Bennett 1987a). Gregory and Cundiff (1980) suggest the use of rotational-terminal sire systems. Combined rotational-terminal sire crossbreeding systems can take advantage of both heterosis provided by rotational systems and complementarity provided by terminal sire systems. The objective of these systems is to use heterosis in all production and to capitalize on breed complementarity, especially increased growth rate of larger breeds in about one-half of the production and two-thirds of the calves marketed.

The combined rotational-terminal sire system is illustrated in Figure 8. Younger cows, with whom greatest calving problems are associated, are used to produce replacement heifers in a rotational crossbreeding system. Cows not necessary for meeting replacement requirements are bred to terminal sires selected to maximize genetic contribution for increased growth rate and performance. All offspring from these matings are then sold.

Two- and three-breed rotational crossbreeding systems and combined two- and three-breed rotational-terminal sire crossbreeding systems are considered in this study. A comparison of the percentage increase in weaning weights above a straightbred system is presented in Figure 9. Three-breed rotations utilize a higher level of heterosis, thus greater increases are expected in systems with three-breed rotations. Use of the terminal sire in combined rotational-terminal sire systems results in marked increases in weaning weight over conventional rotational systems.

The preceding discussion has laid the foundation for the research method that follows. The discussion now focuses on the approach used to derive estimates of animal performance and resource requirements for the alternative breeding systems considered in the study.

Data Development

A study evaluating the profitability of alternative cattle breeding systems is very data intensive. Consideration of a number of alternative retained ownership alternatives magnifies data needs. Animal performance estimates and resource requirements are needed for each linear programming activity for each system considered.

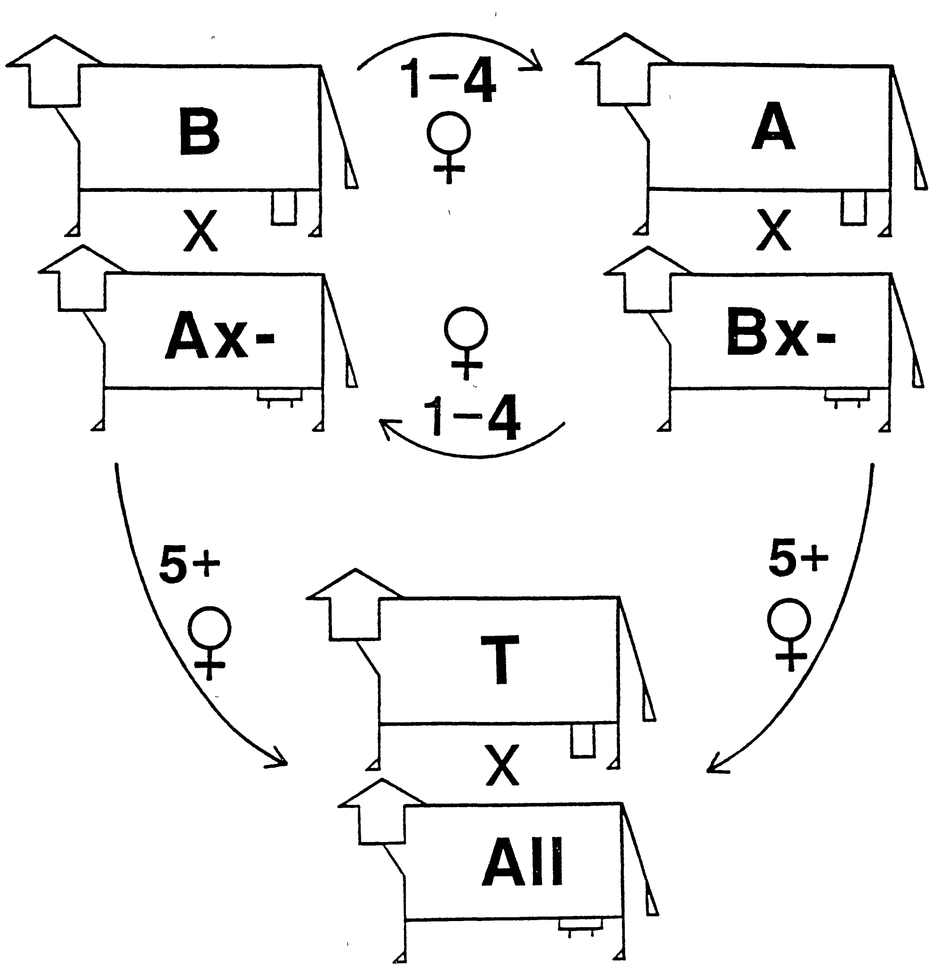


Figure 8. Schematic of a Combined Two-Breed Rotational-Terminal Sire System

Mating type	Percentage of herd[a]	Percentage of calves weaned[a]	Individual heterosis[b]	Maternal heterosis[b]	Terminal sire[c] contribution	Estimated increase in weaning weight per cow exposed[abc]
			(percent)			
Two-breed rotational crossbreeding system						
A B-rotation	100	100	3.1	2.8	0	5.9
						Total 5.9
Three-breed rotational crossbreeding system						
A B C-rotation	100	100	4.0	3.6	0	7.6
						Total 7.6
Combined two-breed rotational-terminal sire crossbreeding system						
A B-rotation	50	33.3 ( )	3.1	2.8	0	2.0
T X (A B-rotation)	50	66.7 (+)	4.7	2.8	5.0	8.0
						Total 10.0
Combined three-breed rotational-terminal sire crossbreeding system						
A B C-rotation	50	33.3 ( )	4.0	3.6	0	2.5
T X (A B C-rotation)	50	66.7 (+)	4.7	3.6	5.0	8 9
						Total 11.4

[a] Assumes 80% calf crop weaned and a 20% replacement rate.
[b] Based on heterosis effect of 4.7% for individual traits and 4.2% for maternal traits and assumes that loss of heterosis is proportional to loss of heterozygosity.
[c] Assumes a 10% increase in breeding value for calf weight produced per cow exposed for terminal sires (T).
[d] Breeds A, B and C are assumed to be approximately equal in size, milk production and maturation rate. Females of cross (B A) are bred to sires of breed C to produce their first calf crop because of likelihood calving difficulty; after first calf crop, they are bred to terminal sires (T), which are assumed to have a breeding value for increase calf weight produced per cow exposed of 10% greater than breeds A and B

Adapted from Gregory, K.E. and L.V. Cundiff. "Crossbreeding in Beef Cattle: Evaluation Systems." Journal of Animal Science. 51:1224-1242. 1980.

Figure 9. Comparison of Crossbreeding Systems

Experiments designed to evaluate alternative crossbreeding systems, with a sufficient volume of cattle to reliably estimate performance in each stocker and feedlot activity, would be the ideal source of primary data. However, such experiments are precluded by their expense.

Alternative data sources must be explored. The alternative used in this study develops animal performance estimates using existing breed data within the context of the theory of animal breeding (Dickerson 1969 and 1972; Sheridan 1981; Bennett 1987a and 1987b).

The primary source of animal performance data is published research results from the beef cattle Germ Plasm Evaluation Program at the Roman L. Hruska U.S. Meat Animal Research Center (MARC) in Clay Center, Nebraska (Koch et al. 1976; Smith et al. 1976; Gregory et al. 1978a; Gregory et al. 1978b; Gregory et al. 1978c; Gregory et al. 1979; Koch et al. 1979; Cundiff et al. 1981; Koch et al. 1982; Koch et al. 1983; Cundiff et al. 1986a; Cundiff et al. 1986b; Gregory et al. 1987). The beef cattle Germ Plasm Evaluation Program at MARC has been conducted in four cycles, beginning in 1969, to evaluate topcross performance of 26 different sire breeds in calves out of Hereford and Angus dams (Cundiff 1974; Cundiff et al. 1986a). Breeding stock at MARC is selected with the goal of obtaining a representative sample of current genetics of the breeds under consideration. All testing is done by crossing purebred sires to Hereford, Angus, or Hereford-Angus cross dams. Hereford and Angus cows were selected because of their predominance in beef breeds throughout the country.

Thirteen breed crosses are divided into five biological types and scored (X lowest, XXXXX highest) relative to growth rate and mature size, lean-to fat ratio, age at puberty, and milk production in Table XV (Cundiff et al 1986a, p.273). Data reported on these crosses provide the basis for the performance

TABLE XV

BREED CROSSES GROUPED IN BIOLOGICAL TYPE ON BASIS OF FOUR MAJOR CRITERIA

Breed Group	Growth Rate and Mature Size	Lean to Fat Ratio	Age at Puberty	Milk Production
Medium Frame - Medium Milk Potential				
Hereford-Angus (HA)	XX	XX	XXX	XX
Medium Frame - Heavy Milk Potential				
Red Poll (RP)	XX	XX	XX	XXX
South Devon (SD)	XXX	XXX	XX	XXX
Tarentaise (T)	XXX	XXX	XX	XXX
Pinzgauer (P)	XXX	XXX	XX	XXX
Large Frame - Heavy Milk Potential				
Brown Swiss (BS)	XXXX	XXXX	XX	XXXX
Gelbvieh (G)	XXXX	XXXX	XX	XXXX
Simmental (S)	XXXXX	XXXX	XXX	XXXX
Maine-Anjou (MA)	XXXXX	XXXX	XXX	XXX
Large Frame - Light Milk Potential				
Limousin (L)	XXX	XXXXX	XXXX	X
Charolais (CH)	XXXXX	XXXXX	XXXX	X
Chianina (C)	XXXXX	XXXXX	XXXX	X
Other (Zebu)				
Brahman (B)	XXXX	XXX	XXXXX	XXX

Cundiff, L.V., K.E. Gregory, R.M. Koch and G.E. Dickerson. 1986. Genetic diversity among cattle breeds and its use to increase beef production efficiency in a temperate environment. Proc. 3rd World Cong. on Genetics Applied to Livestock Production. IX:271.

estimates used in this study. Weaning weight, rate of gain, feed conversion, and finishing weights are calculated for progeny of each frame size and milk potential classification in the crossbreeding systems considered.

Crossbreeding Systems Considered

Numerous crossbreeding alternatives exist, especially when considering the number of breed combinations possible for each system. Specific breed combinations are not considered explicitly in this study. Instead, the breeds are grouped by frame size and milk potential as in Table XV. Eleven crossbreeding systems are designed and evaluated in this study (Figure 10). Estimates of animal performance for each component of the crossbreeding systems identified, either rotational or terminal cross, must be generated.

The analysis is conducted from a long run viewpoint. No consideration is given to the issue of movement among systems or time lag to reach herd configurations. The goal is to evaluate the performance of each system independently in an established, long-run operation.

Research Method

The principle market animal performance traits considered in this study include weaning weight, postweaning average daily gain (ADG), feed efficiency, and finishing weights. Maternal performance traits are considered as well, including mature weight, milk production, calf birth weight, and weaning rate.

To reflect the effects of crossbreeding, additive effects, both individual and maternal, and heterotic effects must be considered. Buchanan and Clutter

System	Description

(0) "Pre-1980s" Two breed rotational cross with medium frame, medium milk potential breeds (RC0)

(1) "Modern" Two breed rotational cross with medium frame, medium milk potential breeds (Base) (RC1)

(2) Combination rotational cross and terminal cross with dams from System (1) and large frame sires
- A. Rotational cross with cows five years old and younger to generate replacements (RC2 = RC1)
- B. Terminal cross with remaining cows and large frame sires (TC2)

(3) Three breed rotational cross, with two medium frame, medium milk potential breeds and one medium frame, high milk potential breed (RC3)

(4) Combination rotational cross and terminal cross with dams from System (3) and large frame sires
- A. Rotational cross with cows five years old and younger to generate replacements (RC4 = RC3)
- B. Terminal cross with remaining cows and large frame sires (TC4)

(5) Two breed rotational cross with medium frame, high milk potential breeds (RC5)

(6) Combination rotational cross and terminal cross with dams from System (5) and large frame sires
- A. Rotational cross with cows five years old and younger to generate replacements (RC6 = RC5)
- B. Terminal cross with remaining cows and large frame sires (TC6)

(7) Three breed rotational cross, with two medium frame, medium milk potential breeds and Brahman (RC7)

(8) Combination rotational cross and terminal cross with dams from System (7) and large frame sires
- A. Rotational cross with cows five years old and younger to generate replacements(RC8 = RC7)
- B. Terminal cross with remaining cows and large frame sires (TC8)

(9) Large frame, high milk potential, two breed rotational cross (RC9)

(10) Large frame, low milk potential, two breed rotational cross (RC10)

Figure 10. Alternative Cattle Breeding Systems Considered in the Analysis

(1989) suggest the following equation to accomplish this for an n breed rotational cross in equilibrium:

$$T_j = \left[A + \left[1/n \sum_{i=1}^{n} (D_i + M_i) \right] \right] (1 + z^*H_I)\,(1 + z^*H_M) \tag{37}$$

where $z = (2^n-2)/(2^n-1)$ and T_j is the jth performance trait, A is a constant, D_i and M_i are the direct and maternal additive effects of the ith breed, and H_I and H_M are percent individual and maternal heterosis. The contributions of each breed to the cross, the additive effects, and the multiplicative effects of heterosis are apparent in Equation (37).

Equation (37) can be modified slightly to reflect the effects of a terminal crossbreeding system, using a terminal sire on females generated by an n-breed rotational cross herd in equilibrium:

$$T_j = \left[A + \left[.5(D_T + 1/n \sum_{i=1}^{n} D_i) + 1/n \sum_{i=1}^{n} M_i \right] \right] (1 + H_I)\,(1 + z^*H_M) \tag{38}$$

where D_T is the direct additive effect of the terminal sire. The terminal cross allows all the individual heterosis effects to be utilized.

The data presented in Tables XVI, XVII, and XVIII are from calves of Angus and Hereford dams and two-breed crossbred dams with Hereford or Angus at least one of the breeds in the cross. In order to use these data to derive the individual and maternal additive breed effects, heterosis effects must first be removed. This is accomplished by dividing the table values by $(1 + H_I)$, where H_I is the percent individual heterosis (Table XIV). When data from F1 dams are used, maternal heterosis effects are removed by dividing the individual heterosis-adjusted value by $(1 + H_M)$, where H_M is percent maternal heterosis. For example, the heterosis-adjusted value for Tarentaise-sired

TABLE XVI

SIRE BREED GROUP MEANS FOR BIRTH AND WEANING TRAITS (CALVES OUT OF HEREFORD OR ANGUS DAMS)

Breed	Number	Gestation length (days)	Calving diff (%)	Survival bir. to wn. (%)	Birth wt. (lb)	200-day wt. (lb)
Hereford-Angus	962	284	2.9	97.3	79	429
Red Poll	214	285	3.7	97.8	79	425
South Devon	232	287	11.9	92.8	83	429
Tarentaise	202	287	6.0	94.8	83	442
Pinzgauer	376	286	6.3	95.2	86	438
Brahman	349	285	10.0	93.5	90	455
Brown Swiss	263	286	8.4	97.2	85	451
Gelbvieh	213	282	8.0	91.5	86	460
Simmental	399	285	14.9	89.1	89	451
Maine Anjou	222	289	20.4	90.8	90	453
Limousin	371	287	9.4	91.7	86	436
Charolais	382	287	18.4	86.5	90	458
Chianina	238	288	11.8	91.1	89	455

Cundiff, L.V., K.E. Gregory, R.M. Koch and G.E. Dickerson. 1986. Genetic diversity among cattle breeds and its use to increase beef production efficiency in a temperate environment. Proc. 3rd World Cong. on Genetics Applied to Livestock Production. IX:271.

TABLE XVII

SIRE BREED GROUP MEANS FOR POSTWEANING GAIN AND EFFICIENCY (CALVES OUT OF HEREFORD OR ANGUS DAMS)

Breed	Number	Postweaning ADG (lb/d)	452-day wt (lb)	Wt at Sm. marb (lb)	Mcal ME/lb gain USDA Ch. 0 day to Sm. marb
Hereford-Angus	508	2.39	1043	1006	10.6
Red Poll	111	2.20	992	986	11.6
South Devon	94	2.57	1080	1072	10.7
Tarentaise	103	2.37	1052	1082	11.4
Pinzgauer	176	2.44	1056	1044	10.8
Brahman	153	2.39	1065	1168	11.8
Brown Swiss	121	2.46	1085	1155	10.9
Gelbvieh	111	2.55	1111	1246	11.0
Simmental	109	2.64	1131	1299	11.1
Maine Anjou	72	2.47	1065	1215	11.3
Limousin	173	2.31	1032	1185	11.8
Charolais	176	2.66	1140	1309	11.0
Chianina	119	2.48	1096	1389	12.2

Cundiff, L.V., K.E. Gregory, R.M. Koch and G.E. Dickerson. 1986. Genetic diversity among cattle breeds and its use to increase beef production efficiency in a temperate environment. Proc. 3rd World Cong. on Genetics Applied to Livestock Production. IX:271.

TABLE XVIII

SIRE BREED GROUP MEANS FOR REPRODUCTIVE AND MATERNAL TRAITS OF CROSSBREED COWS

Breed	Number births	Calf crop born (%)	Calf crop weaned (%)	Calving diff. (%)	Birth wt. (lb)	12-hr milk prod (lb)	Cow wt. (lb)	200-day wt per calf weaned (lb)
Hereford-Angus	1685	91	84	13	86	6.2	1221	473
Red Poll	1685	91	84	13	86	6.2	1221	473
South Devon	603	88	85	15	91	6.6	1263	491
Tarentaise	369	91	85	10	88	7.9	1201	524
Pinzgauer	508	93	85	13	91	7.9	1217	508
Brahman	519	94	86	1	83	9.0	1280	537
Brown Swiss	681	92	85	8	94	8.4	1239	532
Gelbvieh	429	95	87	11	90	8.4	1280	532
Simmental	872	89	83	17	91	8.4	1279	519
Maine Anjou	468	94	86	11	96	6.4	1362	521
Limousin	851	89	82	12	88	5.5	1232	484
Charolais	693	88	80	15	83	5.5	1353	502
Chianina	475	93	86	93	95	6.2	1366	521

Cundiff, L.V., K.E. Gregory, R.M. Koch and G.E. Dickerson. 1986. Genetic diversity among cattle breeds and its use to increase beef production efficiency in a temperate environment. Proc. 3rd World Cong. on Genetics Applied to Livestock Production. IX:271.

calves are 442/(1 + .047) = 422.2 and 524/[(1 + .047)(1 + .042)] = 480.3, where 442 is from Table XVI and 524 is from Table XVIII.

<u>The Additive Effects</u>

<u>Direct Effects</u>. Given the heterosis-adjusted values, which equal the total additive effects, the direct and maternal additive effects relative to the Hereford-Angus control are calculated as follows. The additive effects of the Hereford-Angus two-breed reciprocal cross, HA_{Aj} for trait j can be represented:

$$HA_{Aj} = 1/2D_H + 1/2D_A + 1/2M_H + 1/2M_A \qquad (39)$$

where D and M represent direct and maternal additive effects and the subscripts denote breed (Buchanan 1989). In a two- breed reciprocal cross, half of the direct effects come from the sire breed and half from the dam breed, while all the maternal effects come from the dam breed. Since both Angus and Hereford dams were used in the control group, half of the maternal effects are assumed to arise from each breed.

The additive effects of a two-breed reciprocal cross involving Hereford or Angus dams and some other breed, Y, can be represented:

$$Y_{Aj} = 1/2D_Y + 1/4D_H + 1/4D_A + 1/2M_H + 1/2M_A \qquad (40)$$

where Y_{Aj} is the additive effects for trait j of the Breed Y and Hereford or Angus cross.

Breed Y direct effects are calculated by subtracting HA_{Aj} from Y_{Aj} and solving for D_Y. Because the additive effects are calculated relative to the Hereford-Angus control group, the cumulative direct and maternal effects of the Hereford and Angus breeds in Equation (40) are assumed to equal zero. Thus the direct effects of Breed Y are:

$$D_Y = 2(Y_{Aj} - HA_{Aj}) \qquad (41)$$

For example, Tarentaise direct effects equal two times the difference between Tarentaise additive effects and Hereford-Angus additive effects, 2x (422.2 - 409.7), or 24.8 pounds.

Maternal Effects. The maternal effects are calculated in a similar manner. The data used to calculate the maternal effects are for calves from Hereford and/or Angus crossbred cows mated to an unrelated breed. The additive effects for trait j of the control Hereford-Angus cross dam bred to a sire of a third breed, X, are represented:

$$XHA_{Aj} = 1/2D_X + 1/4D_H + 1/4D_A + 1/2M_H + 1/2M_A \quad (42)$$

The additive effects for trait j of a three-way cross with a Hereford-Breed Y or Angus-Breed Y cross dam bred to a sire of a third breed, X, are represented:

$$XY_{Aj} = 1/2D_X + 1/4D_Y + 1/8D_H + 1/8D_A + 1/2M_Y + 1/4M_H + 1/4M_A \quad (43)$$

The maternal effects of Breed Y, M_Y, are calculated by subtracting XHA_{Aj} from XY_{Aj}, substituting in D_Y from Equation (41), and solving for M_Y:

$$M_Y = 2(XY_{Aj} - XHA_{Aj}) - 1/2D_Y \quad (44)$$

The Hereford and Angus additive effects in Equation (43) are assumed to sum to zero, canceling each other. The direct effects of the unknown sire breed, X, are assumed to be equal in Equations (42) and (43). Thus they are cancelled when subtracting XHA_{Aj} from XY_{Aj}. For example, Tarentaise maternal effects equal two times the difference between the additive effects of a Tarentaise-Hereford or a Tarentaise-Angus crossbred dam bred to a sire of some breed X and the additive effects of a Hereford-Angus crossbred dam bred to a sire of breed X, less half of the direct effects calculated previously, 2 x (480.6 - 433.6) - .5 x (24.8), or 81.1 pounds.

The maternal effects on finishing weight are assumed to equal the maternal effects on weaning weight. Maternal effects on postweaning gain and feed conversion are assumed equal to zero The direct and maternal additive effects relative to the Hereford-Angus control for the economic traits considered in this study are presented in Tables XIX and XX

Heterosis

The heterosis values assumed for Bos taurus crosses in this study were presented in Table XIV Heterosis values for weaning weights reported for Brahman-European crosses have generally averaged more than three times those for European crosses (Koger 1980, Franke 1980, Crockett et al 1978a and 1978b) A more conservative adjustment, two times the individual and maternal heterosis of European crosses (Long 1980), is assumed in this study The crossbreeding systems using the Brahman breed involve three-breed rotations with two medium frame, medium milk potential breeds also in the rotation Koger (1980) suggests that the realized heterosis for a three-breed rotational cross involving Brahman and two European breeds will be slightly less than for a Brahman-European two breed rotation

Research results on heterosis in postweaning traits of Brahman crosses are limited Franke (1980) reports some studies which found nonsignificant differences in performance between crossbreds and parental straightbreds No adjustment to the heterosis values for postweaning traits is made in this study for crosses involving Brahman cattle

Estimating Performance Traits

The calculated additive effects from Tables XIX and XX and the heterosis values from Table XIV are substituted into Equations (37) and (38) to estimate average performance trait levels for the specified rotational and terminal

TABLE XIX

CALCULATED DIRECT AND MATERNAL ADDITIVE BREED EFFECTS RELATIVE TO THE HEREFORD-ANGUS CONTROL, BY BREED FOR THE MARKET ANIMAL PERFORMANCE TRAITS CONSIDERED

Breed[1]	Weaning Weight		Pasture ADG	Feedlot ADG	Feed Conversion	Finishing Weight	
	Direct Effects lbs	Maternal Effects lbs	Direct Effects lb/day	Direct Effects lb/day	Direct Effects lb feed/ lb gain	Direct Effects lbs	Maternal Effects lbs
HA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RP	-7.64	56.98	-0.36	-0.37	2.00	-38.36	56.98
SD	0.00	33.00	0.34	0.35	0.20	127.34	33.00
T	24.83	81.08	-0.04	-0.04	1.60	146.47	81.08
P	17.19	55.57	0.09	0.10	0.40	72.46	55.57
G	59.22	78.55	0.30	0.31	0.80	463.96	78.55
S	42.02	63.32	0.47	0.48	1.00	565.99	63.32
MA	45.85	65.07	0.15	0.15	1.40	402.90	65.07
BS	42.02	87.15	0.13	0.13	0.60	287.92	87.15
CH	55.40	25.47	0.51	0.52	0.80	585.89	25.47
C	49.67	63.16	0.17	0.17	3.20	739.13	63.16
L	13.37	13.48	-0.15	-0.15	2.40	346.28	13.48
B	12.33	68.87	0.00	0.00	2.40	311.88	68.87

[1] Refer to Table XV for explanation of abbreviations.

TABLE XX

CALCULATED DIRECT AND MATERNAL ADDITIVE BREED EFFECTS RELATIVE TO THE HEREFORD-ANGUS CONTROL, BY BREED FOR THE MATERNAL PERFORMANCE TRAITS CONSIDERED

Breed[1]	Birth Weight		Calf Crop Weaned	Dam Mature Weight	12 Hour Milk Production
	Direct Effects lbs	Maternal Effects lbs	Maternal Effects Percent	Maternal Effects lbs	Maternal Effects lbs
HA	0.00	0.00	0.00	0.00	0.00
RP	0.00	5.75	-9.07	-102.42	2.45
SD	7.79	5.69	1.81	81.16	0.75
T	7.79	-0.06	1.81	-38.65	3.20
P	13.63	2.77	1.81	-7.73	3.20
G	13.63	0.85	5.44	114.01	4.15
S	19.47	-0.15	-1.81	112.08	4.15
MA	21.42	8.46	3.63	272.46	0.38
BS	11.68	9.49	1.81	34.78	4.15
CH	21.42	-16.46	-7.26	255.07	-1.32
C	19.47	7.51	3.63	280.19	0.00
L	13.63	-2.98	-3.63	21.26	-1.32
B	16.93	-20.69	3.63	114.01	5.28

[1] Refer to Table XV for explanation of abbreviations.

crossbreeding systems. Some traits can be calculated directly using the MARC data. However, due to the nature of the data and the performance assumptions of the base system, some traits must be calculated indirectly.

Calculating Traits Directly. Percent calf crop weaned, dam milk production, birth weights, weaning weights, and weights at which fed weaned steers grade low choice are calculated directly using Equations (37) and (38) and data from Tables XIX and XX (Tables XXI and XXII).

The constant, A, which reflects a general purebred mean, is selected such that Equation (37) generates percent calf crop weaned, milk production, birth weight, weaning weight, and a finishing (pay) weight for the medium frame, medium milk potential two-breed rotational cross consistent with the values for these traits assumed in the base situation. To calculate percent calf crop weaned and 12 hour milk production, A is set equal to 82.43 and 5.96, respectively. To calculate birth weights, weaning weights, and finishing weights, A is set equal to 75.7, 472, and 1036, respectively. According to Buchanan, the assumption of these values for A is valid, as long as the value selected for A is within the range of the data.

To illustrate the procedure, the derivation of weaning weight for the two-breed rotation with medium frame, heavy milk breeds is discussed. Four medium frame, heavy milk breeds are included (Refer to Table XV). Thus, six two-breed combinations of these breeds are possible. The value used in the study of this system is the simple average of the values estimated in each possible two-breed combination.

The direct and maternal additive effects of the Tarentaise breed are 24.8 and 81.1, respectively; and 17.2 and 55.6, respectively, for the Pinzgauer breed.

TABLE XXI

STEER BIRTH, WEANING, AND FINISHING WEIGHTS CALCULATED FOR EACH CROSSBREEDING SYSTEM

System	Birth Weight lbs	Weaning Weight lbs	Weight At Small Marbling[1] lbs
(0) "Pre-1980s" 2 Breed Rotation Med. Fr.-Med. Milk (RC0)	70	450	1040
(1) "Modern" 2 Breed Rotation Med. Fr.-Med. Milk (RC1, RC2)	79	500	1060
(2) Terminal Cross-(1) Dams with Lg. Fr. Sire (TC2)	89	531	1323
(3) 3 Breed Rotation-2 Med. Fr. Med. Milk Br.,1 Med. Fr. Heavy Milk Breed (RC3, RC4)	83	532	1113
(4) Terminal Cross-(3) Dams with Lg. Fr. Sire (TC4)	91	557	1356
(5) 2 Breed Rotation Med. Fr.-Heavy Milk (RC5, RC6)	90	569	1197
(6) Terminal Cross-(5) Dams with Lg. Fr. Sire (TC6)	96	597	1421
(7) 3 Breed Rotation-2 Med. Fr. Med. Milk Br., Brahman (RC7, RC8)	81	564	1185
(8) Terminal Cross-(7) Dams with Lg. Fr. Sire (TC8)	87	594	1388
(9) 2 Breed Rotation Lg. Fr.-Heavy Milk (RC9)	101	628	1575
(10) 2 Breed Rotation Lg. Fr.-Low Milk (RC10)	94	578	1665

[1] Assumes feeding a weaned spring steer.

TABLE XXII

DAM MATURE WEIGHT, PERCENT CALF CROP WEANED, AND 24 HOUR MILK PRODUCTION, FOR EACH COW TYPE

Cow Type	Dam Mature Weight	Calf Crop Weaned		24 Hour Milk Production
		Percent of Cows and Heifers Exposed	Percent of Ave. No. Cows in the Herd	
	lbs.			lbs.
Pre-1980s 2 Breed Rotation Med. Fr.-Med. Milk	1000	84.62	88.00	12.00
Modern 2 Breed Rotation Med. Fr.-Med. Milk	1125	84.62	88.00	12.20
3 Breed Rotation-2 Med. Fr. Med. Milk Br.,1 Med. Fr. Heavy Milk Breed	1127	85.71	89.30	14.23
2 Breed Rotation Med. Fr.-Heavy Milk	1109	83.69	87.04	17.41
3 Breed Rotation-2 Med. Fr. Med. Milk Br., Brahman	1168	87.40	90.90	16.25
2 Breed Rotation Lg. Fr.-Heavy Milk	1251	86.92	90.40	19.07
2 Breed Rotation Lg. Fr.-Low Milk	1300	82.12	85.40	10.57

Thus, inserting these values into Equation (37) for a Tarentaise-Pinzgauer two breed rotation yields.

$$[472 + \frac{1}{2}(24.8 + 17.2 + 81.1 + 55.6)]\ (1 + \frac{2}{3} \times 0.047)\ (1 + \frac{2}{3} \times 0.042) \qquad (45)$$

Solving Equation (45) results in an expected weaning weight for the Tarentaise-Pinzgauer two breed rotation in equilibrium of 595 pounds. Similarly, for the other possible two-breed rotations, the expected weaning weights are: Red Poll-South Devon, 544 pounds; Red Poll-Tarentaise, 582 pounds; Red Poll-Pinzgauer, 565 pounds; South Devon-Tarentaise, 574 pounds; and South Devon-Pinzgauer, 556 pounds. The expected weaning weight for the two-breed rotation with medium frame, heavy milk breeds (System 5) is the average of the weaning weights for each possible two-breed combination, or 569 pounds (Table XXI).

Calculating Traits Indirectly. The dam mature weights, average daily gains, and feed conversions for each crossbreeding scheme cannot be calculated directly. This is because the values required for A to generate levels for each trait consistent with those in the base situation using Equation (37) are out of the range of the data. Instead, multipliers are used to adjust these traits from the base situation (Table XXIII).

The general mean, A, is selected such that Equation (37) generates the same values for dam mature weight, average daily gain, and feed conversion as reported by Cundiff et al. (1986) for the Hereford-Angus crossbreds. To calculated feedlot adg, pasture adg, feed conversion, and dam mature weight, A is set equal to 2.355, 2.293, 10.6, and 1193.2, respectively.

Given A, then, the levels of these traits for each system using reported data are estimated. The multipliers used to adjust the base values are

TABLE XXIII

MULTIPLIERS USED TO ADJUST BASE PASTURE AND FEEDLOT AVERAGE DAILY GAINS, FEED CONVERSIONS, AND DAM MATURE WEIGHT FOR EACH CROSSBREEDING SYSTEM, USING MARC DATA

System	Pasture ADG	Feedlot ADG	Feed Conversion	Dam Mature Weight
(0) "Pre-1980s" 2 Breed Rotation Med. Fr.-Med. Milk (RC0)	0.993	NA[1]	NA	0.889
(1) "Modern" 2 Breed Rotation Med. Fr.-Med. Milk (RC1, RC2)	1.000	1.000	1.000	1.000
(2) Terminal Cross-(1) Dams with Lg. Fr. Sire (TC2)	1.071	1.064	1.069	NA
(3) 3 Breed Rotation-2 Med. Fr. Med. Milk Br.,1 Med. Fr. Heavy Milk Breed (RC3, RC4)	1.013	1.007	1.033	1.002
(4) Terminal Cross-(3) Dams with Lg. Fr. Sire (TC4)	1.072	1.062	1.085	NA
(5) 2 Breed Rotation Med. Fr.-Heavy Milk (RC5, RC6)	1.004	1.006	1.099	0.986
(6) Terminal Cross-(5) Dams with Lg Fr. Sire (TC6)	1.073	1.066	1.118	NA
(7) 3 Breed Rotation-2 Med. Fr. Med. Milk Br., Brahman (RC7, RC8)	1.012	1.006	1.075	1.039
(8) Terminal Cross-(7) Dams with Lg. Fr. Sire (TC8)	1.071	1.061	1.106	NA
(9) 2 Breed Rotation Lg. Fr.-Heavy Milk (RC9)	1.115	1.114	1.090	1.112
(10) 2 Breed Rotation Lg. Fr.-Low Milk (RC10)	1.077	1.076	1.201	1.156

[1] NA: Not Applicable

calculated by dividing the estimated trait values for each system by the observed values for the Hereford-Angus crossbreds. For example, the observed feedlot adg for Hereford-Angus crossbred steers is 2.39 pounds per day (Table XVII). The feedlot adg for System 5, calculated using the MARC data is 2.404. Thus, the feedlot adg multiplier for System 5 is 2.404/2.39 or 1.006. The feedlot adg study value for System 5, then, is the base feedlot adg (2.79) times the multiplier (1.006), or 2.81 pounds per day.

No pasture average daily gain data were available from the research done at the Meat Animal Research Center. To estimate pasture adg, it is assumed that the breeds perform the same, relatively, on pasture as in the feedlot, although gains on pasture, in absolute terms, will be much lower than feedlot gains. Thus, faster-gaining breeds in the feedlot are assumed to gain faster on pasture.

<u>Adjusting Steer Finishing Weights</u>. Oltjen et al.'s (1984) feedlot growth simulation model is used to generate average daily gains, feed conversions, and finishing weights for steers in each feeding option from Systems 0 and 1. The finishing weights assumed for each feeding option for Systems 0 and 1 correspond to the point at which the steers have about 30 percent body fat and grade low choice.

The finishing weights estimated using MARC data are of spring calves placed on feed at weaning. Estimates of the finishing weights for the other feeding options are also necessary for each crossbreeding scheme. The relationship of the finishing weight of fed weaned spring steers to the finishing weights of the other feeding options in the base situation is assumed the same for the other crossbreeding systems. For example, in the base situation, the finishing weight of a fed wheat pasture stocker is 1.024 times the finishing weight of a fed weaned spring steer. Likewise, the finishing weight of a fed wheat pasture stocker from any of the other crossbreeding systems is 1.024 times the finishing weight of a fed weaned spring steer in that system.

The weights estimated at which the animals reach low choice for the terminal and rotational crosses involving large frame breeds are quite heavy. It is unrealistic to expect a feeder to feed animals to these weights. For the crosses involving large frame breeds, animal scientists and feedlot personnel were consulted to identify reasonable weights at which these large frame animals would be sold.

Heifer Performance. Heifers, on average, will perform at levels slightly below steers of like breeding. Average daily gains and feed efficiency will be lower. Heifers also finish at lighter weights than steers. Heifer average daily gains, feed conversions, and pay weights are assumed 87.89, 104.26, and [illegible]48 percent of the steer gains, conversions, and pay weights, given the crossbreeding scheme and feeding option (Hicks et al. 1990a and 1990b).

The animal performance assumptions and assumptions regarding sale or transfer dates for the retained ownership options for each crossbreeding system are presented in Appendix B.

Estimating Variances and Covariances

An integral part of the modeling effort in a ranch risk analysis is portraying the variability associated with the plan. Production risk is a primary risk source producers face. In livestock production, low weaning rates, high death loss, and slow gains contribute to production risk. The method used to estimate the variance of key animal performance variables and the covariances between those variables is described in this section. The estimated variances and covariances will be used in the risk analysis conducted in Chapter VI.

Estimating Variance

The variance of a particular trait for a given crossbreeding system is influenced by the breeds included in the cross, especially by the sire breed. ariance increases as differences between breeds increase.

Four primary traits contribute to variation in animal performance. These are weaning weight, pasture average daily gains (adg), feedlot adg, and feedlot feed efficiency. The variance associated with each of these traits is estimated following an analysis of variance framework (Figure 11).

A rotational crossbreeding system requires at least one breeding herd for each breed in the rotation. The individual breeding herds are assumed to be of equal size and their traits have equal variances, but different means. For a given trait, the variance attributed to error is that variance which is equal among breeding herds. These common trait variances were obtained from the animal science literature (Woldehawariat et al. 1977; Cundiff et al. 1981). The error sum of squares is found by multiplying the variance due to error by the total number of cows in the herd less the number of breeding herds.

The variance attributed to the "treatments" (breeding herd) reflects the variability of the individual breeding herd means about the mean of the entire herd. Sum of squares from the treatments (breeding herds) is found by multiplying the sum of squared deviations of breeding herd means from the total herd mean by the number of cows in each individual breeding herd.

The equations used to estimate trait means for each breeding herd in two- and three-breed rotational crosses and terminal sire systems using dams from two- and three-breed rotational systems are presented in Figure 12. The general means (A) and heterosis (Table XIV) values are the same as those used to generate mean performance estimates.

Source of Variation	Degrees of freedom	Definition
Treatments	t-1	$SS_T = r\sum_i (\bar{X}_i - \bar{X}_{..})^2$
Error	t (r - 1)	$SS_E = \sum_{i,j} (X_{ij} - \bar{X}_{i.})^2$
Total	rt - 1	$SS_T = \sum_{i,j} (X_{ij} - \bar{X}_{..})^2$

Note: t = Number of breeds in the rotation = Number of Breeding herds

r = Number of cows per breeding herd

rt = Total number of cows in the herd

Source: Steele, R.G.D. and J.H. Torrie. Principles and Procedures of Statistics. New York: McGraw Hill Book Co., Inc. 1960.

Figure 11. Analysis of Variance: One-Way Classification with Equal Replications

Two Breed Rotation, with Breeds 1 and 2

Sire Breed 1:

$T_{j1} = (A + 2/3\ D_1 + 1/3\ D_2 + 1/3\ M_1 + 2/3\ M_2)\ (1 + 2/3\ H_I)\ (1 + 2/3\ H_M)$

Sire Breed 2:

$Tj2 = (A + 1/3\ D_1 + 2/3\ D_2 + 2/3\ M_1 + 1/3\ M_2)\ (1 + 2/3\ H_I)\ (1 + 2/3\ H_M)$

Terminal Sire or Two-Breed Rotational Cross Dams

Dams Sired by Breed 1:

$T_{jT1} = (A + 1/2\ D_T + 1/3\ D_1 + 1/6\ D_2 + 1/3\ M_1 + 2/3\ M_2)\ (1 + H_I)\ (1 + 2/3\ H_M)$

Dams Sired by Breed 2:

$T_{jT2} = (A + 1/2\ D_T + 1/6\ D_1 + 1/3\ D_2 + 2/3\ M_1 + 1/3\ M_2)\ (1 + H_I)\ (1 + 2/3\ H_M)$

Three Breed Rotation, with Breeds 1, 2, and 3

Sire Breed: 1

$T_{j1} = (A + 4/7\ D_1 + 2/7\ D_2 + 1/7\ D_3 + 1/7\ M_1 + 4/7\ M_2 + 2/7\ M_3)\ (1+ 6/7\ H_I)$
$(1 + 6/7\ H_M)$

Sire Breed: 2

$T_{j2} = (A + 1/7\ D_1 + 4/7\ D_2 + 2/7\ D_3 + 2/7\ M_1 + 1/7\ M_2 + 4/7\ M_3)\ (1 + 6/7\ H_I)$
$(1 + 6/7\ H_M)$

Sire Breed: 3

$T_{j3} = (A + 2/7\ D_1 + 1/7\ D_2 + 4/7\ D_3 + 4/7\ M_1 + 2/7\ M_2 + 1/7\ M_1)\ (1 + 6/7\ H_I)$
$(1 + 6/7\ H_M)$

Terminal Sire on Three-Breed Rotational Cross Dams

Dams Sired by Breed 1:

$T_{jT1} = (A + 1/2\ D_T + 2/7\ D_1 + 1/7\ D_2 + 1/14\ D_3 + 1/7\ M_1 + 4/7\ M_2 + 2/7\ M_3)$
$(1 + H_I)\ (1 + 6/7\ H_M)$

Dams Sired by Breed 2:

$T_{jT2} = (A + 1/2\ D_T + 1/14\ D_1 + 2/7\ D_2 + 1/7\ D_3 + 2/7\ M_1 + 1/7\ M_2 + 4/7\ M_3)$
$(1 + H_I)\ (1 + 6/7\ H_M)$

Dams Sired by Breed 3:

$T_{jT3} = (A + 1/2\ D_T + 1/7\ D_1 + 1/14\ D_2 + 2/7\ D_3 + 4/7\ M_1 + 2/7\ M_2 + 1/7\ M_1)$
$(1 + H_I)\ (1 + 6/7\ H_M)$

Figure 12. Equations used to Estimate Trait Means, Given Sire and Dam Breeds, Two- and Three-Breed Rotational and Combined Rotational-Terminal Sire Crossbreeding Systems

The equations in Figure 12 are similar in concept to Equations (37) and (38). However, since sire breed so heavily influences performance variation, breed delineation of the cross is required, both for direct and maternal additive effects. The direct and maternal additive effects of the Hereford and Angus breeds used to calculate the breeding herd averages are presented in Table XXIV (Koch et al. 1963; Gregory et al. 1966; Gregory et al. 1978c; Olson et al. 1978). The direct and maternal effects of the other breeds are in Table XIX.

Systems 1 and 7 are specific breed crosses. Their variances are calculated using breed specific data. The values for Systems 2, 8, and 9 involve an average across the possible breed combinations pertinent to each system. Systems 2 and 8 represent a terminal cross on rotational cross cows from Systems 1 and 7. Seven large frame breeds are considered as terminal sires. Thus, the variances resulting from using each terminal sire breed are calculated and then averaged to obtain the "treatment" variance for Systems 2 and 8.

System 9 represents a two-breed rotation with large frame, heavy milk potential breeds. Four such breeds are considered, yielding six possible two-breed combinations. The variance for each possible combination is calculated. The average of these is assumed to be the variance for System 9.

Like mean weaning weight, weaning weight variance can be calculated directly from the M.A.R.C. data using the equations in Figure 12 and data in Table XXIV. However, variances for the other traits must be calculated indirectly. The values of A required to generate performance estimates for gains and feed efficiency consistent with those assumed in the study are out of the range of the data. For each of these traits, A is selected such that trait levels estimated with Equation (37) for the Hereford-Angus cross equal those reported in the data. Using the M.A.R.C. data, the variances are derived and the

TABLE XXIV

ESTIMATED DIRECT AND MATERNAL ADDITIVE EFFECTS OF THE HEREFORD AND ANGUS BREEDS ON WEANING WEIGHTS, PASTURE AVERAGE DAILY GAINS, FEEDLOT AVERAGE DAILY GAINS, AND FEED CONVERSION

Trait	Direct Effect	Maternal Effect
Weaning Weight (lbs)		
Hereford	-10.63	-21.81
Angus	10.63	21.81
Pasture Average Daily Gain (lbs/day)		
Hereford	0.015	0.0175
Angus	-0.015	-0.0175
Feedlot Average Daily Gain (lbs/day)		
Hereford	0.1103	0.0257
Angus	-0.1103	-0.0257
Feed Conversion (lb feed/lb gain)		
Hereford	-0.1567	-0.1450
Angus	0.1567	0.1450

coefficients of variation calculated. The coefficient of variation from the data and the coefficient of variation from the study values are assumed equal. Given the trait means and coefficients of variation, the study variances can easily be obtained.

Estimating Covariances

Phenotypic correlations among the calf performance traits were obtained from the animal science literature. The correlation between weaning weight and pasture adg is 0.20, between weaning weight and feedlot adg is 0.16, between weaning weight and feedlot feed efficiency is -0.90, and between feedlot average daily gain and feed efficiency is -0.31 (Woldehawariat et al. 1977). Pasture gains are assumed independent of feedlot gains and feed efficiency. No estimates of these correlations could be located in the animal science literature.

The correlation between variables X_1 and X_2, ρ_{x1x2}, is defined as

$$\rho_{x1x2} = \frac{COV(X_1,X_2)}{\sigma_{x1}\sigma_{x2}} \tag{46}$$

where $COV(X_1,X_2)$ is the covariance between X_1 and X_2, and σ_{x1} and σ_{x2} are the standard deviations of the variables, X_1 and X_2. Given ρ_{x1x2}, σ_{x1}, and σ_{x2}, the covariance between X_1 and X_2 is simply

$$COV(X_1,X_2) = \rho_{x1x2}\,\sigma_{x1}\,\sigma_{x2} \tag{47}$$

The estimated variance-covariance matrices for the calf performance traits for Systems 1, 2, 7, 8, and 9 are presented in Table XXV.

TABLE XXV

WEANING WEIGHT, PASTURE GAINS, FEEDLOT GAINS, AND FEED EFFICIENCY VARIANCES AND COVARIANCES, SYSTEMS 1, 2, 7, 8, AND 9

Variance-Covariance Matrix - System 1

	WW	PADG	FLADG	FE
WW	4353.8	1.530	3.556	-2.412
PADG	1.530	0.013	0	0
FLADG	3.556	0	0.113	-0.042
FE	-2.412	0	-0.042	0.165

Variance-Covariance Matrix - System 2

	WW	PADG	FLADG	FE
WW	4373.3	1.536	3.549	-2.418
PADG	1.536	0.013	0	0
FLADG	3.549	0	0.113	-0.042
FE	-2.418	0	-0.042	0.165

Variance-Covariance Matrix - System 7

	WW	PADG	FLADG	FE
WW	4601.7	1.493	3.591	-2.834
PADG	1.493	0.012	0	0
FLADG	3.591	0	0.109	-0.048
FE	-2.834	0	-0.048	0.215

Variance-Covariance Matrix - System 8

	WW	PADG	FLADG	FE
WW	4638.1	1.732	3.787	-2.995
PADG	1.732	0.016	0	0
FLADG	3.787	0	0.121	-0.053
FE	-2.995	0	-0.0530	0.239

Variance-Covariance Matrix - System 9

	WW	PADG	FLADG	FE
WW	4349.7	1.599	3.600	-2.454
PADG	1.599	0.015	0	0
FLADG	3.600	0	0.116	-0.044
FE	-2.454	0	-0.044	0.171

Where
- WW = Weaning Weight
- PADG = Pasture Average Daily Gain
- FLADG = Feedlot Average Daily Gain
- FE = Feed Efficiency

Weaning Rate

Many maternal performance characteristics are reflected in the weaning rate. Weaning rate is primarily a function of cow condition during the breeding season. Condition, in turn, is a function of nutrition management before and during breeding season. Poor condition resulting from inadequate nutrition is a major cause of a low weaning rate. Certain breed characteristics, frame size and milk production potential, also influence weaning rate. For example, as milk production potential increases in small or medium frame breeds, weaning rate decreases. Since the demands placed on the cow's body by lactation are greater for heavier milking cows, size held constant, it is more difficult to attain adequate body condition to ensure a high conception rate.

Weaning rate is assumed independent of the four calf performance variables discussed in the previous section. Weaning rate is also assumed distributed binomial (Table XXVI). The mean and variance of a binomial distribution are np and np(1-p), where n is the number of observations (number of cows in the herd) and p is the probability of success, where success is defined as weaning a calf.

Adjusting Feed Requirements

Beef cows require proper nutrition for maintenance, reproduction, and production. Lemenager et al. (1980) suggest that weight alone cannot be used to accurately determine energy requirements of the larger breeds or breeds with higher milk production potential. Several factors influence required nutrient levels. These factors include stage of reproductive cycle, i.e. gestation, lactation, or both, production level, size, condition, age of cow, dam genotype, and environmental conditions (Miller et al. 1985).

TABLE XXVI

EXPECTED VALUE AND VARIANCE OF WEANING RATE, GIVEN HERD SIZE IN SYSTEMS 1, 2, 7, 8, AND 9

	Herd Size	p	(1-p)	Mean	Variance
System 1	319.6	0.88	0.12	281.248	33.750
System 2	319.6	0.88	0.12	281.248	33.750
System 7	304.1	0.909	0.091	276.427	25.155
System 8	304.1	0.909	0.091	276.427	25.155
System 9	284.8	0.904	0.096	257.459	24.716

Where
- p = probability of success
- n = herd size
- Mean = np
- Variance = npq

The maintenance requirement for energy can be defined as that amount of feed energy that will result in no loss or gain in body energy. For some beef animals, maintenance may be the usual physiological state and the practical feeding goal. Net energy required for maintenance (NEm) is defined as the amount of energy equivalent to the fasting heat production (NRC 1984, p.3).

Miller et al. (1985) developed a computer model which evaluates rations for expected energy intake, crude protein, phosphorus, and vitamin A. Requirements are projected for British and exotic breed cows, based on their current stage of production, weight, condition score, milk production level, and environmental conditions.

The dry matter intake requirements for each cow type are estimated by using a set of multipliers to adjust per cow dry matter intake requirements from the base situation (Table XXVII). Multipliers are used to make the process of modifying the LP model more convenient. The multipliers equal the ratio of expected dry matter intake for each cow type, given the grazing period, to the expected dry matter intake for a medium frame, medium milk potential, two breed rotational cross cow. Expected dry matter intake for each cow type and each grazing period is estimated using Miller et al.'s (1985) beef cow ration analysis model.

The multipliers used to adjust dry matter forage requirements are also used to adjust hay, protein supplement, and 20 percent protein cube (for replacement heifers) requirements per cow. The resulting ration, with dry grass, hay, and protein supplement is inadequate for heavy milking, crossbred cows during late gestation and early lactation. Assuming increased hay or forage consumption to meet the higher needs of these cow types results in unrealistic dry matter consumption levels. Instead, additional 20 percent protein cubes are added to the ration to meet nutritional requirements in a realistic manner (Table

TABLE XXVII

MULTIPLIERS USED TO ADJUST DRY MATTER INTAKE REQUIREMENTS AND ADDITIONAL 20 PERCENT RANGE CUBES REQUIRED FOR EACH COW TYPE, SPRING AND FALL CALVING

Cow Type	Spring Calving				Fall Calving			
	Summer 1 Period	Summer 2 Period	Winter Period	Additional Range Cubes Required (Lbs)	Summer 1 Period	Summer 2 Period	Winter Period	Additional Range Cubes Required (Lbs)
Pre-1980s 2 Breed Rotation Med. Fr.-Med. Milk	0.928	0.924	0.920	0	0.923	0.916	0.929	0
Modern 2 Breed Rotation Med. Fr.-Med. Milk	1.000	1.000	1.000	0	1.000	1.000	1.000	0
3 Breed Rotation-2 Med. Fr. Med. Milk Br.,1 Med. Fr. Heavy Milk Breed	1.025	1.027	1.029	180	1.019	1.008	1.030	259
2 Breed Rotation Med. Fr.-Heavy Milk	1.041	1.031	1.020	220	1.027	0.998	1.055	465
3 Breed Rotation-2 Med. Fr. Med. Milk Br., Brahman	1.050	1.050	1.049	106	1.043	1.030	1.055	222
2 Breed Rotation Lg. Fr.-Heavy Milk	1.122	1.118	1.114	220	1.115	1.093	1.138	490
2 Breed Rotation Lg Fr.-Low Milk	1.098	1.121	1.143	130	1.111	1.121	1.100	173

XXVII). Miller et al.'s (1985) model is used to calculate the amount of additional cubes required per cow.

Multipliers are also used to adjust dry matter intake requirements of stocker steers and heifers from the base situation for stockers from the other crossbreeding systems (Table XXVIII). The multipliers are based on the NRC (1984) dry matter intake requirements for medium and large frame growing cattle. Linear interpolation is used to calculate dry matter intake for the average weight and average daily gain over the stocker period. The multipliers equal the stocker dry matter intake requirements, given the crossbreeding system, sex, stocker program, average weight, and average daily gain, divided by the dry matter intake requirement of a stocker of the same sex in the base situation, for the same stocker program. The multipliers are used to adjust per head hay and supplement requirements as well as forage requirements for each stocker activity.

Adjusting Cattle Prices

Feeder Cattle and Cull Cow Prices

A number of studies have concluded that animal characteristics have significant influence on market price (Buccola 1980; Faminow and Gum 1985; Lambert et al. 1989; Schroeder et al. 1988). Adjustments must be made to the average feeder cattle price to reflect price differentials that exist between cattle of differing types.

The price premiums and discounts reported by Schroeder et al. (1988) are used in this study to adjust feeder cattle and cow prices for frame size and breed (Table XXIX). Schroeder et al.'s (1988) results are used because their study represents the most comprehensive evaluation of the influence of animal

TABLE XXVIII

MULTIPLIERS USED TO ADJUST BASE DRY MATTER FEED INTAKE REQUIREMENTS FOR STOCKERS IN EACH CROSSBREEDING SYSTEM

System	Wheat Pasture Stockers		Grazeout Stockers		Year-Round Stockers	
	Steers	Heifers	Steers	Heifers	Steers	Heifers
(0) "Pre-1980s" 2 Breed Rotation Med. Fr.-Med. Milk (RC0)	0.9263	0.9266	0.9305	0.9295	0.9279	0.9263
(1) "Modern" 2 Breed Rotation Med Fr.-Med. Milk (RC1, RC2)	1.00	1.00	1.00	1.00	1.00	1.00
(2) Terminal Cross-(1) Dams with Lg. Fr. Sire (TC2)	1.1097	1.1342	1.1095	1.1322	1.0956	1.1043
(3) 3 Breed Rotation-2 Med. Fr. Med. Milk Br.,1 Med. Fr. Heavy Milk Breed (RC3, RC4)	1.0522	1.0514	1.0492	1.0497	1.0518	1.0508
(4) Terminal Cross-(3) Dams with Lg. Fr. Sire (TC4)	1.1440	1.1675	1.1396	1.1630	1.1279	1.1369
(5) 2 Breed Rotation Med. Fr.-Heavy Milk (RC5, RC6)	1.0818	1.0836	1.0758	1.0788	1.0798	1.0787
(6) Terminal Cross-(5) Dams with Lg Fr. Sire (TC6)	1 1921	1.2182	1.1839	1.2102	1.1771	1.1865
(7) 3 Breed Rotation-2 Med. Fr Med. Milk Br., Brahman (RC7, RC8)	1.1517	1.1824	1.1425	1.1735	1.1356	1.1467
(8) Terminal Cross-(7) Dams with Lg. Fr. Sire (TC8)	1.2044	1.2321	1.1948	1.2225	1.1900	1.1997
(9) 2 Breed Rotation Lg. Fr.-Heavy Milk (RC9)	1.2406	1.2655	1.2317	1.2570	1.2271	1.2381
(10) 2 Breed Rotation Lg. Fr.-Low Milk (RC10)	1.1921	1 1952	1.1839	1.1885	1.1771	1 1659

TABLE XXIX

PREMIUMS AND DISCOUNTS USED TO ADJUST BASE FEEDER CATTLE AND COW PRICES FOR FRAME SIZE AND BREED

System	Feeder Steers $/cwt	Feeder Heifers $/cwt	Cows $/cwt
(0) "Pre-1980s" 2 Breed Rotation Med. Fr.-Med. Milk (RC0)	0	0	0
(1) "Modern" 2 Breed Rotation Med. Fr.-Med. Milk (RC1, RC2)	0	0	0
(2) Terminal Cross-(1) Dams with Lg. Fr. Sire (TC2)	-1.46	2.04	NA[1]
(3) 3 Breed Rotation-2 Med. Fr. Med. Milk Br.,1 Med. Fr. Heavy Milk Breed (RC3, RC4)	-0.35	0.69	1.67
(4) Terminal Cross-(3) Dams with Lg. Fr. Sire (TC4)	-1.46	2.04	NA
(5) 2 Breed Rotation Med. Fr.-Heavy Milk (RC5, RC6)	-0.35	0.69	1.67
(6) Terminal Cross-(5) Dams with Lg. Fr. Sire (TC6)	-1.46	2.04	NA
(7) 3 Breed Rotation-2 Med. Fr. Med. Milk Br., Brahman (RC7, RC8)	-6.9	-4.79	1.38
(8) Terminal Cross-(7) Dams with Lg. Fr. Sire (TC8)	-3.45	0.26	NA
(9) 2 Breed Rotation Lg. Fr.-Heavy Milk (RC9)	-1.46	2.04	0.94
(10) 2 Breed Rotation Lg. Fr.-Low Milk (RC10)	-1.46	2.04	0.94

[1] Not Applicable.

characteristics on market price. Their auction price data is the most recent and it covered both the spring and fall seasons (Fall 1986 and Spring 1987). Also, their study was conducted in Kansas, sufficiently close to Oklahoma to justify the assumption of no disparity based on location. No adjustment for frame size or breed is made to slaughter cattle or cull bull prices.

Slaughter Cattle Prices

Slaughter cattle prices are not as sensitive to factors such as sex, breed content, and frame size, as long as carcass weights are within a range acceptable to the processor. They are, however, influenced by how the finished steers and heifers grade, both yield and quality grade, and by dressing percent.

Yield grade, or cutability, considers the percentage of closely-trimmed, boneless, major retail cuts which can be derived from a carcass. Measured objectively, yield grade allows a delineation among carcasses of identical grade and weight, but with differing (perhaps significantly) percentages of closely-trimmed, boneless, retail cuts obtainable from the carcasses. The primary factors accounting for retail cut yield variation are the amount of fat that must be trimmed and the thickness and fullness of the muscling (McCoy 1979, p. 290, 299, 306).

Quality grades, Prime, Choice, Select, etc., reflect subjective estimates of the characteristics of the lean, the quality or palatability of the meat when eaten. Determination of quality of the lean is accomplished by considering the degree of marbling, flecks of fat interspersed among muscle fibers in the lean, and firmness in conjunction with maturity. The degree of marbling is considered to be positively associated with palatability, in general, and specifically with flavor, tenderness, and juiciness (McCoy 1979, p. 299).

Based on assumed finishing weights, expected quality and yield grades and dressing percentages for each cattle type considered in the study were obtained from discussions with animal scientists and feedlot personnel (Table XXX). Heifers and steers from the same breeding system are assumed to grade and dress identically.

The slaughter cattle prices used in the model are averages of choice and select fed cattle prices, weighted by the proportion of cattle in a pen expected to grade choice or select. The assumed yield grades for the different cattle types were not significantly different. Thus, yield grades had no appreciable effect on slaughter cattle prices in the model.

Prices for select grade cattle were obtained by subtracting choice-select fed cattle price differentials (Appendix C) from choice fed cattle prices. The price differentials, which are based on the Omaha Livestock Market Source (Western Livestock Marketing Information Project 1989), are assumed to be directly applicable to the Amarillo City Market.

TABLE XXX

QUALITY GRADES, DRESSING PERCENTAGES, AND YIELD GRADES FOR FED STEERS AND HEIFERS, BY CROSSBREEDING SYSTEM AND FEEDING OPTION

Feeding Option[1]	Quality Grade (% Choice)	Dressing Percent (%)	Yield Grade Ave.
System 0 (RC0)			
Option 1	75	62.5	2.6
Option 2	90	63.5	3.4
Option 3	90	63.5	3.4
Option 4	90	63.5	3.4
Option 5	85	62.5	2.9
System 1 (RC1, RC2)			
Option 1	65	62.5	2.2
Option 2	85	63.5	3.0
Option 3	85	63.5	3.0
Option 4	85	63.5	3.0
Option 5	70	62.5	2.5
System 2 (TC2)			
Option 1	50	63.0	2.5
Option 2	65	63.5	2.9
Option 3	67	63.5	3.0
Option 4	67	63.5	3.0
Option 5	57	63.0	2.6
System 3 (RC3, RC4)			
Option 1	60	63.0	2.2
Option 2	70	63.5	2.5
Option 3	72	63.5	3.0
Option 4	72	63.5	3.0
Option 5	67	63.0	2.2
System 4 (TC4)			
Option 1	30	63.0	1.5
Option 2	50	63.5	2.0
Option 3	47	63.5	2.2
Option 4	47	63.5	2.2
Option 5	50	63.0	1.7
System 5 (RC5, RC6)			
Option 1	55	63.0	2.0
Option 2	67	63.0	2.5
Option 3	72	63.0	2.7
Option 4	72	63.0	2.7
Option 5	65	63.0	2.0

TABLE XXX (Continued)

Feeding Option	Quality Grade (% Choice)	Dressing Percent (%)	Yield Grade Ave.
System 6 (TC6)			
Option 1	30	63.5	1.5
Option 2	50	64.0	2.0
Option 3	50	63.5	2.5
Option 4	50	63.5	2.5
Option 5	40	63.0	1.5
System 7 (RC7, RC8)			
Option 1	35	62.5	1.9
Option 2	50	63.0	2.2
Option 3	50	63.0	2.2
Option 4	50	63.0	2.2
Option 5	40	62.5	2.0
System 8 (TC8)			
Option 1	25	62.5	1.9
Option 2	35	63.0	2.2
Option 3	35	63.0	2.2
Option 4	35	63.0	2.2
Option 5	30	62.5	2.0
System 9 (RC9)			
Option 1	40	63.5	2.0
Option 2	55	64.0	2.5
Option 3	55	64.0	2.5
Option 4	55	64.0	2.5
Option 5	45	63.5	2.2
System 10 (RC10)			
Option 1	30	63.0	1.9
Option 2	45	63.5	2.0
Option 3	45	63.5	2.0
Option 4	45	63.5	2.0
Option 5	35	63.0	1.9

[1] Option 1: Fed Weaned Spring Calves
Option 2: Fed Wheat Pasture Stockers
Option 3: Fed Grazeout Stockers
Option 4: Fed Year-Round Stockers
Option 5: Fed Weaned Fall Calves

CHAPTER V

STATIC ANALYSIS OF SOUTH-CENTRAL OKLAHOMA RANCH ALTERNATIVES

The linear programming model described in Chapter III was used to conduct a comparative static analysis of alternative cattle breeding systems in a long-run, perfect knowledge framework. LP identifies the profit-maximizing ranch plans, based on expected prices, animal performance, and forage yields. Each system was analysed independently. No consideration was given to the possibility of moving from one system to another from year to year.

Since LP uses expected prices, gains, calving percentages, and other variables, it does not give information regarding the effects on the optimal ranch plan of low prices or poor performance. The next chapter provides estimates of the distribution of returns for alternative production and marketing plans for a selected group of breeding systems.

As described in Chapter IV, eleven two- and three-breed rotational cross and combined rotational-terminal sire systems were designed and included in the study. The method for estimating animal performance and resource requirements for each was presented in the previous chapter. For convenience, the systems are summarized in Figure 13. The results of the static analysis are presented in this chapter. The profit maximizing ranch plans for all systems are discussed in the next section. Then, results of fixed production and marketing plans for a subset of the systems are presented.

System	Description
(0)	"Pre-1980s" Two breed rotational cross with medium frame, medium milk potential breeds
(1)	"Modern" Two breed rotational cross with medium frame, medium milk potential breeds (Base)
(2)	Combination rotational cross and terminal cross with dams from System (1) and large frame sires
(3)	Three breed rotational cross, with two medium frame, medium milk potential breeds and one medium frame, high milk potential breed
(4)	Combination rotational cross and terminal cross with dams from System (3) and large frame sires
(5)	Two breed rotational cross with medium frame, high milk potential breeds
(6)	Combination rotational cross and terminal cross with dams from System (5) and large frame sires
(7)	Three breed rotational cross, with two medium frame, medium milk potential breeds and Brahman
(8)	Combination rotational cross and terminal cross with dams from System (7) and large frame sires
(9)	Large frame, high milk potential, two breed rotational cross
(10)	Large frame, low milk potential, two breed rotational cross

Figure 13. Alternative Cattle Breeding Systems Considered in the Analysis

Profit-Maximizing Ranch Plans

Residual Returns

The residual returns, herd size, and production and marketing strategies in the optimal ranch plans for the alternative breeding systems are summarized in Table XXXI. The linear programming model maximizes residual return to operator labor, management, equity, and risk. Variable and fixed costs are subtracted from gross returns to obtain residual returns. Variable operating costs cover feed, veterinarian supplies and services, hired labor, marketing charges, pasture maintenance, and interest expenses on borrowed operating and livestock capital. Fixed costs include family living expenses, insurance, real estate taxes, pasture rent, and machinery, equipment, and fence replacement (Refer to Table V). Interest on pre-existing debt, except for breeding livestock, is also included in the overhead charge.

The base cow herd, a Hereford-Angus two breed rotation, has residual returns equaling $7,166. System 0, the pre- 1980s Hereford-Angus rotational system, has higher returns, $7,849. The higher returns in System 0 over System 1 are due primarily to the increased herd size in System 0 and to the higher percentage of cattle grading choice (see Table XXX). System 0 had 24 more cows than System 1. With the coefficients used, the industry move toward larger Hereford-Angus cows appears unprofitable. However, the difference in returns between the two systems is small ($683). A slight decrease in pasture and/or feed costs may result in an order change. Also, System 0 cows are smaller and less compatible with the other breeding systems. For example, because cows in System 0 are smaller, more calving problems would be expected in terminal cross systems.

TABLE XXXI

OPTIMAL RANCH PLANS, HERD SIZE, AND RESIDUAL RETURNS FOR EACH BREEDING SYSTEM CONSIDERED

	Residual Returns	Rank	Herd Size			Calving Season	Optimal Ranch Plan[1]			
			Rot. X	Term X	Total		Rotational Cross		Terminal Cross	
							Steers	Heifers	Steers	Heifers
System 0	$7,849	4	344.4		344.4	Spring	Fed-3	Fed-2		
System 1	7,166	5	319.6		319.6	Spring	Fed-2&3	Fed-2		
System 2	10,116	1	164.5	155.1	319.6	Spring	Fed-2	Fed-2	Fed-3	Fed-2&3
System 3	6,333	8	311.8		311.8	Spring	Fed-1&3	Fed-2		
System 4	6,656	6	160.5	151.3	311.8	Spring	Fed-1	Fed-2	Fed-3	Fed-2&3
System 5	4,434	10	307		307	Spring	Fed-3	Fed-1		
System 6	5,209	9	158	149	307	Spring	Fed-3	Fed-1	Fed-3	Fed-1
System 7	9,093	3	304.1		304.1	Spring	Fed-3	Fed-2		
System 8	9,238	2	156.5	147.6	304.1	Spring	Fed-3	Fed-2	Fed-2	Fed-1
System 9	6,628	7	284.8		284.8	Spring	Fed-1	Fed-3		
System 10	-9,030	11	291.2		291.2	Both	WP,Fed-5	Fed-2,3,5		

Fed-1: Feeding Weaned Spring-born Calves
Fed-2: Feeding Wheat Pasture Stockers
Fed-3: Feeding Grazeout Stockers
Fed-5: Feeding Weaned Fall-born Calves
WP: Wheat Pasture Stockers

Given the assumed price and production levels, System 2, the combined rotational-terminal sire system with Hereford-Angus cross cows had the highest returns of all systems, $10,116. The three-breed systems with Hereford, Angus, and Brahman ranked second and third. The rotational system, System 7, had returns of $9,093. The combined system, System 8, had returns of $9,238. Productivity gains in the terminal portion of the herd, arising from increased heterosis utilization and complementarity, with only slight increases in production costs are the primary factors contributing to the high returns in System 2. Weaning rates were highest for the Brahman cross brood cows. This, coupled with the heavy weaning weights and good postweaning gains resulting from the cross, contributed to the high returns for Systems 7 and 8. However, three-breed rotation and combined rotational-terminal sire systems require a high level of management. An individual producer must decide if the increased returns from such systems compensate for the increased managerial requirements.

System 0 ranked fourth and System 1, fifth. Systems 3 and 4, the three breed rotational crosses with two medium frame, medium milk potential breeds and one medium frame, heavy milk potential breed had the eighth and sixth highest returns, respectively. The rotational system, System 3, had returns of $6,333. The combined system had returns of $6,656.

The large frame, heavy milk production potential, two breed rotation, System 9, had returns of $6,628. It ranked seventh among all systems. System 10, the large frame, light milk, two breed rotation, had the lowest residual returns. This was the only system to generate negative returns, ($9,030). The large steer calves from System 10 were simply not profitable to finish. Compared to other systems, their postweaning rates of gain were good (Refer to Appendix B). However, weaning weights were low relative to the finishing weights, indicating a greater length of time required in the feedlot. System 10's poor performance contradicts a conclusion made by Stokes et al. (1981), that large frame, light milk potential cow types had the highest profit potential.

All combined rotational-terminal sire systems (Systems 2, 4, 6, 8) had higher residual returns than their rotational counterparts (Systems 1, 3, 5, 7). The greatest difference between the rotational and combined systems occurred in Systems 1 and 2, $2,950. These results indicate that the increased productivity in a combined system may be profitable.

Optimal Calf Production and Marketing Plan

Calves were born in the spring in all optimal plans (Table XXXI). System 10 also had a small fall calving herd. In general, all steers and heifers in a given system followed the same production and marketing plan. However, in some systems, steers and/or heifers were divided and fed in different plans. In most instances, when a group was split, part of the group was fed as wheat pasture stockers and the remainder as grazeout stockers. Only slight production cost or output price changes in the activities involved are required for a switch in activities to occur. Hired labor expenses and interest expenses on borrowed operating capital were the primary factors influencing the decision to split a group of steers or heifers between production plans.

All plans involved retained ownership of steers and heifers through finishing, except for steers from System 10, which were sold off wheat pasture in March. Fall-born calves from System 10 were also finished. The most common production and marketing strategy was to place steers and heifers in the feedlot as stockers, either in March, off wheat pasture, or in May, off grazeout wheat pasture. Grazing wheat pasture provides the opportunity for inexpensive but substantial gains.

Given feed price, livestock price, and animal performance assumptions used in the models, the most profitable option in some systems is to place the steers or heifers directly into the feedlot at weaning, rather than on wheat pasture. Steers from System 9 are an example. The assumed finishing weight for fed weaned steers in System 9 is 1275 pounds (Refer to Appendix B). The finishing weight for fed wheat pasture stocker steers is 1500 pounds. The cost of the extra weight gain required (225 pounds in this case) is a major factor contributing to the decision to feed weaned calves. The extra weight gain costs over $105 per head in feed alone. Price discounts for over-sized slaughter cattle are another factor increasing the relative profitability of feeding weaned calves in System 9.

Optimal Herd Size

The number of cows in the herd is dictated primarily by forage availability. As described in Chapter III, the study's land resource base was selected to support a herd size of about 300 cows in a normal forage-yielding year. That herd size is sufficient to employ the owner-operator full-time in an economically viable unit and will facilitate the breeding systems considered.

The total number of cows ranged from 285 in System 9 to 344 in System 0. The base cow herd had 319 cows. Differences reflect forage requirements per cow and the intensity of pasture use which proves most profitable. In the combined rotational terminal sire systems, about 51.5 percent of the cows are in the rotational herd and the remainder in the terminal herd.

Borrowed Operating Capital

The borrowed operating capital requirements by period, short term loan, and the livestock capital requirements for the optimal ranch plans in each system are presented in Table XXXII. Timing of cash outflows and cash inflows from the sale of animals influences borrowing requirements across periods. Seasonal differences among systems are apparent in Table XXXII.

The short term loan reflects perpetual borrowing required to finance the optimal ranch plan over time. The LP model is a single period model reflecting the firm's financial situation at a point in time. The short term loan carrys over borrowing to ensure that interest is charged on an animal retained into the next year. The amount of the short term loan is equal to the total cow operating expenses, stocker operating expenses and/or feeder operating expenses accrued after weaning through the end of the year. The short term loans required in the optimal ranch plans ranged from $49,623 in System 1 to $58,332 in System 9.

Livestock capital requirements are dictated by cow value and the number of cows in the herd. Cow value is a function of breeding value and cull value. Livestock capital requirements were similar for all systems, ranging from $163,631 in Systems 5 and 6 to $179,377 in System 10.

Buying Replacement Heifers

Buying the herd's replacement heifers is an alternative to committing a portion of the herd to the task of producing replacement heifers. Buying replacement heifers would enable a producer to take full advantage of the benefits of heterosis and complementarity by breeding all cows to terminal sires. Sensitivity analysis was used to estimate the value of a purchased

TABLE XXXII

BORROWED OPERATING CAPITAL REQUIREMENTS BY PERIOD, SHORT TERM LOAN, AND ANNUAL LIVESTOCK CAPITAL REQUIREMENTS IN THE OPTIMAL RANCH PLAN OF EACH BREEDING SYSTEM

	SYSTEM 0	1	2	3	4	5	6	7	8	9	10
Operating Capital											
January-February	$24,242	$23,589	$23,587	$29,233	$30,330	$31,537	$31,579	$24,589	$29,174	$35,251	$12,188
March-April	76,742	78,437	79,868	84,633	85,581	81,371	81,705	77,730	85,039	87,763	0
May-June	40,312	0	37,016	0	35,901	39,730	40,477	40,326	43,276	0	0
July-August	0	0	0	0	0	0	0	0	0	0	0
September-October	0	0	0	0	0	0	0	0	0	0	0
November-December	0	0	0	0	0	0	0	0	0	0	0
Short Term Loan	51,427	49,623	49,829	54,900	55,884	56,115	56,286	50,830	53,763	58,332	54,513
Livestock Capital	167,026	172,577	172,577	168,056	168,056	163,631	163,631	169,676	169,676	169,193	179,377

replacement heifer for use in a terminal sire crossbreeding system, as opposed to a combined rotational-terminal sire system.

The values presented in Table XXXIII reflect the amount a producer could pay for a replacement heifer of each cow type for use in a terminal cross herd, given the performance and price assumptions used. Weaning rates and labor requirements were adjusted to reflect increased calving difficulties that result from buying replacement heifers and breeding a large frame, terminal sire to first calf heifers and young cows.

System 2 represents a terminal cross with Hereford-Angus rotational cross cows mated to large frame sires. A producer could pay $579 per head for Hereford-Angus rotational cross replacement heifers. The value of replacement heifers varied widely among systems, ranging from $96 in System 6 to $665 in System 8. Replacement heifer value for a particular breeding system is influenced by the profitability of the terminal cross portion of the herd compared to the rotational cross portion of the herd. It is also influenced by the animal performance parameters used in the model. The replacement heifer value in System 6 was influenced by the low weaning rate in the medium frame, heavy milk potential, three-breed rotation. The weaning rate assumed in the buy replacement activities was even lower, since it was adjusted to reflect the increased calving problems that result from breeding large frame terminal sires to heifers and young cows.

TABLE XXXIII

ESTIMATED VALUE OF A REPLACEMENT HEIFER,
GIVEN THE OPTION TO BUY REPLACEMENT
HEIFERS FOR A SPRING CALVING
TERMINAL SIRE SYSTEM

System	Replacement Heifer Value
2	$579.00
4	332.00
6	96.00
8	665.00

The Effects of Changing the Initial Debt Level and Decreasing Credit Availability on the Optimal Farm Plan

Retained ownership, especially through the feeder phase, is a capital intensive venture. The linear programming model is designed to reflect within year borrowing requirements in two-month periods. The model also has a set of credit limit constraints, also in two-month periods, which reflect the line of credit available to the producer throughout the year. The design of the borrowing and credit limit sections of the LP tableau was discussed in Chapter III.

The effects on the optimal ranch plan and residual returns in System 1 resulting from increasing the producer's beginning debt position and decreasing available credit are discussed in this section (Table XXXIV). The primary impact of increasing the initial debt level is a larger annual ranch overhead payment. The interest expenses charged on the debt owed (excluding breeding livestock debt) at the beginning of the year are included in the overhead charge. The impact of increased interest expenses that accompany a greater initial debt load is apparent in the lower residual returns that occur as the debt-to-asset ratio increases (Table XXXIV).

Increasing the overhead charge has secondary effects, since the overhead charge requires a cash outlay in each period. Less cash is available to cover operating expenses, so more borrowing is required. In System 1's optimal plan, borrowing to finance operating expenses only occurs in the January-February and March-April periods. With a maximum allowed leverage ratio of two, each 15 percent increase in the debt-to-asset ratio resulted in about a $1,755 increase in borrowing in the first period and a $3,967 increase in the second period (Table XXXIV).

TABLE XXXIV

EFFECTS OF INCREASING THE INITIAL DEBT POSITION AND DECREASING AVAILABLE CREDIT ON RESIDUAL RETURNS, OPTIMAL RANCH PLAN, SLACK CREDIT, BORROWING, AND OVERHEAD PAYMENT, SYSTEM 1

Max LR[1]	2	2	2	1	1	1	5	.5	.5
D/A Ratio[2]	30	45	60	30	45	60	.3	.45	60
Returns	7,166	-3464	-14,094	7,166	-3,464	-14,152	6,428	-5,704	-18,245
Change in Optimal Plan	No Change[3]	Revised[4]	Revised[5]	No Change[3]	Revised[4]	Revised[6]	Revised[7]	Revised[8]	Revised[9]
Credit Available in									
Jan-Feb Period	211,533	148,755	85,979	109,108	61,586	16,045	25,647	26,364	28,923
Mar-Apr Period	213,602	148,940	84,279	97,061	47,581	0	0	0	0
May-Jun Period	322,571	260,989	199,406	198,773	152,614	106,124	74,355	47,615	42,517
Jun-Aug Period	394,512	325,442	256,372	269,194	214,625	161,807	143,986	105,845	65,118
Sep-Oct Period	459,234	388,410	317,586	316,737	261,415	205,795	173,637	131,559	87,768
Nov-Dec Period	442,436	369,903	297,370	297,380	240,349	182,978	151,149	106,984	60,677
Borrowed Operating Capital									
Jan-Feb Period	23,589	25,344	27,098	23,589	25,344	25,388	7,898	0	0
Mar-Apr Period	78,437	82,405	86,372	78,437	82,405	84,297	59,399	32,497	4,283
Short Term Loan	49,623	49,623	49,623	49,623	49,623	49,236	47,788	43,625	40,420
Total Overhead Payment	45,190	55,716	66,243	45,190	55,716	66,243	45,190	55,716	66,243

TABLE XXXIV (Continued)

[1] Maximum Leverage Ratio
[2] Debt-to-Asset Ratio
[3] Herd Size 319 6 Cows, 50 8 Fed Wheat Pasture (WP) Stocker Steers, 87 0 Fed Grazeout (GO) Stocker Steers, 94 0 Fed WP Stocker Heifers
[4] Herd Size 319 6 Cows, 57 7 Fed WP Stocker Steers, 80 1 Fed GO Stocker Steers; 94 0 Fed WP Stocker Heifers
[5] Herd Size 319 6 Cows, 64 5 Fed WP Stocker Steers, 73 3 Fed GO Stocker Steers, 94 0 Fed WP Stocker Heifers
[6] Herd Size 318 6 Cows, 62 0 Fed WP Stocker Steers, 73 4 Fed GO Stocker Steers; 93 7 Fed WP Stocker Heifers
[7] Herd Size 310 6 Cows, 27 3 Fed WP Stocker Steers, 88 1 Fed GO Stocker Steers, 18 5 Fed Year-Round (YR) Stocker Steers, 91 3 Fed WP Stocker Heifers
[8] Herd Size· 287 2 Cows, 76 9 Fed GO Stocker Steers, 47 0 Fed YR Stocker Steers; 84 5 Fed WP Stocker Heifers
[9] Herd Size 270 7 Cows, 35 8 Fed GO Stocker Steers, 80 9 Fed YR Stocker Steers, 79 6 Fed WP Stocker Heifers

The maximum leverage ratio allowed reflects limits imposed, either internally or externally, on the amount of debt the operation can assume. The maximum leverage ratio divided by one plus the maximum leverage ratio, (LR/(1+LR)), times the producer's initial assets gives the initial amount of credit available to the producer. The amount of credit is adjusted in each period, based on cash inflows and outflows in the period. Available credit increases when calves are retained, reflecting the increase in the producer's asset position that occurs when he or she retains ownership and can borrow against the value of the retained calves. A maximum leverage ratio of two implies the maximum amount a producer can borrow equals two-thirds of beginning assets plus two-thirds of any increase in assets resulting from retaining ownership.

With maximum leverage ratios of two and one, slight changes in the optimal ranch plan occurred when the debt-to-asset ratio was increased from 0.30 to 0.45 and to 0.60 (Table XXXIV). The number of fed grazeout stocker steers decreased while the number of fed wheat pasture stocker steers increased in each case. Herd size decreased slightly and a small number of steers were retained as year-round stockers, then finished, when the maximum leverage ratio equaled one and the debt-to-asset ratio equaled 0.60. Credit limitations in the March-April period precipitated the ranch plan changes.

When the available credit was restricted further by assuming a maximum leverage ratio of 0.5, the ranch plan changed more drastically. With each successive increase in the debt-to-asset ratio, herd size decreased. The fed wheat pasture stocker steer activity was reduced then eliminated. The number of fed grazeout stockers decreased and the number of fed year-round stockers increased. With a leverage ratio of 0.5, the credit limit was reached only in the March-April period.

These results imply that, based on the expected prices and animal performance estimates used in the model, retained ownership through the feeder phase, on average, is a financially feasible production alternative. For producers willing to assume the debt and for lenders willing to extend the credit necessary to finance the endeavor, retained ownership through the feeder phase appears capable of generating financing to meet requirements. However, at high initial debt levels, debt-to-asset ratios equal to 0.45 and 0.60, residual returns are negative, indicating an inability to meet all long run costs, specifically interests payments on pre-existing debt. Over time, the financial situation would deteriorate.

Fixed Production and Marketing Plans

The results in Table XXXV are for fixed production and marketing plans using Systems 1, 2, 4, 7, 8, and 9. These systems were selected for further analysis for several reasons. System 1 is the base system. The optimal solutions for Systems 2, 8, 7, and 4 had the highest residual returns, in that order. Both two- (Systems 1 and 9) and three-breed (System 7) rotational systems are included. Combined rotational-terminal sire systems with two- (System 2) and three-breed (Systems 4 and 8) rotations are also included. Finally a large frame two breed rotation is represented (System 9).

Selling Weaned Calves

Negative returns were exhibited when selling calves at weaning in all systems. Losses from selling weaned spring- born calves ranged from $10,909 in System 9 to $20,572 in System 7. Sale of fall-born calves resulted in total losses $800 to $1,317, $12 to $16 per cow, more than selling spring-born

TABLE XXXV

RESIDUAL RETURNS, HERD SIZE, AND FORAGE INTENSITY OF FIXED PRODUCTION AND MARKETING PLANS FOR SYSTEMS 1, 2, 4, 7, 8, AND 9

Plan[1]	Residual Returns ($)	Residual Returns ($/cow)	No. of Cows (hd)	Forage Intensity
System 1				
Weaned Spring	-20,159	-64.99	310.2	Medium
Weaned Fall	-20,952	-78.86	265.7	Low
Wht Past Stockers	-6,092	-19.64	310.2	Medium
Grazeout Stockers	-13,053	-42.08	310.2	Medium
Yr-Rnd Stockers	-19,548	-84.77	230.6	Medium
Fed W. Spring	-1,470	-4.60	319.6	High
Fed WP Stockers	7,147	22.36	319.6	High
Fed GO Stockers	4,743	14.84	319.6	High
Fed Yr-Rd Stockers	-5,359	-23.24	230.6	Medium
Fed W. Fall	-3,341	-10.33	323.4	High
System 2				
Weaned Spring	-17,153	-55.30	310.2	Medium
Weaned Fall	-17,952	-67.56	265.7	Low
Wht Past Stockers	-3,878	-12.50	310.2	Medium
Grazeout Stockers	-10,194	-32.86	310.2	Medium
Yr-Rnd Stockers	-17,907	-78.44	228.3	Medium
Fed W. Spring	-424	-1.33	319.6	High
Fed WP Stockers	9,103	28.48	319.6	High
Fed GO Stockers	8,407	26.30	319.6	High
Fed Yr-Rd Stockers	-1,201	-5.10	235.3	High
Fed W. Fall	-418	-1.29	323.4	High
System 4				
Weaned Spring	-17,222	-56.91	302.6	Medium
Weaned Fall	-16,195	-62.15	260.6	Low
Wht Past Stockers	-3,824	-12.64	302.6	Medium
Grazeout Stockers	-10,063	-33.25	302.6	Medium
Yr-Rnd Stockers	-18,028	-81.54	221.1	Medium
Fed W. Spring	856	2.75	311.8	High
Fed WP Stockers	4,932	15.82	311.8	High
Fed GO Stockers	5,882	18.86	311.8	High
Fed Yr-Rd Stockers	-2,922	-12.83	227.8	High
Fed W. Fall	-8,439	-26.60	317.2	High

TABLE XXXV (Continued)

	Residual Returns ($)	Residual Returns ($/cow)	No. of Cows (hd)	Forage Intensity
System 7				
Weaned Spring	-20,572	-69.71	295.1	Medium
Weaned Fall	-21,889	-85.94	254.7	Low
Wht Past Stockers	-12,732	-43.14	295.1	Medium
Grazeout Stockers	-21,145	-71.65	295.1	Medium
Yr-Rnd Stockers	-25,256	-118.85	212.5	Medium
Fed W. Spring	2,196	7.22	304.1	High
Fed WP Stockers	7,940	26.11	304.1	High
Fed GO Stockers	6,126	20.15	304.1	High
Fed Yr-Rd Stockers	-5,998	-28.23	212.5	High
Fed W. Fall	-4,752	-15.33	310.0	High
System 8				
Weaned Spring	-15,051	-51.00	295.1	Medium
Weaned Fall	-16,426	-64.49	254.7	Low
Wht Past Stockers	-5,734	-19.43	295.1	Medium
Grazeout Stockers	-13,863	-46.98	295.1	Medium
Yr-Rnd Stockers	-20,054	-94.60	212.0	Medium
Fed W. Spring	3,731	12.27	304.1	High
Fed WP Stockers	8,039	26.43	304.1	High
Fed GO Stockers	8,267	27.18	304.1	High
Fed Yr-Rd Stockers	-3,909	-17.90	218.4	High
Fed W. Fall	-2,621	-8.45	310.0	High
System 9				
Weaned Spring	-10,909	-39.47	276.4	Medium
Weaned Fall	-14,566	-61.23	237.9	Low
Wht Past Stockers	-50	-0.18	284.8	Medium
Grazeout Stockers	-9,398	-33.00	284.8	Medium
Yr-Rnd Stockers	-15,940	-80.22	198.7	Medium
Fed W. Spring	6,059	21.27	284.8	High
Fed WP Stockers	4,732	16.61	284.8	High
Fed GO Stockers	3,935	13.82	284.8	High
Fed Yr-Rd Stockers	-3,781	-18.46	204.8	High
Fed W. Fall	-3,113	-10.75	289.6	High

[1] Wht Past Stockers: Wheat Pasture Stockers
Yr-Rnd Stockers: Year-Round Stockers
Fed W. Spring: Fed Weaned Spring-born Calves
Fed WP Stockers: Fed Wheat Pasture Stockers
Fed GO Stockers: Fed Grazeout Stockers
Fed Yr-Rd Stockers: Fed Year-Round Stockers
Fed W. Fall: Fed Weaned Fall-born Calves

calves in Systems 1, 2, 3, 7, and 8. The difference was even greater in System 9, $3,657, over $21 per cow.

The LP model was also run with the option to sell either or both spring and fall born calves at weaning in System 1. The optimal ranch plan in this case involved a mix of both spring (72 percent of the herd) and fall calving (28 percent of the herd) cows. Returns were $113 higher than those of the straight spring calving herd and $906 higher than the fall calving herd.

Selling Stocker Cattle

Sale of wheat pasture stockers was the best stocker production and marketing alternative considered, followed by grazeout stockers, and year-round stockers. Returns from selling wheat pasture stockers ranged from ($12,732) in System 7 to ($50) in System 9. Returns from selling grazeout stockers ranged from ($21,145) in System 7 to ($9,398) in System 9.

Compared to selling weaned calves, sale of year-round stockers cut losses only in System 1. In all other systems selling year-round stockers resulted in greater losses than selling weaned calves.

Selling Finished Cattle

The results indicate that retained ownership through the feeder phase, on average, increases returns significantly. Selling fed wheat pasture stockers and fed grazeout stockers generated positive returns in all systems considered. Returns from selling fed wheat pasture stockers ranged from $4,732 in System 9 to $9,103 in System 2. Returns from selling fed grazeout wheat pasture stockers ranged from $3,935 in System 9 to $8,407 in System 2.

Selling fed weaned spring calves had positive returns in Systems 3, 7, 8, and 9. Selling fed weaned spring calves had returns ranging from ($1,470) in System 1 to $6,059 in System 9. Selling fed year-round stockers had negative returns in all systems, ranging from ($1,201) in System 2 to ($5,998) in System 7. Selling fed weaned fall calves also generated negative returns in all systems, ranging from ($418) in System 2 to ($4,752) in System 7.

Comparing Production and Marketing Plans

The results for the fixed production and marketing plans provide the basis for two types of comparisons. First, production and marketing plans can be compared within systems. Second, given a particular production and marketing plan, the breeding systems can be evaluated.

Comparing fixed production and marketing plans for a given system illustrates the potential retaining ownership has as a means of increasing residual returns to the ranch operation. The difference in residual returns across plans from the most profitable fixed production and marketing plan and the profit ranking of the plans for each system are presented in Table XXXVI. On average, returns are increased relative to selling weaned calves by retaining ownership in all of the alternatives considered except for selling year-round stockers.

The results illustrate the stability of retained ownership in the ranch plan, usually through the feeder phase. In general, the five most profitable plans for each system were the five feedlot activities. Selling fed wheat pasture stockers was the most profitable fixed production and marketing plan in Systems 1, 2, and 7. Selling fed grazeout stockers was most profitable in Systems 4 and 8; and fed weaned spring calves in System 9. Generally, the three most profitable

TABLE XXXVI

EVALUATING FIXED PRODUCTION AND MARKETING PLANS, GIVEN BREEDING SYSTEM

System		Weaning		Stockers			Feeder				
		Spring	Fall	Wheat Pasture	Grazeout	Year-Round	Weaned Spring	Wheat Pasture	Grazeout	Year-Round	Weaned Fall
		Difference from Most Profitable Plan Across Plans, Given System									
1		$27,306	$28,099	$13,239	$20,200	$26,696	$8,617	$0	$2,404	$12,506	$10,488
	Rank	9	10	6	7	8	3	1	2	5	4
2		26,256	27,055	12,980	19,296	27,010	9,526	0	696	10,303	9,520
	Rank	8	10	6	7	9	4	1	2	5	3
4		23,104	22,077	9,706	15,944	23,910	5,026	950	0	8,804	14,321
	Rank	9	8	5	7	10	3	2	1	4	6
7		28,512	29,829	20,671	29,084	33,196	5,744	0	1,813	13,938	12,692
	Rank	7	9	6	8	10	3	1	2	5	4
8		23,318	24,693	14,001	22,129	28,321	4,536	228	0	12,176	10,887
	Rank	8	9	6	7	10	3	2	1	5	4
9		16,968	20,625	6,109	15,456	21,999	0	1,327	2,123	9,839	9,172
	Rank	8	9	4	7	10	1	2	3	6	5

plans involved feeding wheat pasture stockers, grazeout stockers, and spring calves from weaning. The least profitable feeding activities involved feeding weaned fall calves and year-round stockers.

In System 9, selling wheat pasture stockers ranked higher than selling fed weaned fall calves and fed year-round stockers. Selling wheat pasture stockers in March was the most profitable stocker activity in all systems, followed by grazeout stockers. Returns from selling wheat pasture stockers ranged from $6,109 in System 9 to $20,671 in System 7 below the profit-maximizing fixed production plans. Returns from selling grazeout stockers ranged from $15,546 in System 9 to $29,084 in System 7 below the profit-maximizing fixed plans.

Selling year-round stockers was the least profitable fixed plan in Systems 3, 7, 8, and 9, while selling fall born weaned calves at weaning was least profitable in Systems 1 and 2. Selling weaned spring born calves was from $800 to $3,600 more profitable than selling weaned fall born calves.

The negative impact of price discounts for Brahman cross calves at the stocker level is apparent in the results for System 7. Returns from the sale of stockers in all three stocker activities for System 7 were lower than returns for like activities in the other systems. The difference in returns between the sale of weaned calves or stockers and the returns in the profit maximizing fixed production plan in System 7 were greater than the differences observed in other systems. Returns from selling stockers and weaned calves in System 7 were from $20,671 to $33,196 below the returns from selling fed wheat pasture stockers, the profit-maximizing fixed plan in System 7. These results point to the importance of retaining ownership through the feeder phase to maximize profits in those systems with Brahman in the rotation.

Comparing Breeding Systems, Given Fixed Production Plans

The second comparison using the results of the fixed production and marketing plans is of the alternative breeding systems, given a plan (Table XXXVII). The results indicate that, given the price and production assumptions used, a system producing large calves with heavy weaning and stocker weights has the most potential for maximizing returns, on average, for producers selling calves at weaning or as stockers. Selling spring born calves at weaning in System 9 was from $4,142 to $9,663 more profitable than selling weaned spring calves in the other systems. Selling wheat pasture stockers in System 9 had returns from $3,774 to $12,681 higher than the other systems.

System 8 had the second highest returns from selling weaned spring calves. System 4 ranked second when selling weaned fall calves, wheat pasture stockers, and grazeout stockers, while System 2 ranked second when selling year-round stockers. Systems 1, 7, and 8 had the lowest returns from selling weaned calves and stockers. The low returns from selling stockers in Systems 7 and 8 were due primarily to the price discounts associated with Brahman-cross stocker cattle. System 1's low returns were primarily a function of lower animal performance relative to the other systems, especially with regard to weaning weight.

Returns were highest in System 9 when selling fed weaned spring calves and highest in System 2 when selling fed wheat pasture stockers and fed grazeout stockers. System 2 also had highest returns when selling fed year-round stockers and fed weaned fall calves.

Returns from selling fed weaned spring calves ranged from $2,328 in System 8 to $7,529 in System 1 below those of System 9. Returns from selling

TABLE XXXVII

EVALUATING BREEDING SYSTEM PERFORMANCE, GIVEN FIXED PRODUCTION AND MARKETING PLANS

	Weaning				Stockers						Feeder									
System	Spring	Rank	Fall	Rank	Wheat Pasture	Rank	Grazeout	Rank	Year-Round	Rank	Weaned Spring	Rank	Wheat Pasture	Rank	Grazeout	Rank	Year-Round	Rank	Weaned Fall	Rank
	Difference from Most Profitable Plan Across Systems, Given Plan																			
1	$9,250	5	$6,386	5	$6,042	5	$3,655	4	$3,608	4	$7,529	6	$1,955	4	$3,633	5	$4,158	5	$2,923	4
2	6,244	3	3,386	4	3,828	3	796	3	1,967	2	6,482	5	0	1	0	1	0	1	0	1
4	6,313	4	1,629	2	3,774	2	665	2	2,088	3	5,203	4	4,171	5	2,525	4	1,722	2	8,021	6
7	9,663	6	7,323	6	12,681	6	11,747	6	9,316	6	3,863	3	1,163	3	2,280	3	4,797	6	4,335	5
8	4,142	2	1,860	3	5,684	4	4,465	5	4,114	5	2,328	2	1,064	2	140	2	2,709	4	2,203	2
9	0	1	0	1	0	1	0	1	0	1	0	1	4,371	6	4,471	6	2,580	3	2,696	3

fed wheat pasture stockers ranged from $1,064 in System 8 to $4,371 in System 9 less than the returns in System 2. Again, the price discounts associated with selling large animals are the expense of feeding large calves to a satisfactory degree of finish are the reasons returns from selling fed wheat pasture and fed grazeout stockers in System 9 are the lowest of the systems considered for these two fixed plans.

Productivity

The total hundredweights (cwt) of steers and heifers sold in the fixed production and marketing plan for each system provides a basis for comparison of the physical productivity of the alternative breeding systems (Table XXXVIII). System 9 had the highest total production of steers and heifers for sale in the fixed stocker plans and all feedlot plans except the fed weaned spring plan. System 8 had the highest total weaned calf production, both spring and fall calving, the most fed weaned spring production, and ranked second behind System 9 in the other fixed plans.

While interesting, total productivity is not a useful performance measure for evaluating alternative breeding systems. For example, System 9 had the highest total steer and heifer productivity in the fed wheat pasture stocker and fed grazeout stocker plans because their finishing weights were the highest. However, System 9 also had the lowest residual returns of the systems considered in those plans.

Operating Capital Borrowing Requirements

The linear programming model assures that bi-monthly operating capital requirements are met by using cash on hand and from livestock sales or by

TABLE XXXVIII

TOTAL BEEF PRODUCTIVITY IN THE FIXED PRODUCTION AND MARKETING PLANS, SYSTEMS 1, 2, 4, 7, 8, AND 9

Plan[1]	System 1	System 2	System 4	System 7	System 8	System 9
	(cwt)					
Weaned Spring	1,097.9	1,116.0	1,166.6	1,224.3	1,239.1	1,268.7
Weaned Fall	1,080.8	1,098.9	1,154.6	1,214.2	1,229.0	1,254.4
Wht Past Stockers	1,616.7	1,647.4	1,695.2	1,743.2	1,766.1	1,855.6
Grazeout Stockers	1,837.4	1,872.2	1,919.4	1,963.4	1,989.3	2,025.9
Yr-Rnd Stockers	1,252.5	1,263.7	1,298.8	1,303.5	1,317.6	1,344.9
Fed W. Spring	2,332.1	2,528.5	2,552.1	2,576.6	2,612.1	2,580.1
Fed WP Stockers	2,363.1	2,587.7	2,611.1	2,611.1	2,672.1	3,005.1
Fed GO Stockers	2,483.0	2,761.1	2,815.5	2,742.4	2,818.2	3,005.1
Fed Yr-Rd Stockers	1,733.3	2,008.1	2,009.8	1,854.5	1,997.8	2,160.3
Fed W. Fall	2,337.5	2,549.3	2,587.4	2,602.4	2,652.9	2,674.9

[1] Refer to Table XXXV for an explanation of abbreviations.

borrowing within the firm's borrowing capacity. The model also has cash transfer activities to transfer surplus cash from one period to the next. Table XXXIX contains the operating capital borrowed in each two month period and the short term loan for the fixed production and marketing plans in System 1.

In general, the relative amounts of borrowing are similar among systems, while absolute borrowing levels vary. Fed year-round stockers and fed weaned fall calves are exceptions. In several systems, the length of time required to finish the calves in these two activities is such that the calves are sold in the year after they entered the feedlot. In those cases, both the within year borrowing and the short term loan will be different from System 1.

Within-year borrowing for a given plan is strongly influenced by when calves are sold. In general, the sale of the steers and heifers generated sufficient revenue to repay within year operating capital loans from prior periods and to cover operating expenses incurred in subsequent periods throughout the remainder of the year.

Hired Labor Requirements

Some producers may have reservations about retained ownership due to the additional labor requirements associated with running stockers. These may arise due to problems with locating sufficient part-time help when it is needed. Monthly hired labor requirements for each of the fixed production and marketing plans in System 1 are presented in Table XL. Hiring patterns are similar for the other systems, although absolute levels will vary slightly.

Peak hiring occurs in the winter, when cows require supplemental feeding and care, and in the months when calves are transferred to subsequent

TABLE XXXIX

BORROWING REQUIREMENTS IN EACH FIXED PRODUCTION AND MARKETING PLAN IN SYSTEM 1 - GIVEN CONSTANT INITIAL NET WORTH POSITION (DEBT-TO-ASSET RATIO = 0.3)

	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	Sh. Term Loan
Weaned Spring	$19,661	$53,629	$63,840	$68,204	$0	$0	$0
Weaned Fall	14,232	26,690	39,705	0	0	2,403	0
Wht Past Stockers	23,133	0	0	0	0	0	48,613
Grazeout Stockers	23,133	68,070	0	0	0	0	48,613
Yr-Rnd Stockers	19,793	51,692	62,688	69,056	0	0	32,647
Fed W. Spring	38,205	92,329	0	0	0	0	60,619
Fed WP Stockers	23,589	82,837	0	0	0	0	49,623
Fed GO Stockers	23,589	69,582	105,399	0	0	0	49,623
Fed Yr-Rd Stockers	0	0	0	0	0	0	52,909
Fed W. Fall	18,417	28,748	47,849	75,615	114,215	0	0

[1] Refer to Table XXXV for an explanation of abbreviations.

TABLE XL

MONTHLY HIRED LABOR REQUIREMENTS FOR EACH FIXED PRODUCTION AND MARKETING PLAN IN SYSTEM 1

Plan	Jan	Feb	May	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
							(Hours)						
W Spr	145	222	209	351	17	0	0	0	0	63	141	231	1,371
W Fall	128	105	105	563	0	0	0	0	0	128	128	216	1,373
WP St	271	346	333	361	17	0	0	0	0	63	327	355	2,063
GO St	271	346	333	471	118	0	0	0	0	63	507	474	2,583
YR St	101	157	147	371	0	0	0	0	0	0	156	185	1,117
Fed W Spr	159	235	222	349	31	0	0	0	0	72	152	243	1,463
Fed WP St	286	363	350	349	31	0	0	0	0	72	344	370	2,165
Fed GO St	286	363	350	472	136	0	0	0	0	72	529	493	2,701
Fed YR St	101	157	147	371	0	0	0	0	0	0	156	185	1,117
Fed W Fall	205	176	176	597	27	0	8	0	0	205	205	289	1,888

enterprises. Very little hired labor is required during the summer months, from May through September.

Importance of Weaning Rate

The cow herd's weaning rate, or calf crop, has a dramatic impact on ranch productivity and ultimately, profitability. To illustrate the importance of weaning rate, the LP models for Systems 1 and 2 were run, ceteris paribus, with assumed weaning rates of 70, 80, 90, and 100 percent (Table XLI). Herd size was fixed at 310 cows by eliminating the lovegrass activity with 150 pounds of nitrogen applied per acre. Otherwise, at higher weaning rates, more intensive grazing practices are employed, resulting in a greater herd size.

The results presented in Table XLI illustrate the importance of weaning rate to the profitability of the ranch operation. For a producer retaining ownership of his calves as wheat pasture stockers, then finishing them, each one percent increase in weaning rate, ceteris paribus, increases returns per cow, on average, $5.23 in System 1 and $5.45 in System 2. The increased returns reflect the maximum amount a producer could pay to improve his weaning rate.

The increase in ranch profitability that results from increasing the weaning rate stems from increased herd productivity. A one percent increase in weaning rate results in an increase of about 5 pounds per cow in the quantity of steers and heifers weaned in Systems 1 and 2.

Gains in productivity are even greater when considering retained ownership through the feeder stage. The total live weight of steers and heifers sold per cow increases over 10 pounds per cow in System 1 and almost 11.5 pounds in System 2 with each one percent increase in weaning rate.

TABLE XLI

RESIDUAL RETURNS, WEANED CALF PRODUCTION, AND TOTAL LIVE WEIGHT OF CALVES SOLD IN SYSTEMS 1 AND 2, WITH WEANING RATES OF 70, 80, 90, AND 100 PERCENT

Weaning Rate	Residual Returns		Weaned Calf Production		Total Live Weight Sold	
	($)	($/cow)	(cwt)	(cwt/cow)	(cwt)	(cwt/cow)
System 1						
70 Percent	$-22,103	$-71.25	857.4	2.76	1,767.2	5.70
80 Percent	-5,889	$-18.98	1,009.8	3.26	2,085.4	6.72
88 Percent	7,082	$22.83	1,131.7	3.65	2,339.6	7.54
90 Percent	10,325	$33.28	1,162.3	3.75	2,403.6	7.75
100 Percent	26,539	$85.55	1,314.7	4.24	2,721.7	8.77
System 2						
70 Percent	$-20,416	$-65.82	867.9	2.80	1,942.7	6.26
80 Percent	-3,524	$-11.36	1,024.9	3.30	2,296.9	7.40
88 Percent	9,992	$32.21	1,150.6	3.71	2,580.3	8.32
90 Percent	13,368	$43.09	1,182.0	3.81	2,651.1	8.55
100 Percent	30,260	$97.55	1,338.9	4.32	3,005.3	9.69

The results presented in this chapter have been of the comparative static analysis of the retained ownership alternatives and the alternative breeding systems. These results indicate the expected returns, based on expected cattle and feed prices and animal performance estimates. However, producers need more information than just expected returns. The goal of Chapter VI is to provide estimates of the distribution of returns for several of the fixed production and marketing plans for Systems 1, 2, 7, 8, and 9.

CHAPTER VI

THE RISK ANALYSIS

The research reported in the previous chapter was conducted in a static framework, assuming perfect knowledge. In order to more accurately reflect the decision-making process, the stochastic element must be included in the modeling effort. Producers have differing risk attitudes as well as differing risk-bearing capabilities. As a result, they need information about the full range of possible returns.

This chapter provides a risk analysis using the information developed in previous chapters. The objective is to generate a distribution of returns for representative fixed production and marketing plans. The variability represented is the within year variability arising from uncertain cattle production and uncertain input and output prices. The plans considered include selling weaned calves, wheat pasture stockers, fed weaned calves, and fed wheat pasture stockers.

The analysis will focus on Systems 1, 2, 7, 8, and 9. System 1, the base system, is a two-breed rotation with medium frame, medium milk potential breeds. System 2 is a combined rotational-terminal sire system with the same cow type as System 1. System 7 is a three-breed rotation with two medium frame, medium milk breeds and Brahman. System 8 is a combined rotational-terminal sire system with the same cow type as System 7. System 9 is a two-breed rotation with large frame, heavy milk breeds. Selection of these systems for additional analysis was justified in Chapter V.

Animal performance, input price, and output price variables are considered stochastic and independent in the risk model. Forage production and quality and input quality are not directly treated as stochastic in this analysis. Independence of animal performance and prices is a reasonable assumption since a single producer cannot influence price in a competitive market. The key animal performance variables are weaning rate, weaning weight, pasture average daily gain (adg), feedlot average daily gain, and feedlot feed efficiency (pounds of feed per pound of gain). Input price variables include grain sorghum, cottonseed meal (CSM), alfalfa, and non-legume hay prices. Output prices include prices for each sex and weight class of livestock.

The procedures for generating random animal performance and prices are described in the following sections. Then, the information is combined to produce whole-ranch returns estimates in a risky environment.

Animal Performance

Four calf performance traits, weaning weight, pasture average daily gain, feedlot average daily gain, and feedlot feed efficiency, are stochastic in the model. Weaning rate, which reflects maternal performance, is also stochastic. The calf performance traits are assumed correlated with each other, while weaning rate is assumed independent of calf performance.

The calf performance variables, each with a specified mean and variance (Refer to Table XXV), are assumed to comprise a multivariant normal distribution. The multivariant distribution is fully described by the vector of expected values for each of its marginals, μ, and by a positive, symmetrical variance-covariance matrix, Ω, which is defined by the following expression (King 1979, p. 225).

$$\Omega = E[(X-\mu)\ (X-\mu)] \tag{48}$$

The method of deriving the variance-covariance matrix for the calf performance traits for each system was described in Chapter IV. The variance-covariance matrices in Chapter IV are for a single head. To use these matrixes, they must be adjusted to represent variability of a group, in this case, the group of steers produced in a calf crop. The variance-covariance matrix for the group of steers, W, equals the variance-covariance matrix for a single head divided by the total number of steers produced in a single calf crop.

Since the calf performance variables are correlated, the procedure described by Naylor (1966) must be used to generate random observations from a multivariate normal distribution (King 1979, p. 225). The procedure is based on a theorem proved by Anderson (1959), which states that if Z is a vector of independent standard normal random variables, there exists a unique lower triangular matrix, T, such that

$$X = \mu + TZ \tag{49}$$

It follows directly that the variance-covariance matrix of $(X-\mu)$, also the variance-covariance matrix of X, since μ is a vector of constants, is defined by the expression TT' (King 1979 p. 225). Thus

$$\Omega = TT' \tag{50}$$

The procedure for deriving T, given Ω, is described in Kocher (1990, p. 91).

Given μ, T, and a vector of independent standard normal random variables, a random draw on the vector X can be found using Equation (49). Each simulation run requires a new vector of independent standard normal random variables. In any given simulation run, the same random vector Z is used to calculate X for each crossbreeding system.

Appropriately correlated random observations on weaning weight, pasture adg, feedlot adg, and feedlot feed efficiency were obtained as described above for 150 simulation runs. Summary statistics for each trait and each system are presented in Table XLII.

Random observations on weaning rate for each system are obtained by following the procedure for generating a binomial random distribution described by Trapp (1989). In the procedure, a value for p, the probability of success, is identified. Success, in this case, is defined as weaning a calf. Thus, p is the probability a cow will wean a calf, the weaning rate.

Given p, a set of n (n equals herd size) random observations on the Uniform (0,1) distribution are drawn. A successful event occurs when the Uniform (0,1) observation is less than or equal to p. The weaning rate for a period, then, is the sum of the number of successes, the number of times in n draws the random observation on the Uniform (0,1) is less than or equal to p. Summary statistics on simulated weaning rates are presented in Table XLIII.

Livestock Prices

Livestock price uncertainty is a primary source of variability in ranch returns. Thus stochastic cattle prices are an important component in the risk model. Variability in livestock prices is based on the variability in the monthly 400 to 500 pound steer price. Random draws on the 400 to 500 pound steer prices are obtained using Equation (49), where the arguments are scalers, μ is the average price and T is the standard deviation. Observations on the 400 to 500 pound steer price are truncated at \$71.67 and \$125 per cwt (real 1988 dollars). Prices for the other classes of cattle are obtained using Equation (33) and the data in Table VII. The seasonal indexes and relationships between the 400 to 500 pound steer price and the prices for other classes of cattle are assumed constant in the risk analysis. Adjustments for frame size and breed

TABLE XLII

SUMMARY STATISTICS ON HERD AVERAGE ANIMAL PERFORMANCE TRAITS USED IN THE RANCH SIMULATION, SYSTEMS 1, 2, 7, 8, 9

	Weaning Weight		Pasture ADG		Fed Weaned Feedlot ADG		Fed Wheat Pasture Feedlot ADG		Fed Weaned Feed Efficiency		Fed Wheat Pasture Feed Efficiency	
	Steers	Heifers	Steers	Heifers	Steers	Heifers	Steers	Heifers	Steers	Heifers	Steers	Heifers
System 1												
Average	500	483	1.80	1.62	2.79	2.45	3.28	2.88	6.23	6.49	6.15	6.41
Std. Deviation	5.17	5.00	0.0101	0.0091	0.0270	0.0237	0.0270	0.0237	0.0319	0.0333	0.0319	0.0333
Maximum	516	498	1.83	1.64	2.86	2.51	3.35	2.94	6.32	6.59	6.24	6.51
Minimum	488	472	1.78	1.60	2.70	2.37	3.19	2.80	6.14	6.41	6.06	6.32
System 2 - Rotational Cross												
Average	500	483	1.80	1.62	2.78	2.45	3.27	2.88	6.23	6.49	6.15	6.41
Std. Deviation	7.20	6.96	0.0141	0.0127	0.0376	0.0330	0.0376	0.0330	0.0445	0.0464	0.0445	0.0464
Maximum	522	504	1.84	1.65	2.89	2.54	3.38	2.97	6.35	6.63	6.27	6.54
Minimum	483	467	1.77	1.59	2.66	2.34	3.15	2.77	6.11	6.37	6.03	6.29
System 2 - Terminal Cross												
Average	531	513	1.93	1.74	2.96	2 61	3.48	3.06	6.66	6.94	6.57	6.85
Std. Deviation	7.44	7.19	0.0145	0.0131	0.0386	0.0339	0.0386	0.0339	0.0458	0.0478	0.0458	0.0478
Maximum	554	535	1.97	1.77	3.07	2.70	3.59	3.16	6.79	7.08	6.70	6.98
Minimum	514	496	1.90	1.71	2.84	2.49	3.36	3.95	6.54	6.82	6.45	6.72
System 7												
Average	564	545	1.82	1.67	2 81	2.47	3.30	2.90	6.70	6.98	6.61	6.89
Std. Deviation	5.36	5.19	0.0097	0 0087	0.0267	0.0235	0.0267	0.0235	0.0368	0.0384	0.0368	0.0384
Maximum	580	561	1 84	1 69	2.88	2.53	3 37	2.96	6.80	7.09	6.71	7.00
Minimum	551	533	1 80	1 65	2.72	2.39	3.21	2.82	6 60	6.88	6 51	6.79

TABLE XLII (Continued)

	Weaning Weight		Pasture ADG		Fed Weaned Feedlot ADG		Fed Wheat Pasture Feedlot ADG		Fed Weaned Feed Effiiciency		Fed Wheat Pasture Feed Efficiency	
	Steers	Heifers	Steers	Heifers	Steers	Heifers	Steers	Heifers	Steers	Heifers	Steers	Heifers
System 8 - Rotational Cross												
Average	564	545	1.82	1.67	2.80	2.47	3.29	2.90	6.70	6.98	6.61	6.89
Std. Deviation	7.47	7.22	0.0135	0.0121	0.0372	0.0327	0.0372	0.0327	0.0513	0.0535	0.0513	0.0535
Maximum	587	567	1.85	1.70	2.91	2.55	3.40	2.99	6.84	7.13	6.75	7.04
Minimum	546	528	1.79	1.64	2 68	2.36	3.17	2.79	6.56	6.84	6.47	6.75
System 8 - Terminal Cross												
Average	594	574	1.93	1.74	2.95	2.60	3.47	3.05	6.89	7.18	6.80	7.09
Std. Deviation	7.73	7.48	0.0161	0.0145	0.0403	0.0355	0.0403	0.0355	0 0557	0.0581	0.0557	0.0581
Maximum	617	597	1.97	1.78	3.06	2.69	3.58	3.15	7.05	7.35	6.96	7.25
Minimum	576	557	1.89	1.71	2.82	2.48	3.34	2.94	6.74	7.03	6.65	6.93
System 9												
Average	628	607	2.01	1 81	3.11	2.73	3.65	3.20	6.79	7.08	6.70	6.98
Std. Deviation	5.40	5.22	0.0110	0.0099	0.0285	0.0251	0.0285	0.0251	0.0340	0.0354	0.0340	0.0354
Maximum	644	623	2.04	1.84	3.18	2.80	3.72	3.27	6.88	7.18	6.79	7.08
Minimum	615	595	1.98	1.79	3.01	2.65	3.55	3.12	6.70	6.98	6.61	6.89

TABLE XLIII

SUMMARY STATISTICS ON HERD AVERAGE WEANING RATE AND NUMBER OF COWS WEANING A CALF USED IN THE RANCH SIMULATION, SYSTEMS 1,2,7,8,9

	System 1	System 2	System 7	System 8	System 9
Average Weaning Rate (%)	88.17	88.17	90.97	90.97	90.49
Average Number of Cows Weaning a Calf	282.14	282.14	276.54	276.54	257.91
Expected Number of Cows Weaning a Calf	281.25	281.25	276.43	276.43	257.46
Deviation from Expected Value	0.89	0.89	0.11	0.11	0.45
Sample Variance	31.55	31.55	24.12	24.12	24.87
Maximum	297	297	288	288	270
Minimum	267	267	259	259	241

Note: The statistics reported in this table are influenced by herd size (Refer to Table XXVI).

content were made to stocker and cow prices. (Refer to Table XXIX) Price discounts for overweight slaughter cattle were also included, $1.00 per cwt for over 1300 pounds, $5.00 per cwt for over 1450 pounds.

Input Prices

Feed is among the largest expense items in livestock budgets. For example, in the base spring calving operation, feed expenses for hay, protein supplement, and 20 percent protein cubes constituted 45 percent of total variable expenses, excluding labor and interest expenses. The proportion is even greater in those breeding systems requiring additional supplemental due to higher maintenance requirement. Feed expenses make up over 85 percent of total variable expenses, excluding interest expenses, in the feedlot activities.

Feed expenses directly influence ranch profitability. The prominence of feed expenses in the makeup of total operating expenses and the variable nature of feed prices are the primary reasons feed prices are stochastic in the risk model. Other variable expenses, veterinary supplies and services, pasture costs, machinery equipment repair, labor, etc. are maintained at constant levels in the model. Hired labor requirements are obtained from the fixed production and marketing plan linear programming solutions.

Prices for four feedstuffs, grain sorghum, non-legume hay, cottonseed meal (CSM), and alfalfa, are stochastic in the model. The 20 percent protein cubes fed to replacement heifers and heavy milk potential cows are assumed 72 percent grain sorghum and 28 percent CSM. The feedlot finishing ration is assumed 80 percent grain sorghum, eight percent CSM, eight percent alfalfa, and 4 percent animal fat.

Prices for 20 percent cubes and the finishing ration are driven by the prices of their component feedstuffs. The finishing ration has a fixed allocation of $3.21 per hundredweight (cwt) to cover the cost of other items in the ration, the animal fat, trace minerals, etc.

Random feed prices are generated in the same manner as livestock production (Equations 48 and 49). Price variances and covariances of the four feedstuffs (Table XLIV) were derived from historical prices (USDA, Agricultural Prices: Oklahoma Agricultural Statistics Service). Prices were truncated to avoid unrealistic price extremes. Grain sorghum prices were truncated at $2.57 and $8.11; non legume hay prices, $2.10 and $4.83; cottonseed meal prices, $10.03 and $21.17; and alfalfa prices, $3.99 and $9.44 per hundred weight. The average grain sorghum price was $5.04 per cwt; hay price, $3.23 per cwt; cottonseed meal price, $14.60 per cwt; and alfalfa price, $6.31 per cwt.

Generating Returns Estimates

Residual returns from selling weaned calves, wheat pasture stockers, fed weaned calves, and fed wheat pasture stockers were estimated in a computer spreadsheet simulation model written for the purpose. The model was verified by entering the coefficients from the LP models and replicating the LP results. The model was run for a total of 150 iterations. The results of the simulation runs are discussed in this section.

Herd size for each fixed production and marketing plan is kept constant at the optimal level from the linear programming results. Hired labor, interest, pasture, and non-feed operating expenses are also constant at the levels suggested by the LP results. For each iteration, total operating expenses equal the sum of the per cow operating expenses times the number of cows, plus the

TABLE XLIV

VARIANCE-COVARIANCE MATRIX FOR GRAIN SORGHUM, NON-LEGUME HAY, COTTONSEED MEAL, AND ALFALFA PRICES

	Grain Sorghum	Hay	CSM	Alfalfa
Grain Sorghum	1.8599	0.4998	3.2166	0.4100
Hay	0.4998	0.3885	1.0840	0.4133
CSM	3.2166	1.0840	7.6884	1.0821
Alfalfa	0.4100	0.4133	1.0821	1.7769

stocker and/or feeder operating expenses per head times the number of stockers and/or feeders retained, plus the constant cost items.

Total returns equal the sum of returns from selling cull breeding stock plus the returns of selling weaned calves, stockers, or finished cattle. Residual returns equal total returns minus total operating costs and the fixed overhead charge. The summary statistics on the simulation results for systems 1, 2, 7, 8, and 9 are presented in Table XLV. Average residual returns were, in general, lower than the returns observed in the LP analysis. Feed prices used in the LP analysis were adapted from enterprise budgets, while historic price series were used in the simulation analysis. Feed prices in the simulation model were typically higher than the prices used in the LP model.

Retained ownership increased average residual returns in all five systems considered. Selling weaned calves had the lowest average returns of the production plans considered, ranging from ($23,514) in System 7 to ($13,824) in System 9. However, the variability in returns from selling weaned calves increased as returns increased. The coefficient of variation, the standard deviation divided by the mean, is a unit-free measure of variability. It provides a basis for direct comparison of the different production and marketing plans and the different breeding systems. The coefficient of variation for selling weaned calves was the least in Systems 1 and 7 and the greatest in System 9. The range between the maximum and minimum observed returns estimates was least in System 1, $74,646, and greatest in Systems 8 and 9, $81,136 and $81,990.

A primary factor contributing to the higher returns variability in Systems 8 and 9 is price variation. An equal absolute change in price will affect total returns and thus, residual returns, more in those systems with the heaviest weaning weights. Systems 8 and 9 also had substantial weight variation.

TABLE XLV

SUMMARY STATISTICS ON SIMULATION RESULTS FOR RESIDUAL RETURNS, SYSTEMS 1, 2, 7, 8, 9

	Selling Weaned Calves	Selling Wht Past Stockers	Selling Fed W Calves	Selling Fed WP Stockers
System 1				
Average	-$22,613	-$7,796	-$4,317	$5,273
Std Dev	21,881	28,737	40,040	39,503
Max	15,112	41,795	68,581	75,533
Min	-59,534	-55,978	-78,450	-64,775
C. of Var	-0.97	-3.69	-9.27	7.49
Skewness	0.03	0.03	0.00	0.02
System 2				
Average	-19,713	-5,715	3,131	13,441
Std Dev	22,398	29,217	43,932	43,653
Max	18,759	44,644	83,573	90,866
Min	-57,301	-54,692	-78,791	-65,193
C. of Var	-1.14	-5.11	14.03	3.25
Skewness	0.03	0.04	-0.01	0.01
System 7				
Average	-23,514	-14,915	-1,366	5,476
Std Dev	23,055	29,665	42,947	41,889
Max	16,541	35,747	75,632	79,575
Min	-63,056	-65,510	-82,111	-70,398
C. of Var	-0.98	-1.99	-31.43	7.65
Skewness	0.00	0.01	-0.02	0.00
System 8				
Average	-21,038	-12,339	1,196	8,988
Std Dev	23,535	30,188	43,894	43,190
Max	19,840	39,140	80,387	84,873
Min	-61,296	-63,790	-81,427	-69,604
C. of Var	-1.12	-2.45	36.70	4.81
Skewness	0.01	0.02	-0.02	0.00
System 9				
Average	-13,994	4,105	2,465	1,961
Std Dev	23,462	30,897	43,338	47,323
Max	27,138	58,178	82,138	92,043
Min	-54,852	-48,855	-78,267	-84,278
C. of Var	-1.68	7.53	17.58	24.13
Skewness	-0.01	0.01	-0.04	-0.02

Retaining calves as wheat pasture stockers and selling them in March increased returns, on average, from $8,600 in System 7 to over $18,000 in System 9 above the returns from selling weaned calves. System 9 was the only system with positive average residual returns from selling wheat pasture stockers, $4,105. However, returns in System 9 were also the most variable. The coefficient of variation ranged from (1.99) in System 7 to 7.65 in System 9. The range between the maximum and minimum returns observations was the least in System 2, $97,773, and the greatest in System 9, $107,033. Again, the size difference and the resulting greater absolute magnitude of change in total returns with a change in price is the major factor contributing to the greater returns variability in System 9, compared to the other systems. This is also a major reason why variability is greater when selling stockers and feeders in all systems, than selling weaned calves.

Systems 7 and 8 had the lowest average returns when selling wheat pasture stockers. The impact of the price discounts associated with Brahman-cross stocker cattle on residual returns, especially in System 7, are apparent in the results.

Average returns from selling fed weaned calves ranged from ($4,317) in System 1 to $3,131 in System 2. System 9, which had the highest returns from selling weaned calves in the LP analysis, ranked second among the systems considered in the risk analysis. The price discount associated with over-sized slaughter cattle is one factor resulting in System 9's lower returns. Another factor is the expense of feeding the cattle to the heavy weights required for finishing. System 9 is more sensitive to high feed prices because of high feed requirements.

The coefficient of variation of returns from selling fed weaned calves ranged from (9.27) in System 1 to 36.7 in System 8. The range from the maximum to the minimum returns observations was greatest in System 9, $176,321, and least in System 1, $147,031.

Average returns from selling fed wheat pasture stockers were lowest in System 9, $1,961, and highest in System 2, $13,441. In Systems 1, 2, 7, and 8, selling fed wheat pasture stockers was the most profitable fixed plan considered. Relative variability of returns, as indicated by the coefficient of variation, was lower for these systems than for systems selling fed weaned calves. The coefficient of variation associated with selling fed wheat pasture stockers was higher than that of selling fed weaned calves in System 9. With the exception of System 9, the range between maximum and minimum returns observations when selling fed wheat pasture stockers was less than when selling fed weaned calves. Also, the maximum returns were higher, while the minimum returns were less negative.

The increase in variability of returns from retaining ownership is illustrated in the frequency distributions for each breeding system and each production and marketing plan presented in Table XLVI. The potential for wider swings in returns increases in the retained ownership alternatives.

The cumulative distribution functions for selling weaned calves, wheat pasture stockers, fed weaned calves, and fed wheat pasture stockers in System 2 are illustrated in Figure 14. The cumulative distributions for the other systems are similar. The cumulative distribution functions for selling wheat pasture stockers and fed wheat pasture stockers in Systems 1, 2, 7, 8, and 9 are illustrated in Figures 15 and 16.

TABLE XLVI

RESIDUAL RETURNS FREQUENCY DISTRIBUTIONS, SYSTEMS 1, 2, 7, 8, 9

	SYSTEM 1				SYSTEM 2				SYSTEM 7				SYSTEM 8				SYSTEM 9			
	Selling Weaned Calves	Selling Wht Past Stockers	Selling Fed W Calves	Selling Fed WP Stockers	Selling Weaned Calves	Selling Wht Past Stockers	Selling Fed W Calves	Selling Fed WP Stockers	Selling Weaned Calves	Selling Wht Past Stockers	Selling Fed W Calves	Selling Fed WP Stockers	Selling Weaned Calves	Selling Wht Past Stockers	Selling Fed W Calves	Selling Fed WP Stockers	Selling Weaned Calves	Selling Wht Past Stockers	Selling Fed W Calves	Selling Fed WP Stockers
($1,000)																				
Less than (80)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2
(80)-(70)	0	0	6	0	0	0	5	0	0	0	8	1	0	0	8	0	0	0	6	8
(70)-(60)	0	0	8	3	0	0	8	3	6	6	6	6	3	4	5	7	0	0	5	7
(60)-(50)	22	10	12	12	17	6	9	8	20	19	10	12	20	18	9	9	7	0	11	10
(50)-(40)	20	17	10	11	22	18	10	11	18	16	10	11	17	15	9	11	21	13	9	8
(40)-(30)	20	16	11	11	16	17	9	10	19	12	9	8	19	12	10	9	16	14	8	9
(30)-(20)	14	16	10	11	15	14	11	10	15	13	11	10	16	14	12	8	18	14	11	9
(20)-(10)	27	10	10	11	24	11	9	9	26	13	11	11	21	13	8	13	18	15	9	9
(10)-0	18	20	11	7	23	17	9	11	17	21	7	8	20	19	8	8	24	10	10	6
0-10	17	16	12	11	14	19	9	5	16	14	9	12	15	16	10	6	17	16	14	12
10-20	12	14	14	16	19	16	13	11	13	11	15	12	19	10	15	11	15	19	14	11
20-30	0	12	13	13	0	9	13	15	0	16	14	12	0	11	12	17	14	13	10	13
30-40	0	15	9	11	0	13	12	13	0	9	9	12	0	18	11	10	0	11	8	9
40-50	0	4	7	7	0	10	8	8	0	0	9	10	0	0	8	10	0	11	8	8
50-60	0	0	9	9	0	0	6	9	0	0	8	4	0	0	6	8	0	14	8	8
60-70	0	0	8	11	0	0	8	8	0	0	6	12	0	0	10	8	0	0	8	8
70-80	0	0	0	6	0	0	7	8	0	0	7	9	0	0	7	8	0	0	8	7
Greater than 80	0	0	0	0	0	0	4	11	0	0	0	0	0	0	1	7	0	0	1	6

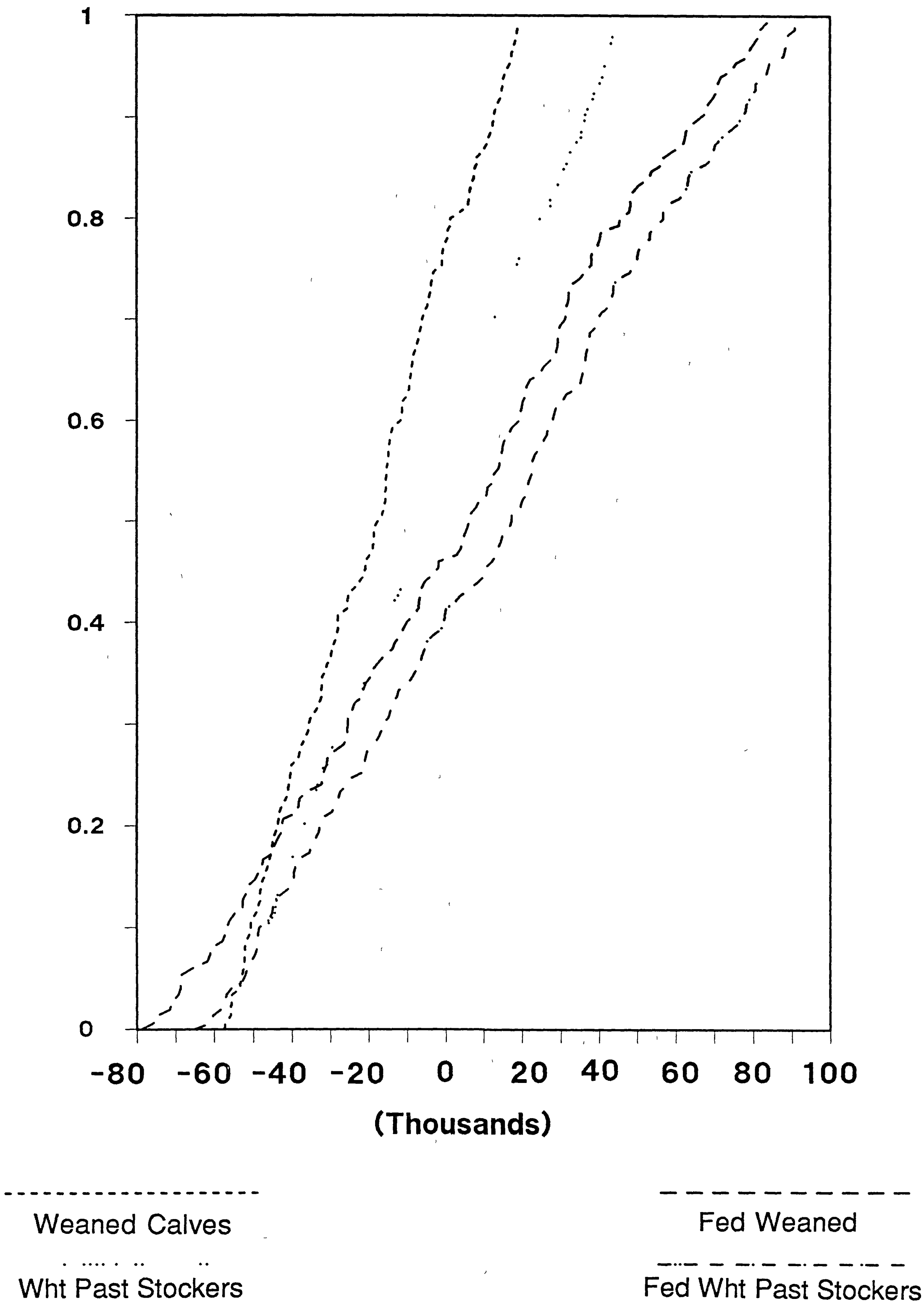


Figure 14. Cumulative Distribution Functions for the Production and Marketing Plans in System 2

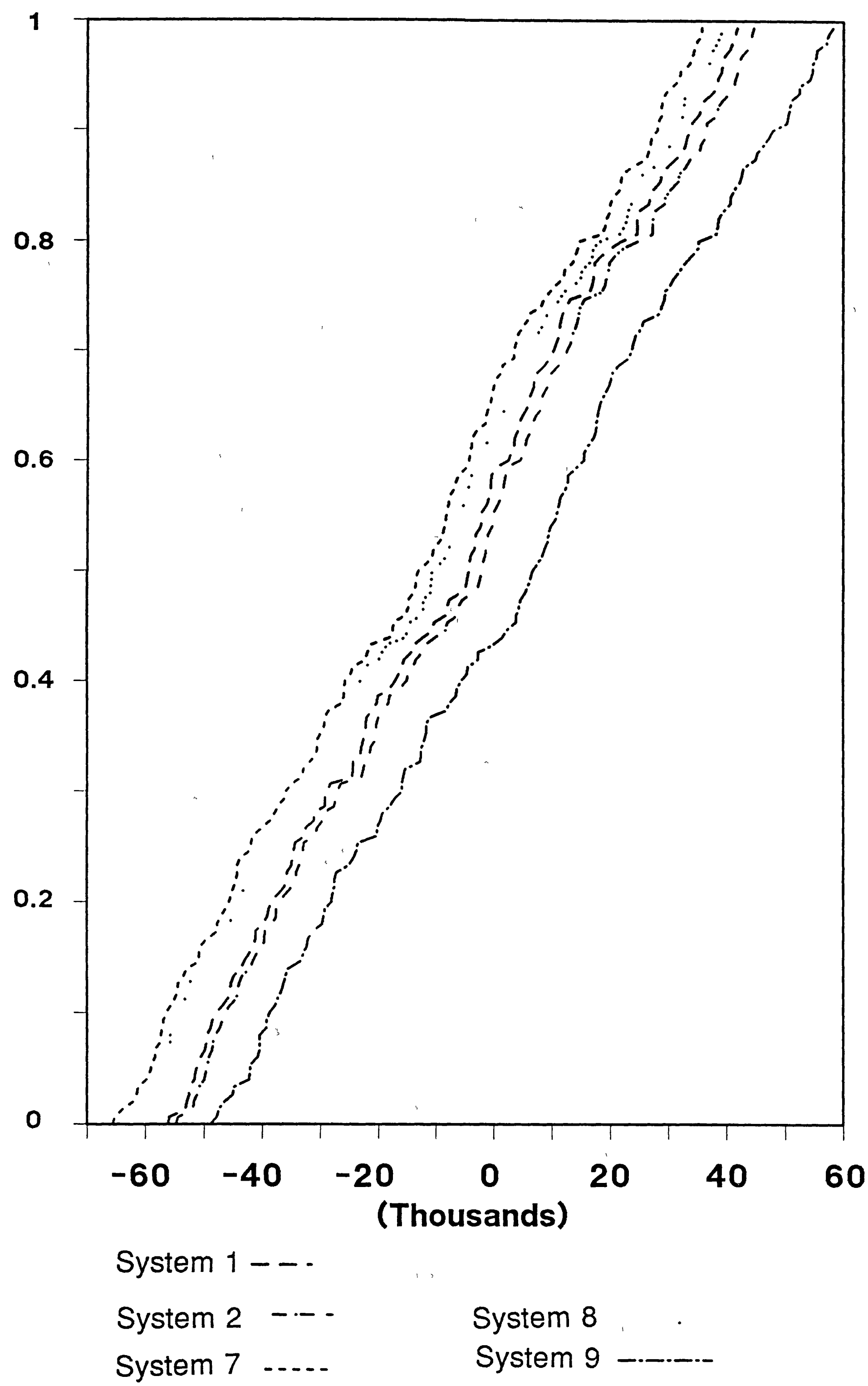


Figure 15. Cumulative Distribution Functions for Selling Wheat Pasture Stockers, Systems 1, 2, 7, 8, 9

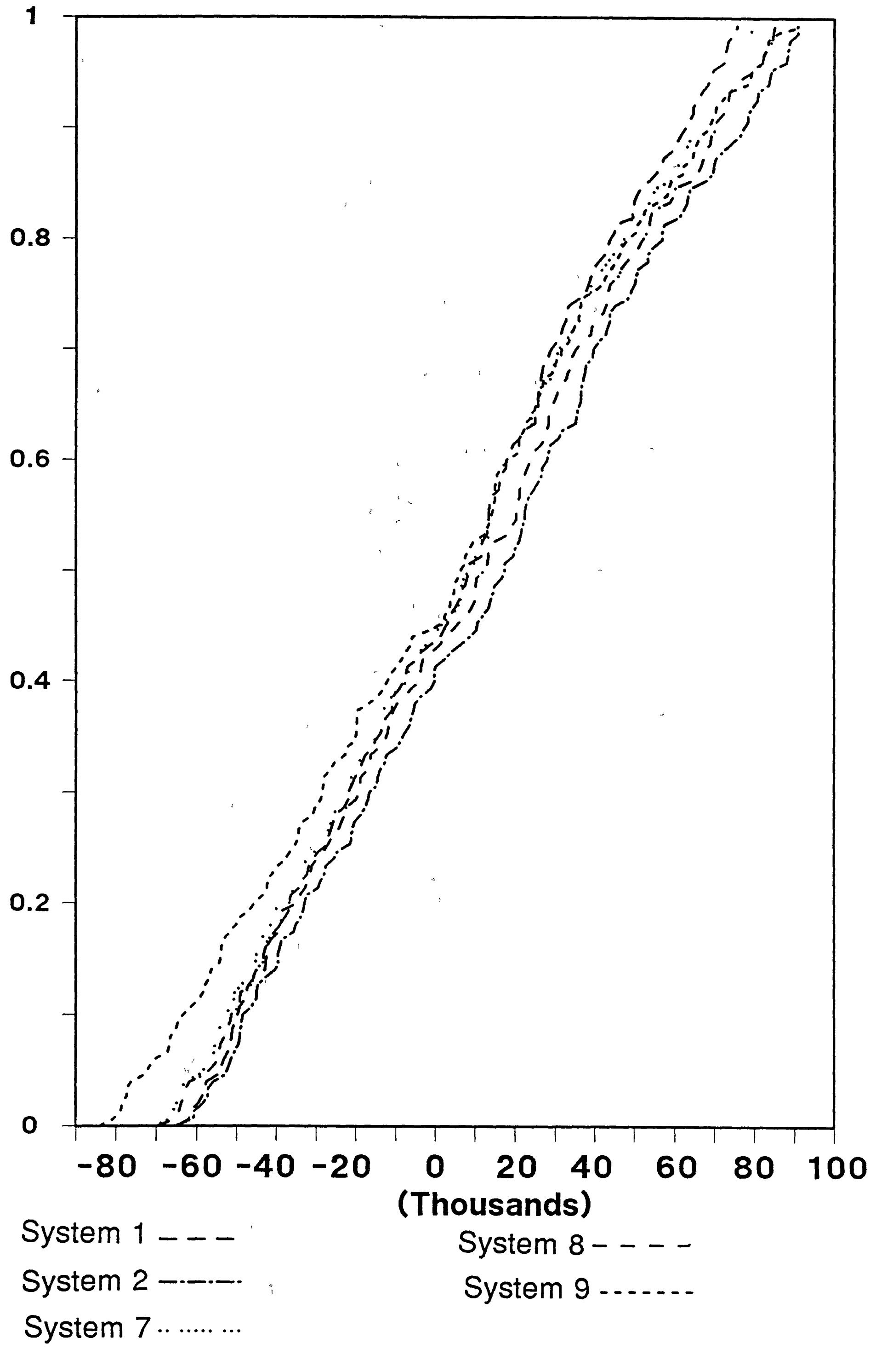


Figure 16. Cumulative Distribution Functions for Selling Fed Wheat Pasture Stockers, Systems 1, 2, 7, 8, 9

Ranking Breeding Systems and Production Plans

Stochastic dominance efficiency criteria are used to provide a partial ordering of the alternative breeding systems and fixed production and marketing plans. Using stochastic dominance to select the most efficient strategies relies on comparing cumulative probability distributions of possible returns for each strategy (Williams 1988).

An efficiency criterion is a decision rule that provides a partial ordering of choices for decision makers whose preferences conform to a specified set of conditions (King and Robison 1981). An efficiency criterion divides the decision alternatives into two mutually exclusive sets: an efficient set and an inefficient set. The efficient set contains the preferred choice of every individual whose preferences conform to the specified conditions (King and Robison 1984).

Three efficiency criteria: first degree stochastic dominance, second degree stochastic dominance, and stochastic dominance with respect to a function, are discussed and applied to the problem of selecting among alternative breeding systems and production plans in this section. The results of applying each criterion are presented following a brief discussion of that criterion. The stochastic dominance results are obtained using Cochran and Raskin's (1988) generalized stochastic dominance program.

The stochastic dominance analysis is conducted using two approaches. First, selection is among production and marketing plans, given a breeding system. Second, selection is among breeding systems, given a production plan.

First Degree Stochastic Dominance

First degree stochastic dominance (FSD), the simplest efficiency criterion, holds for all decision makers who prefer more to less; those who have positive marginal utility for the performance measure under consideration (returns, in this instance) (King and Robison 1981).

Under FSD, an alternative with an outcome distribution defined by cumulative distribution function F(y) is preferred to a second alternative with cumulative distribution function G(y) if

$$F(y) \leq G(y) \tag{51}$$

for all possible values of y and if the inequality is strict for some value of y. Graphically, the FSD criterion requires that the cumulative of the dominant distribution never lie above the cumulative of the dominated distribution (King and Robison 1984).

Because FSD is the least restrictive criterion, it may not limit the efficient set when many alternatives must be evaluated. Other efficiency criteria are more discriminating.

The FSD efficient sets are presented in Table XLVII. In the analysis of alternative production plans, given the breeding system, four plans are considered: selling weaned calves, wheat pasture stockers, fed weaned calves, and fed weaned stockers. In Systems 1 and 2, FSD narrowed the efficient set to two alternatives, selling wheat pasture stockers and fed wheat pasture stockers. In Systems 7 and 8, only the alternative to sell fed weaned calves was eliminated from their efficient sets by FSD. Wheat pasture stockers dominated the other production alternatives in System 9.

TABLE XLVII

EFFICIENT SETS USING FIRST AND SECOND DEGREE STOCHASTIC DOMINANCE, BY PRODUCTION PLAN, GIVEN BREEDING SYSTEM AND BY BREEDING SYSTEM, GIVEN PRODUCTION PLAN[1]

	FSD Efficient Set	SSD Efficient Set
By Production Plan, Given System		
System 1	WP1, FEDWP1	WP1, FEDWP1
System 2	WP2, FEDWP2	WP2, FEDWP2
System 7	WC7, WP7, FEDWP7	WC7, WP7, FEDWP7
System 8	WC8, WP8, FEDWP8	WC8, WP8, FEDWP8
System 9	WP9	WP9
By System, Given Production Plan		
Selling Weaned Calves	WC9	WC9
Selling Wheat Pasture Stockers	WP9	WP9
Selling Fed Weaned Calves	FEDW1, FEDW2, FEDW9	FEDW1, FEDW2, FEDW9
Selling Fed Wheat Pasture Stockers	FEDWP1, FEDWP2, FEDWP9	FEDWP1, FEDWP2

[1] Number denotes breeding system.
WC = Selling weaned calves
WP = Selling wheat pasture stockers
FEDW = Selling fed weaned calves
FEDWP = Selling fed wheat pasture stockers

When analyzing crossbreeding systems, given a production plan, selection is among the five breeding systems considered in the risk analysis. System 9 was the dominant system when selling weaned calves or wheat pasture stockers. When selling fed weaned calves and fed wheat pasture stockers, the efficient set consisted of Systems 1, 2, and 9. Systems 7 and 8 were dominated by the other systems in FSD.

Second Degree Stochastic Dominance

Second degree stochastic dominance (SSD) is more discriminating than FSD, since it places an additional restriction on decision maker preferences. It requires that the decision maker's marginal utility be both positive and decreasing (King and Robison 1981). These individuals are risk averse. Under SSD, an alternative with the cumulative distribution function F(y) is preferred to a second alternative G(y) if

$$\int_{-\infty}^{y} F(y)\,dy \leq \int_{-\infty}^{y} G(y)\,dy \qquad (52)$$

for all possible values of y, and if the inequality is strict for some value of y (King and Robison 1984).

SSD is a widely used decision criterion. The assumption of risk aversion usually holds, but not in all situations. Also, even though SSD is more discriminating than FSD, it still may not effectively reduce the size of the efficient set (King and Robison 1984).

Applying SSD failed to reduce the size of the efficient sets when selecting among alternative production plans, given the breeding system (Table XLVII). SSD did not reduce the number of systems in the efficient set, when selecting among breeding systems selling fed weaned calves. System 9 was eliminated from the FSD efficient set for selling fed wheat pasture stockers by SSD.

Stochastic Dominance with Respect to a Function

Stochastic dominance with respect to a function (SDWRF) is the most flexible of the commonly-used decision criteria. It is an efficiency criterion which orders uncertain choices for decision makers whose absolute risk-aversion functions lie between specified bounds. The absolute risk-aversion function (Pratt 1964; Arrow 1971), r(y), is defined as

$$r(y) = -u''(y)/u'(y) \tag{53}$$

where u'(y) and u"(y) are the first and second derivatives of a von Neumann-Morgenstern utility function, u(y) (King and Robison 1981).

The SDWRF solution procedure requires the identification of a utility function u_0 (y) which minimizes

$$\int_{-\infty}^{\infty} [G(y) - F(y)]\, u'(y)\, dy \tag{54}$$

subject to the constraint

$$r_1(y) \leq r(y) \leq r_2(y) \tag{55}$$

for all y. The expression in Equation (54) equals the difference between the expected utilities of outcome distributions F(y) and G(y). If, for a given class of decision makers, the minimum of this difference is positive, F(y) is unanimously preferred to G(y), since this implies that the expected utility of F(y) is always greater than that of G(y). If the minimum is zero, it is possible for an individual to be indifferent between the two alternatives, and they cannot be ordered. Should the minimum be negative, F(y) cannot be said to be unanimously preferred to G(y). In this case, the expression

$$\int_{-\infty}^{\infty} [F(y) - G(y)]\, u'(y)\, dy \tag{56}$$

is minimized subject to Equation (55) to determine if G(y) is unanimously preferred to F(y) (King and Robison 1981, p. 512).

SDWRF is a generalized version of FSD and SSD (Cochran et al. 1985). In FSD, the bounds on the absolute risk-aversion functions are positive and negative infinity. In SSD, the bounds are zero and positive infinity.

Five arbitrarily assumed absolute risk-aversion coefficient intervals are used in the SDWRF analysis. The selected intervals were based on work reported in the literature (Cochran 1986; Williams 1988). The intervals include: strongly risk-averse, 0.0003 to 0.0006; moderately risk-averse, 0.0001 to 0.0003; risk-neutral, -0.0001 to 0.0001; moderately risk-preferring, -0.0003 to -0.0001; and strongly risk-preferring, -0.0006 to -0.0003.

Selecting Among Plans, Given a Breeding System. Results of the SDRWF analysis of alternative production and marketing plans, given a breeding system, are presented in Table XLVIII. For strongly risk-averse decision makers, those with absolute risk-aversion coefficients between 0.003 and 0.006, wheat pasture stockers was the dominant production plan in Systems 1, 2, and 9. Selling weaned calves dominated the feedlot activities in Systems 1, 2, and 9.

For strongly risk-averse decision makers, selling weaned calves dominated in Systems 7 and 8. The wheat pasture alternative dominated the feedlot activities in these two systems. In all except System 9, fed wheat pasture stockers dominated fed weaned calves.

Wheat pasture stockers was also the dominant alternative for moderately risk-averse decision makers. However, with the decrease in risk aversion, the

TABLE XLVIII

PAIRWISE COMPARISONS OF FIXED PRODUCTION AND MARKETING PLANS[1], GIVEN CROSSBREEDING SYSTEM, USING STOCHASTIC DOMINANCE WITH RESPECT TO A FUNCTION, SYSTEMS 1, 2, 7, 8, 9[2]

	Strongly Risk Averse				Moderately Risk Averse				Risk Neutral				Moderately Risk Preferring				Strongly Risk Preferring			
	R1=0.0003		R2=0.0006		R1=0.0001		R2=0.0003		R1=-0.0001		R2=0.0001		R1=-0.0001		R2=-0.0003		R1=-0.0003		R2=-0.0006	
System 1	WC1	WP1	FEDW1	FEDWP1	WC1	WP1	FEDW1	FEDWP1	WC1	WP1	FEDW1	FEDWP1	WC1	WP1	FEDW1	FEDWP1	WC1	WP1	FEDW1	FEDWP1
WC1	--	0	1	1	--	0	1	?	--	0	?	0	--	0	0	0	--	0	0	0
WP1	1	--	1	1	1	--	1	1	1	--	?	?	1	--	0	0	1	--	0	0
FEDW1	0	0	--	0	0	0	--	0	?	?	--	0	1	1	--	0	1	1	--	0
FEDWP1	0	0	1	--	?	0	1	--	1	?	1	--	1	1	1	--	1	1	1	--
System 2	WC2	WP2	FEDW2	FEDWP2	WC2	WP2	FEDW2	FEDWP2	WC2	WP2	FEDW2	FEDWP2	WC2	WP2	FEDW2	FEDWP2	WC2	WP2	FEDW2	FEDWP2
WC2	--	0	1	1	--	0	1	?	--	0	?	0	--	0	0	0	--	0	0	0
WP2	1	--	1	1	1	--	1	1	1	--	?	?	1	--	0	0	1	--	0	0
FEDW2	0	0	--	0	0	0	--	0	?	?	--	0	1	1	--	0	1	1	--	0
FEDWP2	0	0	1	--	?	0	1	--	1	?	1	--	1	1	1	--	1	1	1	--
System 7	WC7	WP7	FEDW7	FEDWP7	WC7	WP7	FEDW7	FEDWP7	WC7	WP7	FEDW7	FEDWP7	WC7	WP7	FEDW7	FEDWP7	WC7	WP7	FEDW7	FEDWP7
WC7	--	1	1	1	--	1	1	?	--	?	?	0	--	0	0	0	--	0	0	0
WP7	0	--	1	1	0	--	1	?	?	--	?	0	1	--	0	0	1	--	0	0
FEDW7	0	0	--	0	0	0	--	0	?	?	--	0	1	1	--	0	1	1	--	0
FEDWP7	0	0	1	--	?	?	1	--	1	1	1	--	1	1	1	--	1	1	1	--
System 8	WC8	WP8	FEDW8	FEDWP8	WC8	WP8	FEDW8	FEDWP8	WC8	WP8	FEDW8	FEDWP8	WC8	WP8	FEDW8	FEDWP8	WC8	WP8	FEDW8	FEDWP8
WC8	--	1	1	1	--	1	1	?	--	?	?	0	--	0	0	0	--	0	0	0
WP8	0	--	1	1	0	--	1	?	?	--	?	0	1	--	0	0	1	--	0	0
FEDW8	0	0	--	0	0	0	--	0	?	?	--	0	1	1	--	0	1	1	--	0
FEDWP8	0	0	1	--	?	?	1	--	1	1	1	--	1	1	1	--	1	1	1	--
System 9	WC9	WP9	FEDW9	FEDWP9	WC9	WP9	FEDW9	FEDWP9	WC9	WP9	FEDW9	FEDWP9	WC9	WP9	FEDW9	FEDWP9	WC9	WP9	FEDW9	FEDWP9
WC9	--	0	1	1	--	0	1	1	--	0	?	?	--	0	0	0	--	0	0	0
WP9	1	--	1	1	1	--	1	1	1	--	?	?	1	--	0	0	1	--	0	0
FEDW9	0	0	--	1	0	0	--	1	?	?	--	?	1	1	--	0	1	1	--	0
FEDWP9	0	0	0	--	0	0	0	--	?	?	?	--	1	1	1	--	1	1	1	--

[1] For an explanation of notation, refer to Table XLVII

[2] A "1" indicates that the distribution in the row dominates the distribution in the column
A "0" indicates that the distribution in the row is dominated by the distribution in the column
A "?" indicates no dominance for either distribution

decision maker became indifferent between selling weaned calves and fed wheat pasture stockers in all systems. Additionally, the producer became indifferent between selling wheat pasture stockers and fed wheat pasture stockers in Systems 7 and 8. Selling weaned calves dominated selling wheat pasture stockers and fed weaned steers in Systems 7 and 8. System 9's ranking of alternatives was identical for moderately risk-averse and strongly risk-averse decision makers.

The risk-neutral decision maker is indifferent between more pairs of alternative than risk-averse or risk-preferring decision makers. No alternative dominated all others in Systems 1, 2, and 9, while selling fed wheat pasture stockers dominated in Systems 7 and 8. Apart from the dominance of fed wheat pasture stockers in Systems 7 and 8, no ranking of alternatives occurred. In Systems 1 and 2, wheat pasture stockers and fed wheat pasture stockers dominated fed weaned calves. In System 9, the only ranking to occur was the dominance of wheat pasture stockers over weaned calves.

Fed wheat pasture stockers was the dominant alternative in all systems for moderately and strongly risk-preferring decision makers. Selling fed weaned calves dominated wheat pasture stockers and weaned calves; and wheat pasture stockers dominated weaned calves in all systems for risk-preferring decision makers.

Selecting Among Systems, Given a Production Plan. Results of the SDRWF analysis of alternative breeding systems, given a production and marketing plan, are presented in Table XLIX. Selling weaned calves and wheat pasture stockers in System 9 dominated all other systems for all classes of decision makers. System 2 dominated the other systems (except System 9) when selling wheat pasture stockers for all classes of decision makers and

TABLE XLIX

PAIRWISE COMPARISONS OF CROSSBREEDING SYSTEMS[1], GIVEN PRODUCTION PLANS, USING STOCHASTIC DOMINANCE WITH RESPECT TO A FUNCTION, SYSTEMS 1, 2, 7, 8, 9[2]

	Strongly Risk Averse R1=0 0003 R2=0.0006					Moderately Risk Averse R1=0 0001 R2=0 0003					Risk Neutral R1=-0 0001 R2=0 0001					Moderately Risk Preferring R1=-0 0001 R2=-0 0003					Strongly Risk Preferring R1=-0 0003 R2=-0 0006				
	Selling Weaned Calves					Selling Weaned Calves					Selling Weaned Calves					Selling Weaned Calves					Selling Weaned Calves				
	WC1	WC2	WC7	WC8	WC9	WC1	WC2	WC7	WC8	WC9	WC1	WC2	WC7	WC8	WC9	WC1	WC2	WC7	WC8	WC9	WC1	WC2	WC7	WC8	WC9
WC1	–	0	1	1	0	–	0	1	1	0	–	0	?	?	0	–	0	0	0	0	–	0	0	0	0
WC2	1	–	1	1	0	1	–	1	1	0	1	–	1	1	0	1	–	1	?	0	1	–	1	0	0
WC7	0	0	–	0	0	0	0	–	0	0	?	0	–	0	0	1	0	–	0	0	1	0	–	0	0
WC8	0	0	1	–	0	0	0	1	–	0	?	0	1	–	0	1	?	1	–	0	1	1	1	–	0
WC9	1	1	1	1	–	1	1	1	1	–	1	1	1	1	–	1	1	1	1	–	1	1	1	1	–
	Selling Wheat Pasture Stockers					Selling Wheat Pasture Stockers					Selling Wheat Pasture Stockers					Selling Wheat Pasture Stockers					Selling Wheat Pasture Stockers				
	WP1	WP2	WP7	WP8	WP9	WP1	WP2	WP7	WP8	WP9	WP1	WP2	WP7	WP8	WP9	WP1	WP2	WP7	WP8	WP9	WP1	WP2	WP7	WP8	WP9
WP1	–	0	1	1	0	–	0	1	1	0	–	0	1	1	0	–	0	1	1	0	–	0	1	1	0
WP2	1	–	1	1	0	1	–	1	1	0	1	–	1	1	0	1	–	1	1	0	1	–	1	1	0
WP7	0	0	–	0	0	0	0	–	0	0	0	0	–	0	0	0	0	–	0	0	0	0	–	0	0
WP8	0	0	1	–	0	0	0	1	–	0	0	0	1	–	0	0	0	1	–	0	0	0	1	–	0
WP9	1	1	1	1	–	1	1	1	1	–	1	1	1	1	–	1	1	1	1	–	1	1	1	1	–
	Selling Fed Weaned Calves					Selling Fed Weaned Calves					Selling Fed Weaned Calves					Selling Fed Weaned Calves					Selling Fed Weaned Calves				
	FEDW1	FEDW2	FEDW7	FEDW8	FEDW9	FEDW1	FEDW2	FEDW7	FEDW8	FEDW9	FEDW1	FEDW2	FEDW7	FEDW8	FEDW9	FEDW1	FEDW2	FEDW7	FEDW8	FEDW9	FEDW1	FEDW2	FEDW7	FEDW8	FEDW9
FEDW1	–	1	1	1	?	–	?	1	1	?	–	0	?	?	0	–	0	0	0	0	–	0	0	0	0
FEDW2	0	–	1	1	?	?	–	1	1	?	1	–	1	1	?	1	–	1	1	1	1	–	1	1	1
FEDW7	0	0	–	0	0	0	0	–	0	0	?	0	–	0	0	1	0	–	0	0	1	0	–	0	0
FEDW8	0	0	1	–	0	0	0	1	–	0	?	0	1	–	0	1	0	1	–	0	1	0	1	–	0
FEDW9	?	?	1	1	–	?	?	1	1	–	1	?	1	1	–	1	0	1	1	–	1	0	1	1	–
	Selling Fed Wheat Pasture Stockers					Selling Fed Wheat Pasture Stockers					Selling Fed Wheat Pasture Stockers					Selling Fed Wheat Pasture Stockers					Selling Fed Wheat Pasture Stockers				
	FEDWP1	FEDWP2	FEDWP7	FEDWP8	FEDWP9	FEDWP1	FEDWP2	FEDWP7	FEDWP8	FEDWP9	FEDWP1	FEDWP2	FEDWP7	FEDWP8	FEDWP9	FEDWP1	FEDWP2	FEDWP7	FEDWP8	FEDWP9	FEDWP1	FEDWP2	FEDWP7	FEDWP8	FEDWP9
FEDWP1	–	?	1	1	1	–	0	1	1	1	–	0	?	?	?	–	0	0	0	0	–	0	0	0	0
FEDWP2	?	–	1	1	1	1	–	1	1	1	1	–	1	1	1	1	–	1	1	1	1	–	1	1	1
FEDWP7	0	0	–	0	1	0	0	–	0	1	?	0	–	0	?	1	0	–	0	0	1	0	–	0	0
FEDWP8	0	0	1	–	1	0	0	1	–	1	?	0	1	–	?	1	0	1	–	0	1	0	1	–	0
FEDWP9	0	0	0	0	–	0	0	0	0	–	?	0	?	?	–	1	0	1	1	–	1	0	1	1	–

[1] For an explanation of notation, refer to Table XLVII

[2] A "1" indicates that the distribution in the row dominates the distribution in the column
A "0" indicates that the distribution in the row is dominated by the distribution in the column
A "?" indicates no dominance for either distribution

when selling weaned calves for risk-averse and risk-neutral decision makers. The ranking of systems producing wheat pasture stockers was the same for all classes of decision makers.

Selling weaned calves in System 1 dominated selling weaned calves in Systems 7 and 8 for risk-averse decision makers. Risk-neutral decision makers would be indifferent between Systems 1 and 7 and 1 and 8. Risk seekers would prefer Systems 7 and 8 over System 1. Moderately risk-preferring decision makers would select System 2 over Systems 1 and 7 and be indifferent between Systems 2 and 8 when selling weaned calves. Strongly risk-preferring individuals would prefer System 8 over the other systems, except System 9. They would also prefer System 2 over Systems 7 and 1.

No crossbreeding system was dominant when selling fed weaned calves for risk-averse and risk-neutral decision makers. Strongly risk-averse individuals would prefer System 1 over Systems 2, 7, and 8 and be indifferent between Systems 1 and 9. They would also prefer Systems 2 and 9 over Systems 7 and 8 and be indifferent between Systems 2 and 9. Moderately risk-averse decision makers would be indifferent between Systems 1 and 2, as well as between Systems 1 and 9 and 2 and 9. Risk-neutral individuals would prefer to feed weaned calves from System 9 than from System 1 and be indifferent between Systems 1 and 7 and 1 and 8.

System 2 dominated all other systems while System 1 was dominated by all other systems when selling fed weaned calves by risk-preferring decision makers. System 9 also dominated Systems 7 and 8 and System 8 dominated System 7 for risk-preferring decision makers.

System 2 was the dominant system when selling fed wheat pasture stockers for all classes of decision makers, except strongly risk-averse producers, who were indifferent between Systems 1 and 2. System 1 was preferred over Systems 7, 8, and 9 by risk-averse decision makers. System 9 was dominated by all systems for risk-averse decision makers. Risk-neutral decision makers would be indifferent between Systems 1 and 7, 1 and 8, 1 and 9, 7 and 9, and 8 and 9.

Risk-preferring decision makers would prefer System 2 over all systems when selling fed wheat pasture stockers. They would also prefer System 9 over Systems 1, 7, and 8. System 8 would be preferred over Systems 1 and 7 and System 7 over System 1 for risk-preferring individuals.

The stochastic dominance with respect to a function analysis confirms producer behavior observed in the marketplace. Despite the higher expected returns from retaining ownership through the feedlot, many cow-calf producers choose to sell their calves at weaning or as wheat pasture stockers. This analysis showed those alternatives to be preferred by risk-averse decision makers.

Conversely, many producers do retain ownership through the feedlot, the preferred choice for risk seekers. Risk seekers attempt to capture the large payoffs, with little regard for the potential of greater losses. The feedlot activities analyzed in this study had larger payoffs than selling weaned calves or wheat pasture stockers. Thus, they would be preferred by risk seekers. They also recorded greater losses.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Cattle producers are frequently exhorted to increase productive efficiency to remain competitive. A key factor in increasing efficiency is the adoption and use of the most efficient production technology feasible. Perhaps the most critical technology-related decisions a cow-calf producer makes regard the cow herd. The producer must select the best breed or breed combination and breeding system for his or her operation, within the limitations imposed by available resources. Breed selection and type of breeding system determine the type of calf that will be produced.

In addition to the production-related decisions of the cow herd and breeding system, cow-calf producers also face the dilemma of when to market the calves. Should they retain ownership through the stocker and/or feeder phases? These decisions have a direct influence on the productivity, efficiency, and ultimately, the profitability of the ranch operation.

The beef breeds available and a variety of cattle breeding systems allow producers to utilize a high level of heterosis and complementarity in their herds. Many retained ownership alternatives are available to producers. Producers need factual information about alternative breeding systems and alternative production and marketing plans to assist their decision making. The major objective of this research was to provide such information. Specifically, this study compared the profitability of eleven crossbreeding systems in a whole ranch setting. Within that context, the potential impact on ranch profitability of retained ownership alternatives was explored. Also, the influence of the firm's financial position on the decision to retain ownership was evaluated.

Since producers operate in an environment characterized by much price and production uncertainty, they need information about the distribution of returns as well. Thus, the distribution of returns for selected breeding systems with retained ownership alternatives in a risky environment were generated in this study.

The objectives were addressed in two phases. First, a comparative static analysis approach was used in a perfect knowledge framework. Linear programming provided estimates of residual returns to operator labor, management, equity, and risk for the profit-maximizing ranch plans for each system, as well as residual returns of fixed production and marketing plans for selected systems. In the second phase, the risk analysis, a simulation modeling approach was used to generate a distribution of returns for selected breeding systems and ranch plans.

The Base Situation

The representative ranch for this study was assumed to be located in South-Central Oklahoma. The land resource base was selected to support a herd size of about 300 cows in a normal forage-yielding year. That herd size is sufficient to employ the owner-operator full-time in an economically viable unit and will facilitate the breeding system considered.

The base breeding system was a two-breed rotation with medium frame, medium milk breeds (Hereford and Angus). The Hereford-Angus cross was selected as the base because of its popularity and predominance as brood cows.

Animal performance estimates and resource requirements for the base cow and stocker activities were derived from enterprise budgets developed at Oklahoma State University (Walker et al. 1987). Both spring and fall calving activities were considered. Animal performance estimates and resource requirements for the base feedlot activities were developed using enterprise budgets and a feedlot animal growth simulation model (Oltjen et al. 1984).

Retained Ownership Alternatives

The retained ownership alternatives considered in the study are typical options available to Oklahoma cattle producers. Spring-born calves could be retained in three stocker activities. Two involve grazing winter wheat pasture. In the first, the stockers are removed from the wheat pasture on March 15; in the second, on May 15. The third stocker activity involves feeding the stockers a high-roughage, maintenance ration through the winter, followed by grazing on summer pasture through mid-September.

Both spring and fall-born calves can be fed from weaning. Also, the producer has the option to finish stockers coming out of each stocker activity.

Alternative Breeding Systems

Eleven crossbreeding systems were considered in the study. Both two and three-breed rotational and combined rotational-terminal sire systems were evaluated. Rather than evaluate specific breed combinations, breeds were classified by milk production potential and frame size.

In addition to the base system, other rotational systems included a two-breed rotation with medium frame, medium milk breeds; a two-breed rotation with large frame, heavy milk breeds; a two-breed rotation with large frame, light milk breeds; a three-breed rotation with two medium frame, medium milk breeds and one medium frame, heavy milk breed; and a three-breed rotation with two medium frame, medium milk breeds and Brahman. One system involved a "pre-1980s" Hereford-Angus cross cow herd to be contrasted with the larger Hereford-Angus cross of today, which was the base system.

In the combined rotational-terminal sire systems, the younger cows in the herd are kept in the rotational herd, while the older cows are bred to large frame terminal sires. Replacement heifers are produced in the rotational herd. Only the older cows are bred to large frame sires to minimize calving difficulties in younger cows. The combined rotational-terminal sire systems involved all rotational systems except the two large frame rotational crosses and the "pre-1980s" Hereford-Angus rotational cross.

Animal performance estimates for each crossbreeding system were developed using existing beef breed data within the context of theoretical relationships from the theory of animal breeding. The primary data source of breed performance data for the study was published research results from the Germ Plasm Evaluation Program at the Roman L. Hruska U.S. Meat Animal Research Center (MARC) in Clay Center, Nebraska.

Static Analysis Results

Retained Ownership

The results of the static analysis suggest a strong potential for retained ownership to increase residual returns to owned resources. Residual returns were increased over selling weaned calves, on average, in all breeding systems.

In general, the profit-maximizing ranch plans in all systems involved finishing stockers, either off wheat pasture in March, or off grazeout wheat pasture in May. The most common optimal steer activities involved grazing grazeout wheat pasture, followed by feedlot finishing. The most common optimal heifer activities involved grazing wheat pasture, followed by feedlot finishing. Feeding weaned spring-born steers or heifers was optimal a few plans.

Residual returns from fixed production and marketing plans were estimated for selected breeding systems. Selling weaned calves was the least profitable plan in most systems. Selling fall-born calves at weaning was $800 to over $3,600 less profitable than selling spring-born calves at weaning. Selling calves at weaning generated negative residual returns in all systems considered.

Selling wheat pasture stockers was the most profitable stocker production and marketing alternative considered, followed by grazeout stockers and year-round stockers. Selling wheat pasture stockers increased returns $7,840 to almost $17,000 as compared to selling spring-born calves at weaning. Selling stockers yielded negative returns in all systems considered. In several systems, selling year-round stockers generated lower returns than selling weaned spring-born calves, the only case in which returns from retaining ownership were less than returns from selling calves at weaning.

The results indicate that retained ownership through the feeder phase, on average, increases returns significantly. Selling fed wheat pasture stockers and fed grazeout stockers generated positive returns in all systems considered. Selling fed wheat pasture stockers generated returns ranging from $4,732 to $9,103, while returns from selling fed grazeout wheat pasture stockers ranged from $3,935 to $8,407.

Selling fed weaned spring-born calves generated positive returns in four systems, with returns ranging from ($1,470) to $6,059. Selling fed year-round stockers and fed weaned fall-born calves from weaning generated negative returns in all systems.

The results indicate that, on the average, retained ownership through the feeder phase is a profitable production alternative. For producers willing to assume the debt and for lenders willing and able to extend the credit necessary to finance the endeavor, retained ownership through the feeder phase appears capable of generating financing to meet requirements.

Alternative Breeding Systems

The combined Hereford-Angus rotational-terminal sire system (System 2) had the highest returns in the profit-maximizing ranch plans, followed by the combined rotational-terminal sire and rotational systems with Brahman in the rotation. The "pre-1980s" Hereford-Angus rotational system ranked fourth, followed closely by the more modern Hereford-Angus rotation system. The large frame, light milk two breed rotational system had the lowest returns; it was the only system with negative returns in the profit-maximizing ranch plans.

Residual returns in fixed production and marketing plans were estimated for the top six crossbreeding systems (excluding the "pre-1980s" Hereford-Angus rotational system). The combined Hereford-Angus rotational terminal sire system had the highest returns when selling fed wheat pasture, fed grazeout, and fed year-round stockers, and fed weaned fall-born calves.

The Brahman-cross combined rotational-terminal sire system had the second highest returns when selling fed weaned spring-born and fall-born calves and fed wheat pasture and fed grazeout stockers. Returns in the

Brahman-cross rotational system ranked third when selling fed weaned spring-born calves and fed wheat pasture and fed grazeout stockers. While the Brahman-cross systems fared well when selling finished cattle, low returns, precipitated by price discounts associated with selling Brahman-cross stocker cattle, resulted when selling weaned calves and stockers. The Brahman-cross rotational system had the lowest returns when selling-stockers and weaned calves, while the combined rotational-terminal sire system was second-lowest when selling stockers.

The large frame, heavy milk potential two breed rotation had the highest returns of the systems considered in the fixed plans when selling weaned calves, both fall- and spring-born, stockers, and fed spring-born weaned calves. This indicates that producers who do not retain ownership through the feedlot phase have incentive to produce larger calves. The impact of the price discount when selling over-sized slaughter cattle is evident in the returns of selling fed wheat pasture and grazeout stockers; the large frame rotational system had the lowest returns in these two fixed plans. The expense of feeding the cattle to such heavy weights also contributed to the lower returns.

The results indicate that the returns of the combined rotational-terminal sire systems are higher than their counterpart rotational systems. The combined system with the medium frame, medium milk two-breed rotation had the greatest increase in returns over the straight rotational cross. This indicates that the increase in returns from improved performance more than offsets the additional expenses associated with increased resource requirements.

Weaning Rate

The results of the study indicate that weaning rate is critical to the profitability of the ranch operation. Each one percent increase in the herd's weaning rate resulted in an increase in returns of over $4.00 per cow, on average. The increased returns reflect the maximum amount a producer could pay to improve his weaning rate.

The Risk Analysis

Producers have differing risk attitudes as well as differing risk bearing capabilities. As a result, they need information about the full range of possible returns. A simulation model was constructed to generate a distribution of returns for representative fixed production and marketing plans for selected breeding systems. The production plans considered included selling weaned calves, wheat pasture stockers, fed weaned calves, and fed wheat pasture stockers.

The variability represented in the simulation model is the within year variability arising from uncertain production and uncertain input and output prices. Animal performance, input prices, and output prices were considered stochastic and independent in the model. The key animal performance variables were weaning rate, weaning weight, pasture average daily gain, feedlot average daily gain, and feedlot feed efficiency. Input price variables included prices of the primary feedstuffs, grain sorghum, cottonseed meal, alfalfa, and non-legume hay. Output prices included prices for each sex and weight class of livestock sold.

Residual returns from selling weaned calves, wheat pasture stockers, fed weaned calves, and fed wheat pasture stockers were estimated in the simulation model. The model was run for 150 iterations. The average returns for the fixed plans follow the same pattern as the returns estimated by the linear programming model. Selling weaned calves was the least profitable plan. Returns were increased by retaining ownership, especially through finishing. Selling fed wheat pasture stockers was most profitable in all systems except the large frame, heavy milk potential two-breed rotation. Selling fed wheat pasture stockers generated positive average returns in all systems, while selling fed weaned calves had positive average returns in three systems. Only the large frame rotational cross had positive average returns from selling wheat pasture stockers. Average returns from selling weaned calves were negative for all systems.

Variability of returns increased as the calves were retained longer. In all systems the coefficient of variation (in absolute value) was higher when selling wheat pasture stockers than when selling weaned calves. The coefficient of variation was higher in the feedlot activities than when selling stockers, except in the combined rotational-terminal sire system with medium frame, medium milk potential breeds. In this system, the coefficient of variation from selling fed wheat pasture stockers was slightly lower than that of selling stockers.

Stochastic dominance criteria were used to provide a partial ordering of the alternative breeding systems and fixed production and marketing plans. The stochastic dominance analysis was conducted using two approaches. First, selection was among production and marketing plans, given a breeding system. Second, selection was among systems, given a production plan.

The stochastic dominance with respect to a function analysis confirms producer behavior observed in the marketplace. Despite higher expected returns from retaining ownership through the feedlot, many cow-calf producers choose to sell their calves at weaning or as wheat pasture stockers. This analysis showed sale at weaning or as wheat pasture stockers to be preferred by risk-averse decision makers.

Conversely, many producers do retain ownership through the feedlot. This analysis showed retention through the feedlot to be preferred by risk-seeking decision makers. Risk seekers attempt to capture the large payoff, with little regard for the potential of greater losses. The feedlot activities considered in this study had larger payoffs than selling weaned calves or wheat pasture stockers. Thus, they would be preferred by risk seekers. The feedlot alternatives also recorded greater losses.

Conclusions

The results of this study illustrate the potential retained ownership has for improving residual returns to the ranch's owned resources. Selling calves at weaning was the least profitable production and marketing plan. Retaining calves as stockers increased returns somewhat, as compared to selling weaned calves. Retention through the feeder phase has the most potential of increasing expected returns. The optimal ranch plans for all systems but one involved retention through the feeder phase. Variability of returns increases as calves are retained longer.

Even though expected returns from selling weaned calves and stockers were negative in this study, these enterprises are common in beef production. How can an operation survive with negative residual returns? The operation may be subsidized by off-farm income. Family living expenses may be lower than what was assumed in this study ($16,000). Also, individual operations may be more profitable than the one depicted in this study.

Risk-averse producers would prefer to sell calves at weaning or as wheat pasture stockers, to avoid the potential for substantial losses associated with feeding cattle. Risk-seeking producers, on the other hand, would retain cattle as wheat pasture stockers, then finish them, in an attempt to capture potentially high returns from feeding cattle.

According to these results, the profit-maximizing breeding system was a combined rotational-terminal sire system with two medium frame, medium milk potential breeds. The combined rotational-terminal sire system with Brahman ranked second. The Brahman rotational cross cows had the highest weaning rate, a major contributor to their superior performance. The results demonstrate the importance of retaining ownership of Brahman cross cattle through the feeder phase. The Brahman rotational system ranked last when selling the calves as stockers, due to the price discounts for stockers with a high proportion of Brahman breeding.

The results also indicate that producers selling weaned calves or stockers should produce heavy calves from large frame, heavy milk breeds. The large frame, heavy milk potential, two breed rotation had the highest returns when selling weaned calves and stockers.

In general, the combined rotational-terminal sire systems had higher residual returns than their straight rotational counterparts. However in some instances, the increase was insignificant. Individual producers must decide if the increase in returns from the more complex combined system warrant the additional managerial requirements associated with it.

Suggestions for Further Research

A number of extensions of this research are needed. Alternative marketing strategies, hedging, options, forward contracting, for example, should be explored as ways to decrease risks from retaining cattle. Also, the effects of changing cattle-feed price relationships should be evaluated. In a similar vein, the effects of timing in the cattle cycle, especially with regard to cattle price relationships, on the optimal ranch plan should be determined. If such a study reveals that flexibility in retention is optimal, the income tax ramifications of a flexible production and marketing plan need to be evaluated.

The next step needed in the risk analysis is to use the stochastic within-year simulation model as the basis for building a dynamic simulation model to evaluate economic performance, specifically financial performance, across time. In this context, the impact of retained ownership and choice of breeding system on ranch survival could be explored.

The simulation model could be modified to explicitly incorporate variation in resource availability and quality (especially forage). As designed, the price mechanism in the model assumes constant price spreads between 400 to 500 pound steers and the other classes of cattle sold. The price spread could also be stochastic to more accurately portray the risk producers face when retaining ownership. Also, the simulation model could be used to generate a deviations matrix for a MOTAD type model, which could then be used to generate a risk efficient frontier of ranch plans.

BIBLIOGRAPHY

Aderogba, K. A.; G. M. Sullivan, N. R. Martin, and R. R. Harris. "Feeding Cattle to Slaughter Weight Can Reduce Producers' Risks." Highlights of Agricultural Research. Vol. 32, No. 1. Alabama Agricultural Experiment Station, Auburn University. Spring 1985, p. 18.

Anderson, T. W. An Introduction to Multivariate Statistical Analysis. New York: John Wiley and Sons, Inc. 1958.

Angirasa, Adita K., C. Richard Shumway, T. C. Nelsen, and T. C. Cartwright. "Integration, Risk, and Supply Response: A Simulation and Linear Programming Analysis of an East Texas Cow-calf Producer." Southern Journal Agricultural Economics, 13(1):89-98, 1981.

Araji, Ahmed A. "The Effect of Vertical Integration on the Production Efficiency of Beef Cattle Operations." American Journal Agricultural Economics, 58(1):101-104, 1976.

Arrow, Kenneth J. Essays in the Theory of Risk Bearing. Chicago: Markham Publishing Co. 1971.

Barry, Peter J., John A. Hopkin, and C. B. Baker. Financial Management in Agriculture. 4th Ed. Danville, IL: The Interstate Printers and Publishers, Inc. 1988.

Beattie, Bruce R. and C. Robert Taylor. The Economics of Production. New York: John Wiley & Sons. 1985.

Bennett, Gary L. "Periodic Rotational Crosses. I. Breed and Heterosis Utilization." Journal Animal Science, 65:1471-1476, 1987a.

Bennett, Gary L. "Periodic Rotational Crosses. II. Optimizing Breed and Heterosis Use." Journal Animal Science, 65:1477-1486, 1987b.

Black, William E. and James E. Haskell. "Vertical Integration Through Ownership." No. 7 in the Series, Marketing Alternatives for Agriculture. Ithaca, NY: Cooperative Extension Service, Cornell University. January 1977.

Blakely, Leo V. "Seasonal Price Index Update for Oklahoma Agricultural Commodities." Current Farm Economics. Selected December Issues, 1979 to 1987.

Boehlje, Michael D. and Vernon R. Eidman. Farm Management. New York: John Wiley & Sons. 1984.

Boehlje, Michael D. and Larry D. Trede. "Risk Management in Agriculture." Journal of the American Society of Farm Managers and Rural Appraisers. 41(1):20-29, 1977.

Buccola, Steven T. "An Approach to the Analysis of Feeder Cattle Price Differentials." American Journal of Agricultural Economics, 62(1):574-580, 1980.

Buchanan, David S. Personal Communication.

Buchanan, D. S. and A. C. Clutter. Animal Breeding: Principles and Applications. 2nd Ed. Stillwater: Oklahoma, Board of Regents, Oklahoma State University. 1989.

Carmon, J. L., H. A. Stewart, C. C. Cockerham, and R. E. Comstock. "Prediction Equations for Rotational Crossbreeding." Journal of Animal Science. 15:930, 1956.

Cartwright, T. C. "Selection Criteria for Beef Cattle for the Future." Journal of Animal Science. 30:706-711, 1970.

Cartwright, T.C., H. A. Fitzhugh, and C. R. Long. "Systems Analysis of Sources of Genetic and Environmental Variation in Efficiency of Beef Production: Mating Plans." Journal of Animal Science. 40(3):433-443, 1975.

Cochran, Mark J. "Stochastic Dominance: The State of the Art in Agricultural Economics." Risk Analysis for Agricultural Production Firms: Implications for Managers, Policymakers, and Researchers. Proceedings of a Seminar Sponsored by Southern Regional Project S-180. Pullman, WA: Department of Agricultural Economics, Washington State University. August 1986.

Cochran, Mark J. and Rob Raskin. "A User's Guide to Generalized Stochastic Dominance Program for IBM PC Version GSD 2.1." Staff Paper SPO688. Fayetteville, AR: Department of Agricultural Economics, University of Arkansas. 1988.

Cochran, Mark J., Lindon J. Robison, and Weldon Lodwick. "Improving the Efficiency of Stochastic Dominance Techniques Using Convex Set Stochastic Dominance." American Journal of Agricultural Economics. 67(2):289-295, 1985.

Crockett, J. R., M. Koger, and D. E. Franke. "Rotational Crossbreeding of Beef Cattle: Reproduction by Generation." <u>Journal of Animal Science</u>. 46:1163-1169, 1978a.

Crockett, J. R., M. Koger, and D. E. Franke. "Rotational Crossbreeding of Beef Cattle: Preweaning Traits by Generation." <u>Journal of Animal Science</u>. 46:1163-1169, 1978a.

Cundiff, L. V. "Crossbreeding Research at the U.S. Meat Animal Research Center with Beef Cattle." Proceedings of the Working Symposium on Breed Evaluation and Crossing Experiments with Farm Animals. Zeist. 1974.

Cundiff, L. V. "Experimental Results on Crossbreeding Cattle for Beef Production." <u>Journal of Animal Science</u>. 30:694-705, 1970.

Cundiff, L. V. and K. E. Gregory. <u>Beef Cattle Breeding</u>. Agricultural Information Bulletin No. 286. USDA. November 1977 (Revised).

Cundiff, L. V., K. E. Gregory, Robert M. Koch, and Gordon E. Dickerson. "Genetic Diversity Among Cattle Breeds and Its Use to Increase Beef Production Efficiency in a Temperate Environment." Proceedings, Third World Congress on Genetics Applied to Livestock Production. IX:271-282, 1986a.

Cundiff, L. V., R. M. Koch, K. E. Gregory, and G. M. Smith. "Characterization of Biological Types of Cattle - Cycle II. IV. Postweaning Growth and Feed Efficiency of Steers." <u>Journal of Animal Science</u>. 53(2):332-346, 1981.

Cundiff, L. V., R. M. Koch, and K. E. Gregory. "Characterization of Biological Types of Cattle (Cycle III). IV. Postweaning Growth and Feed Efficiency." <u>Journal of Animal Science</u>. 58(2):312-323, 1984.

Cundiff, L. V., M. D. MacNeil, K. E. Gregory, and R M. Koch. "Between- and Within-Breed Genetic Analysis of Calving Traits and Survival to Weaning in Beef Cattle." <u>Journal of Animal Science</u>. 63:27-33, 1986b.

Dickerson, G. "Experimental Approaches in Utilizing Breed Resources." <u>Animal Breeding Abstract</u>. 37:191-202, 1969.

Dickerson, G. "Inbreeding and Heterosis in Animals." Animal Breeding and Genetics Symposium, pp. 54-77, 1972.

Eidman, Vernon R. "Planning an Integrated Approach to Farm Risk Management." <u>Journal of Agribusiness</u>. 3(1):11-16, 1985.

Ensminger, M. E. <u>Beef Cattle Science</u>. 6th Ed. Danville, IL: The Interstate Printers & Publishers, Inc. 1987.

Faminow, Merle D. and Russell L. Gum. "Feeder Cattle Price Differentials in Arizona Auction Markets." Western Journal of Agricultural Economics. 11(2):156-163, 1986.

Ford, M. J., D. C. Clanton, and M. E. England. "Computer Simulation - Retained Ownership Profitable." 1986 Beef Cattle Report. Lincoln, NE: Agric. Exp. Station, University of Nebraska. 1985.

.anke, D. E. "Breed and Heterosis Effects of American Zebu Cattle." Journal of Animal Science. 50:1206-1214, 1980.

Gabriel, Stephen C. and C. B. Baker. "Concepts of Business and Financial Risk." American Journal of Agricultural Economics. 62(3):560-564. 1980.

Gebremeskel, Tesfaye and C. Richard Shumway. "Farm Planning and Calf Marketing Strategies for Risk Management: An Application of Linear Programming and Statistical Decision Theory." American Journal of Agricultural Economics. 61(2):363-370, 1979.

Gill, Donald; Kent Barnes, Clem Ward, and Keith Lusby. "Rancher's Guide to Custom Cattle Feeding." O.S.U. Extension Facts, No. 3022. Stillwater, Oklahoma: Cooperative Extension Service, Oklahoma State University, 1986.

Gilliam, Henry C, Jr. The U.S. Beef Cow-Calf Industry. Agricultural Economic Report No. 515. Economics Research Service, U.S. Department of Agriculture. 1984.

Gray, F. H. and H. M. Galloway. Soils of Oklahoma. O.S.U. Miscellaneous Publication No. 56. Stillwater, Oklahoma. Oklahoma State University. July 1959.

Gregory, K. E., J. D. Crouse, R. M. Koch, D. B. Laster, L. V Cundiff, and G. M. Smith. "Heterosis and Breed Maternal and Transmitted Effects in Beef Cattle: IV. Carcass Traits of Steers." Journal of Animal Science. 47(5):1063-1079, 1978a.

Gregory, K. E. and L. V. Cundiff. "Crossbreeding in Beef Cattle: Evaluation of Systems." Journal of Animal Science. 51:1224-1242, 1980.

Gregory, K. E., L. V Cundiff, R. M. Koch, D. B. Laster, and G. M.Smith. "Heterosis and Breed Maternal and Transmitted Effects in Beef Cattle: I. Preweaning Traits." Journal of Animal Science. 47(5):1031-1041, 1978b.

Gregory, K. E., L. V Cundiff, G. M. Smith, D. B. Laster, and H. A. Fitzhugh. "Characterization of Biological Types of Cattle - Cycle II: I. Birth and Weaning Weights." Journal of Animal Science. 47(5):1022-1030, 1978c.

Gregory, K. E., D. D. Dearborn, L. V Cundiff, and R. M. Koch. "Maternal Heterosis and Grandmaternal Effects in Beef Cattle: Postweaning Growth and Carcass Traits." Journal of Animal Science. 65:1180-1194, 1987.

Gregory, K. E., D. B. Laster, L. V Cundiff, G. M. Smith, and R. M. Koch. "Characterization of Biological Types of Cattle - Cycle III: II. Growth Rate and Puberty in Females." Journal of Animal Science. 49(2):461-471, 1979.

Gregory, K. E., L. A. Swiger, R. M. Koch, L. J. Sumption, J. E. Ingalls, W. W. Rowden, and J. A. Rothlisberger. "Heterosis Effects on Growth Rate of Heifers." Journal of Animal Science. 25:290-298, 1966.

Halter, Albert N. and Gerald W. Dean. Decisions Under Uncertainty. Cincinnati: South-Western Publishing Co. 1971.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning Under Uncertainty." American Journal of Agricultural Economics. 53(1):53-62, 1971.

Hazell, P. B. R. and R. D. Norton. Mathematical Programming for Economic Analysis in Agriculture. New York: Macmillan Publishing Co. 1986.

Heady, Earl O. "Diversification in Resource Allocation and Minimization of Income Variability." Journal of Farm Economics. 34(4):482-496, 1952.

Henderson, D. R. and Robert B. Schwart, Jr. "Vertical Coordination Between Cow-calf Enterprises and Feedlots in the United States." A Research Report of the Beef Subsector Task Force Subcommittee on Vertical Coordination, NC-117. February 1977.

Hey, John D. Uncertainty in Microeconomics. New York: New York University Press. 1979.

Hicks, R. B., F. N. Owens, D. R. Gill, J. W. Oltjen, and R. P. Lake. "Daily Dry Matter Intake by Feedlot Cattle: Influence of Breed and Gender." Journal of Animal Science. 68:245-253, 1990a.

Hicks, R. B., F. N. Owens, D. R. Gill, J. W. Oltjen, and R. P. Lake. "Daily Dry Matter Intake by Feedlot Beef Steers: Influence of Initial Weight, Time on Feed and Season of Year Received in Yard." Journal of Animal Science. 68:254-265, 1990b.

Hillier, Frederick S. and Gerald J. Lieberman. Introduction to Operations Research. Third Ed. San Francisco: Holden-Day, Inc. 1980.

Johnson, D. Gale, John M. Connor, Timothy Josling, Andrew Schmitz, and G. Edward Schuh. Competitive Issues in the Beef Sector: Can Beef Compete in the 1990s? Humphrey Institute Report No. 1. Minneapolis: Hubert H. Humphrey Institute of Public Affairs, Univ. of Minn. October 1989.

Kilmer, Richard L. "Vertical Integration in Agricultural and Food Marketing." American Journal of Agricultural Economics. 68(5):1155-1160, 1986.

King, Robert P. "Operational Technique for Applied Decision Analysis Under Uncertainty." Unpublished Ph.D. Dissertation. East Lansing, Michigan. Michigan State University. 1979.

King, Robert P. and Lindon J. Robison. "An Interval Approach to Measuring Decision Maker Preferences." American Journal of Agricultural Economics. 63(3):510-520, 1981.

King, Robert P. and Lindon J. Robison. "Risk Efficiency Models." Risk Management in Agriculture. Peter J. Barry, Ed. Ames, IA: Iowa State University Press. 1984.

Koch, R. M., M. E. Dikeman, D. M. Allen, M. May, J. D. Crouse, and D. R. Campion. "Characterization of Biological Types of Cattle II. Carcass Composition, Quality, and Palatability." Journal of Animal Science. 43(1):48-62, 1976.

Koch, R. M., M. E. Dikeman, and J. D. Crouse. "Characterization of Biological Types of Cattle (Cycle III). III. Carcass Composition, Quality, and Palatability." Journal of Animal Science. 54(1):35-45, 1982.

Koch, R. M., M. E. Dikeman, Henryk Grodzk, J. D. Crouse, and L. V. Cundiff. "Individual and Maternal Genetic Effects for Beef Carcass Traits of Breeds Representing Diverse Biological Types (Cycle I). Journal of Animal Science. 57(5):1124-1132, 1983.

Koch, R. M., M. E. Dikeman, R. Jerry Lipsey, D. M. Allen, and J. D. Crouse. "Characterization of Biological Types of Cattle - Cycle II: III. Carcass Composition, Quality, and Palatability." Journal of Animal Science. 49(2):448-460, 1979.

Koch, R. M., L. A. Swiger, D. Chambers, and K. E. Gregory. "Efficiency of Feed Use in Beef Cattle." Journal of Animal Science. 22:486-494, 1963.

Kocher, Eric K. "Finite Sample Properties of Two Pretest Estimators of Distributed Lag Model Coefficients." Unpublished Ph.D. Dissertation. Stillwater, Oklahoma. Department of Agricultural Economics, Oklahoma State University. 1990.

Koger, Marvin. "Effective Crossbreeding Systems Utilizing Zebu Cattle." Journal of Animal Science. 50:1215-1220, 1980.

Kress, D. D. and T. C. Nelsen. Crossbreeding Beef Cattle for Western Range Environments. TB-88-1. Nevada Agricultural Experiment Station. Reno: University of Nevada-Reno. November 1988.

Lambert, Charles D., Mark S. McNulty, Orlen C. Grunewald, and Larry R. Corah. "An Analysis of Feeder Cattle Price Differentials." Journal of Agribusiness. 5(1):9-23, 1989.

Lambert, Chuck and Michael B. Sands. Kansas Steer Futurities - Summary of Nine Years of Retained Ownership. Bulletin MF-712. Manhattan: Cooperative Extension Service, Kansas State University. 1984.

Lambert, David K. "Calf Retention and Production Decisions Over Time." Western Journal of Agricultural Economics. 14(1):9-19, 1989.

Lasley, John F. Genetics of Livestock Improvement. Fourth Ed. Englewood Cliffs, NJ: Prentice Hall, Inc. 1987.

Lemenager, R. P., L. A. Nelson, and K. S. Hendrix. "Influence of Cow Size and Breed Type on Energy Requirements." Journal of Animal Science. 51:566-576, 1980.

Logan, Samuel H. "A Conceptual Framework for Analyzing Economies of Vertical Integration." American Journal of Agricultural Economics. 51(4):834-848, 1969.

Long, Charles R. "Crossbreeding for Beef Production: Experimental Results." Journal of Animal Science. 51:1197-1223, 1980.

MacNeil, M. D., L. V. Cundiff, K. E. Gregory, and Robert M. Koch. "Evaluation of Crossbreeding Systems for Preweaning Traits in Beef Cattle." Proceedings, Third World Congress on Genetics Applied to Livestock Production. IX:353-358, 1986.

Mapp, Harry P., Jr.; Michael L. Hardin, Odell L. Walker, and Tillak Persaud. "Analysis of Risk Management Strategies for Agricultural Producers." American Journal of Agricultural Economics. 61(5):1071-1077, 1979.

Marlowe, T. J., A. L. Eller, Jr., J. A. Gaines, and D. R. Notter. "Guidelines on Crossbreeding for Beef Production." 1978-1979 Livestock Research Report. Research Div. Report No. 175. Blacksburg: Virginia Polytechnic Institute and State University. July 1979.

Marsh, John M. "Monthly Price Premiums and Discounts Between Steer Calves and Yearlings." American Journal of Agricultural Economics. 67(2):307-314, 1985.

McCoy, John H. Livestock and Meat Marketing. Second Ed. Westport, Connecticut: AVI Publishing Company, Inc. 1979.

McMorris, M. R. and J. W. Wilton. "Breeding System, Cow Weight, and Milk Yield Effects on Various Biological Variables in Beef Production." Journal of Animal Science. 63:1361-1372, 1986.

McMorris, M. R., J. W. Wilton, and W. C. Pfeiffer. "Breeding System, Cow Weight, and Milk Yield Effects on Various Economic Variables in Beef Production." Journal of Animal Science. 63:1373-1383, 1986.

Mighell, Ronald L. and Lawrence A. Jones. Vertical Coordination in Agriculture. Agricultural Economics Report 19. USDA, ERS. 1963.

Miller, Michael M., Daryl Strohbehn, Dan Loy, and Phil Spike. "Beef Cow Ration Analysis." "Microcomputer Worksheets for Agriculture." MCS-13. Ames, IA: Cooperative Extension Service, Iowa State University. 1985.

Mintert, James R., Frank K. Brazle, Ted C. Schroeder, and Orlen Grunewald. "Factors Affecting Auction Prices of Feeder Cattle." Extension Report C-697. Manhattan, Kansas: Cooperative Extension Service, Kansas State University. September 1988.

Morris, C. A. and J. W. Wilton. "Influence of Mature Cow Weight on Economic Efficiency in Beef Cattle Production." Canadian Journal of Animal Science. 55:233-250, 1975.

National Research Council (NRC). Nutrient Requirements of Beef Cattle. Sixth Ed. Washington, D.C.: National Academy Press. 1984.

Naylor, T. H., J. L. Balintty, D. S. Burdick, K. Chu. Computer Simulation Techniques. New York: John Wiley and Sons, Inc. 1958.

Notter, David R., J. O. Sanders, G. E. Dickerson, G. M. Smith, and T. C. Cartwright. "Simulated Efficiency of Beef Production for a Mid-Western Cow-Calf Feedlot Management System. III. Crossbreeding Systems." Journal of Animal Science. 49:92-102, 1979.

Olson, Larry W., G. E. Dickerson, Larry V. Cundiff, and K. E. Gregory. "Individual Heterosis for Postweaning Growth." Journal of Animal Science. 46(6):1529-1551, 1978.

Oltjen, J. W., L. G. Burditt, and D. R. Gill. "An Interactive Microcomputer Program to Simulate Performance of Feedlot Cattle." Mimeograph. Stillwater, Oklahoma: Department of Animal Science, Oklahoma State University. 1984.

Oklahoma Agricultural Statistics Service. Oklahoma Agricultural Statistics-1989. Oklahoma City: Oklahoma Department of Agriculture. 1989.

Oklahoma Agricultural Statistics Service. "1990 Farm Finance Survey." Oklahoma Farm Statistics. 10(8):1-4, June 1990.

Petritz, David C., Steven P. Erickson, and Jack H. Armstrong. The Cattle and Beef Industry in the United States: Buying, Selling, Pricing. CES Paper 93. West Lafayette, Indiana: Cooperative Extension Service, Purdue University.

Plaxico, James S. and Marcia L. Tilley. "The 1986 Farm Financial Survey: Preliminary Results." Current Farm Economics. 59(2):3-13, 1986.

Pope, Rulon D. and Richard Prescott. "Diversification in Relation to Farm Size and Other Socioeconomic Characteristics." American Journal of Agricultural Economics. 62(3):554-559, 1980.

Pratt, J. W. "Risk Aversion in the Small and in the Large." Econometrica. 32:122-136, 1964.

Purcell, Wayne D. "An Approach to Research on Vertical Coordination: The Beef Sector in Oklahoma." American Journal of Agricultural Economics. 55(1):65-68, 1973.

Robison, Lindon J. and Peter J. Barry. The Competitive Firm's Response to Risk. New York: Macmillan Publishing Co. 1987.

Saez, Roberto R., C. Richard Shumway, Monte Rouquette, Jr., and Lonnie L. Jones. "Managing the Cow-calf Enterprise for Higher Profit and Lower Risk." Journal of the American Society Farm Managers Rural Appraisers. 44(2):16-22, 1980.

Sandmo, Agnar. "On the Theory of the Competitive Firm Under Price Uncertainty." American Economic Review. 61:65-73, 1971.

Schroeder, Ted, James Mintert, Frank Brazle, and Orlen Grunewald. Feeder Cattle and Cow Price Differentials at Kansas Cattle Auctions - Fall 1986 and Spring 1987. Report of Progress 547. Manhattan: Agricultural Experiment Station, Kansas State University. June 1988.

Scott, John T. and Chester B. Baker. "A Practical Way to Select an Optimum Farm Plan Under Risk." American Journal Agricultural Economics. 54(4):657-660, 1972.

Selk, Glenn E. and Keith S. Lusby. "The Management of Beef Cattle for Efficient Reproduction." In: Oklahoma Beef Cattle Manual. 2nd Ed. Keith S. Lusby, Ed. Stillwater: Cooperative Extension Service, Oklahoma State University. 1989.

Sheridan, A. K. "Crossbreeding and Heterosis." Animal Breeding Abstract. 49(3):131-144, 1981.

Smith, Gerald M., D. B. Laster, and Keith E. Gregory. "Characterization of Biological Types of Cattle I. Dystocia and Preweaning Growth. Journal of Animal Science. 43(1):27-36, 1976.

Sonka, Steven T. and George F. Patrick. "Risk Management and Decision Making in Agricultural Firms." Risk Management In Agriculture. Peter J. Barry, Ed. Ames, IA: Iowa State University Press. 1984.

Steele, Robert G. D. and James H. Torrie. Principles and Procedures of Statistics. New York: McGraw Hill Book Co., Inc. 1960.

Stokes, K. W., Donald E. Farris, and T. C. Cartwright. "Economics of Alternative Beef Cattle Genotype and Management/Marketing Systems." Southern Journal of Agricultural Economics. 13(2):1-10, 1981.

Stokes, K. W., C. R. Shumway, P. E. Doren, W. O. Ajayi, T. C. Nelson, and T. C. Cartwright. "Economic Effects of Alternative Beef Cow Size and Milking Potential in Cow-calf Operations." Journal of Animal Science. 62:1154-1163, 1986.

Taylor, Robert E. Beef Production and the Beef Industry: A Beef Producer's Perspective. Minneapolis: Burgess Publishing Co. 1984.

Trapp, James N. "Simulation and Systems Modeling." In: Agricultural Policy Analysis Tools for Economic Development. Luther Tweeten, Ed. Boulder, CO: Westview Press. 1989.

Trapp, James N. "Seasonal Price Index Update for Oklahoma Agricultural Commodities, 1978-1987." Current Farm Economics. 61(1-4):31-46, 1988.

Trapp, James N. "Changes in Beef, Pork, and Poultry Production Costs and Their Impact on Meat Market Shares." Current Farm Economics. 58(3):3-14, 1985.

U.S. Department of Agriculture. Agricultural Marketing Service. Livestock and Seed Division. Livestock Detailed Quotations, Amarillo Market.

U.S. Department of Agriculture. Agricultural Marketing Service. Livestock and Seed Division. Livestock Detailed Quotations, Oklahoma City Market.

U.S. Department of Agriculture. National Agricultural Statistics Service. Agricultural Prices. Selected Monthly and Annual Issues.

U.S. Department of Commerce. 1987 Census of Agriculture, State Summary: Oklahoma. Washington D.C.: U.S. Dept. of Commerce. 1989.

Walker, Odell L., Daniel J. Bernardo, James N. Trapp, and Abelardo L. Rodriguez. A Survey of Wheat Pasture Utilization Systems in Western

Oklahoma. Research Report P-903. Stillwater, OK: Agricultural Experiment Station, Oklahoma State University. September 1988.

Walker, Odell L., Keith S. Lusby, and Wilfred E. McMurphy. Beef and Pasture Systems for Oklahoma: A Business Management Manual. Research Report P-888. Stillwater, OK: Agricultural Experiment Station, Oklahoma State University. February 1987.

Watt, David L., Randall D. Little, and Timothy A. Petry. "Retained Ownership is an Option for Cow-calf Operations." Journal of the American Society Farm Managers and Rural Appraisers. 51(2):80-87, 1987.

Western Livestock Marketing Information Project. "Monthly Average Choice Yield Grade #3 Over Select Yield Grade #1-3, Omaha-Central U.S., 600-700 lbs." December 1989.

Whitson, Robert E., Peter J. Barry, and Ronald D. Lacewell. "Vertical Integration for Risk Management: An Application to a Cattle Ranch." Southern Journal of Agricultural Economics. 8(2):45-50, 1976.

Willham, R. L. "Genetic Consequences of Crossbreeding." Journal of Animal Science. 30:690-693, 1970.

Williams, Jeffrey R. "A Stochastic Dominance Analysis of Tillage and Crop Insurance Practices in a Semiarid Region." American Journal of Agricultural Economics. 70(1):113-120, 1988.

Williams, Robert P., Janusz Kubica, and Constance F. Dixon. Leading Commodity Cash Receipts, 1960-87. Statistical Bulletin No. 777. Economic Research Service. U.S. Department of Agriculture. 1989.

Wilton, J. W. and C. A. Morris. "Effects of Reproductive Performance and Mating Systems on Farm Gross Margins in Beef Production." Canadian Journal of Animal Science. 56:171-186, 1976.

Wilton, J. W., C. A. Morris, E. A. Jenson, A. O. Leigh, and W. C. Pfeiffer. "A Linear Programming Model for Beef Cattle Production." Canadian Journal of Animal Science. 54:693-707, 1974.

Woldehawariat, Girma, Miguel A. Talamantes, Robert R. Petty, Jr., and T. C. Cartwright. A Summary of Genetic and Environmental Statistics for Growth and Confirmation Characters of Beef Cattle. 2nd Ed. Technical Report. No. 103. College Station, TX: Department of Animal Science, Texas Agricultural Experiment Station. 1977.

APPENDIX A

MONTHLY LABOR REQUIREMENTS PER HEAD FOR
COW-CALF, WHEAT PASTURE, GRAZEOUT
WHEAT PASTURE, AND YEAR-ROUND
STOCKER ACTIVITIES

APPENDIX TABLE I

MONTHLY LABOR REQUIREMENTS PER HEAD FOR COW-CALF, WHEAT PASTURE, GRAZEOUT WHEAT PASTURE, AND YEAR-ROUND STOCKER ACTIVITIES

Month	Spring Calving	Fall Calving	Wheat Pasture Stockers Steers	Heifers	Grazeout Stockers Steers	Heifers	Year-Round Stockers Steers	Heifers
	Hours/Hd							
January	1.20	1.33	0.54	0.54	0.53	0.53	0.29	0.29
February	1.44	1.24	0.54	0.54	0.53	0.53	0.29	0.29
March	1.40	1.24	0.54	0.54	0.53	0.53	0.29	0.29
April	0.38	1.22	0	0	0.53	0.53	0.29	0.29
May	0.78	0.68	0	0	0.45	0.45	0.15	0.15
June	0.38	0.38	0	0	0	0	0.15	0.15
July	0.38	0.62	0	0	0	0	0.15	0.15
August	0.38	0.38	0	0	0	0	0.15	0.15
September	0.38	0.50	0	0	0	0	0.15	0.15
October	0.93	1.33	0	0	0	0	0	0
November	1.18	1.33	0.81	0.81	0.8	0.8	0.64	0.64
December	1.20	1.33	0.54	0.54	0.53	0.53	0.29	0.29

APPENDIX B

ASSUMPTIONS REGARDING SALE OR TRANSFER DATES AND WEIGHTS, GAIN RATES, AND FEED EFFICIENCY FOR RETAINED OWNERSHIP OPTIONS, BY CROSSBREEDING SYSTEM

APPENDIX TABLE II

SYSTEM 1 AND SYSTEM 2 ROTATIONAL CROSS ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		----------------	(Lbs)	----------------				
Weaned Steers, Spring-Calving					500	485	210	31-Oct
Weaned Heifers, Spring-Calving					483	469	210	31-Oct
Weaned Steers, Fall-Calving					580	563	285	15-Jul
Weaned Heifers, Fall-Calving					547	531	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	493	1 80		758	736	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	476	1 62		716	695	135	15-Mar
Grazeout Stocker Steers	31-Oct	493	1 77		864	838	195	14-May
Grazeout Stocker Heifers	31-Oct	476	1 59		810	786	195	14-May
Year-Round Stocker Steers	31-Oct	493	0 83		790	766	330	26-Sep
Year-Round Stocker Heifers	31-Oct	476	0 75		746	724	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	485	2 79	6 23		1060	206	25-May
1 Feeding Weaned Spring Heifers	31-Oct	469	2 45	6 50		927	187	05-May
2 Feeding Stocker Steers	15-Mar	736	3 28	6 15		1085	107	29-Jun
2 Feeding Stocker Heifers	15-Mar	695	2 88	6 41		949	88	11-Jun
3 Feeding Grazeout Steers	14-May	838	3 49	6 23		1140	87	08-Aug
3 Feeding Grazeout Heifers	14-May	786	3 07	6 50		997	69	21-Jul
4 Feeding Year-Round Steers	26-Sep	766	3 20	6 67		1103	105	09-Jan
4 Feeding Year-Round Heifers	26-Sep	724	2 81	6 95		965	86	20-Dec
5 Feeding Weaned Fall Steers	15-Jul	563	3 03	5 93		1050	161	22-Dec
5 Feeding Weaned Fall Heifers	15-Jul	531	2 66	6 18		919	146	07-Dec

APPENDIX TABLE III

SYSTEM 0 ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		----------------	----------------	(Lbs)	----------------	----------------		
Weaned Steers, Spring-Calving					450	437	210	31-Oct
Weaned Heifers, Spring-Calving					435	422	210	31-Oct
Weaned Steers, Fall-Calving					522	506	285	15-Jul
Weaned Heifers, Fall-Calving					493	478	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	443	1 79		706	685	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	428	1 61		666	646	135	15-Mar
Grazeout Stocker Steers	31-Oct	443	1 76		810	786	195	14-May
Grazeout Stocker Heifers	31-Oct	428	1 58		759	736	195	14-May
Year-Round Stocker Steers	31-Oct	443	0 82		737	715	330	26-Sep
Year-Round Stocker Heifers	31-Oct	428	0 74		695	674	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	437	2 72	5 78		1040	222	09-Jun
1 Feeding Weaned Spring Heifers	31-Oct	422	2 39	6 03		910	204	23-May
2 Feeding Stocker Steers	15-Mar	685	3 20	6 08		1060	117	10-Jul
2 Feeding Stocker Heifers	15-Mar	646	2 81	6 34		927	100	23-Jun
3 Feeding Grazeout Steers	14-May	786	3 39	6.21		1115	97	19-Aug
3 Feeding Grazeout Heifers	14-May	736	2 98	6 47		975	80	02-Aug
4 Feeding Year-Round Steers	26-Sep	715	3 35	6 14		1075	107	11-Jan
4 Feeding Year-Round Heifers	26-Sep	674	2 94	6 40		940	90	25-Dec
5 Feeding Weaned Fall Steers	15-Jul	506	2 91	5 82		1035	182	12-Jan
5 Feeding Weaned Fall Heifers	15-Jul	478	2 56	6 07		905	167	29-Dec

APPENDIX TABLE IV

SYSTEM 2 TERMINAL CROSS ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		---------------	---------------	(Lbs) ---------------	---------------	---------------		
Weaned Steers, Spring-Calving					531	515	210	31-Oct
Weaned Heifers, Spring-Calving					513	498	210	31-Oct
Weaned Steers, Fall-Calving					616	597	285	15-Jul
Weaned Heifers, Fall-Calving					581	564	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	523	1 93		808	783	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	506	1 74		763	740	135	15-Mar
Grazeout Stocker Steers	31-Oct	523	1 90		920	893	195	14-May
Grazeout Stocker Heifers	31-Oct	506	1.70		864	838	195	14-May
Year-Round Stocker Steers	31-Oct	523	0 89		842	816	330	26-Sep
Year-Round Stocker Heifers	31-Oct	506	0.80		795	771	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	515	2 97	6 66		1250	248	05-Jul
1 Feeding Weaned Spring Heifers	31-Oct	498	2 61	6 94		1094	228	16-Jun
2 Feeding Stocker Steers	15-Mar	783	3 49	6 57		1300	148	10-Aug
2 Feeding Stocker Heifers	15-Mar	740	3 07	6 85		1137	130	22-Jul
3 Feeding Grazeout Steers	14-May	893	3 71	6 66		1400	137	27-Sep
3 Feeding Grazeout Heifers	14-May	838	3 26	6 94		1225	119	09-Sep
4 Feeding Year-Round Steers	26-Sep	816	3 40	7 13		1400	171	16-Mar
4 Feeding Year-Round Heifers	26-Sep	771	2 99	7 43		1225	152	24-Feb
5 Feeding Weaned Fall Steers	15-Jul	597	3 22	6 34		1250	202	02-Feb
5 Feeding Weaned Fall Heifers	15-Jul	564	2 83	6 61		1094	187	17-Jan

APPENDIX TABLE V

SYSTEM 3 AND SYSTEM 4 ROTATIONAL CROSS ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		----------------	----------------	(Lbs)	----------------	----------------		
Weaned Steers, Spring-Calving					532	516	210	31-Oct
Weaned Heifers, Spring-Calving					514	499	210	31-Oct
Weaned Steers, Fall-Calving					617	599	285	15-Jul
Weaned Heifers, Fall-Calving					582	565	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	524	1 82		794	770	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	507	1.64		751	728	135	15-Mar
Grazeout Stocker Steers	31-Oct	524	1 79		901	874	195	14-May
Grazeout Stocker Heifers	31-Oct	507	1 61		846	821	195	14-May
Year-Round Stocker Steers	31-Oct	524	0 84		826	801	330	26-Sep
Year-Round Stocker Heifers	31-Oct	507	0 76		781	757	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	516	2 81	6.44		1113	212	31-May
1 Feeding Weaned Spring Heifers	31-Oct	499	2 47	6 71		974	192	11-May
2 Feeding Stocker Steers	15-Mar	770	3 30	6.35		1139	112	04-Jul
2 Feeding Stocker Heifers	15-Mar	728	2.90	6 62		996	92	15-Jun
3 Feeding Grazeout Steers	14-May	874	3 51	6 44		1197	92	14-Aug
3 Feeding Grazeout Heifers	14-May	821	3 09	6 71		1047	73	26-Jul
4 Feeding Year-Round Steers	26-Sep	801	3.22	6.89		1158	111	14-Jan
4 Feeding Year-Round Heifer	26-Sep	757	2 83	7 18		1013	90	25-Dec
5 Feeding Weaned Fall Steers	15-Jul	599	3 05	6 13		1103	165	27-Dec
5 Feeding Weaned Fall Heifers	15-Jul	565	2 68	6 39		965	149	11-Dec

APPENDIX TABLE VI

SYSTEM 4 TERMINAL CROSS ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		---------------- (Lbs) ----------------						
Weaned Steers, Spring-Calving					557	540	210	31-Oct
Weaned Heifers, Spring-Calving					538	522	210	31-Oct
Weaned Steers, Fall-Calving					646	627	285	15-Jul
Weaned Heifers, Fall-Calving					610	591	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	549	1 93		834	809	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	530	1 74		788	765	135	15-Mar
Grazeout Stocker Steers	31-Oct	549	1.90		947	919	195	14-May
Grazeout Stocker Heifers	31-Oct	530	1.70		889	863	195	14-May
Year-Round Stocker Steers	31-Oct	549	0 89		868	842	330	26-Sep
Year-Round Stocker Heifers	31-Oct	530	0 80		820	796	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	540	2 96	6 76		1250	240	27-Jun
1 Feeding Weaned Spring Heifers	31-Oct	522	2 60	7 05		1094	219	07-Jun
2 Feeding Stocker Steers	15-Mar	809	3 48	6 67		1300	141	02-Aug
2 Feeding Stocker Heifers	15-Mar	765	3 06	6 96		1137	122	14-Jul
3 Feeding Grazeout Steers	14-May	919	3 71	6 76		1400	130	20-Sep
3 Feeding Grazeout Heifers	14-May	863	3 26	7 05		1225	111	02-Sep
4 Feeding Year-Round Steers	26-Sep	842	3 40	7 24		1400	164	09-Mar
4 Feeding Year-Round Heifers	26-Sep	796	2 99	7 55		1225	144	16-Feb
5 Feeding Weaned Fall Steers	15-Jul	627	3 22	6 43		1250	194	24-Jan
5 Feeding Weaned Fall Heifers	15-Jul	591	2.83	6 71		1094	178	08-Jan

APPENDIX TABLE VII

SYSTEM 5 AND SYSTEM 6 ROTATIONAL CROSS ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		----------------	----------------	(Lbs)	----------------	----------------		
Weaned Steers, Spring-Calving					569	552	210	31-Oct
Weaned Heifers, Spring-Calving					550	534	210	31-Oct
Weaned Steers, Fall-Calving					660	640	285	15-Jul
Weaned Heifers, Fall-Calving					623	604	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	560	1 81		829	804	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	542	1 63		785	761	135	15-Mar
Grazeout Stocker Steers	31-Oct	560	1 78		935	907	195	14-May
Grazeout Stocker Heifers	31-Oct	542	1 60		879	853	195	14-May
Year-Round Stocker Steers	31-Oct	560	0 83		861	835	330	26-Sep
Year-Round Stocker Heifers	31-Oct	542	0 75		815	790	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	552	2 81	6.85		1197	230	17-Jun
1 Feeding Weaned Spring Heifers	31-Oct	534	2 47	7 14		1047	208	27-May
2 Feeding Stocker Steers	15-Mar	804	3 30	6 76		1225	127	20-Jul
2 Feeding Stocker Heifers	15-Mar	761	2 90	7.05		1072	107	29-Jun
3 Feeding Grazeout Steers	14-May	907	3 51	6 85		1287	108	30-Aug
3 Feeding Grazeout Heifers	14-May	853	3 09	7 14		1126	88	10-Aug
4 Feeding Year-Round Steers	26-Sep	835	3 22	7 33		1246	128	31-Jan
4 Feeding Year-Round Heifers	26-Sep	790	2 83	7 64		1090	106	09-Jan
5 Feeding Weaned Fall Steers	15-Jul	640	3 05	6.52		1186	179	10-Jan
5 Feeding Weaned Fall Heifers	15-Jul	604	2 68	6 79		1038	162	23-Dec

APPENDIX TABLE VIII

SYSTEM 6 TERMINAL CROSS ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		---------------- (Lbs) ----------------						
Weaned Steers, Spring-Calving					597	579	210	31-Oct
Weaned Heifers, Spring-Calving					577	560	210	31-Oct
Weaned Steers, Fall-Calving					693	672	285	15-Jul
Weaned Heifers, Fall-Calving					653	634	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	588	1 93		875	849	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	568	1 74		828	803	135	15-Mar
Grazeout Stocker Steers	31-Oct	588	1 90		988	958	195	14-May
Grazeout Stocker Heifers	31-Oct	568	1 71		929	901	195	14-May
Year-Round Stocker Steers	31-Oct	588	0 89		909	882	330	26-Sep
Year-Round Stocker Heifers	31-Oct	568	0 80		860	834	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	579	2 97	6 97		1275	234	21-Jun
1 Feeding Weaned Spring Heifers	31-Oct	560	2 61	7.26		1115	213	31-May
2 Feeding Stocker Steers	15-Mar	849	3 50	6 88		1325	136	29-Jul
2. Feeding Stocker Heifers	15-Mar	803	3 07	7 17		1159	116	08-Jul
3 Feeding Grazeout Steers	14-May	958	3 72	6 97		1425	125	16-Sep
3 Feeding Grazeout Heifers	14-May	901	3 27	7 26		1247	106	27-Aug
4 Feeding Year-Round Steers	26-Sep	882	3 41	7 46		1425	159	04-Mar
4 Feeding Year-Round Heifers	26-Sep	834	3 00	7 77		1247	138	10-Feb
5 Feeding Weaned Fall Steers	15-Jul	672	3 23	6 63		1250	179	10-Jan
5 Feeding Weaned Fall Heifers	15-Jul	634	2 84	6 91		1094	162	23-Dec

APPENDIX TABLE IX

SYSTEM 7 AND SYSTEM 8 ROTATIONAL CROSS ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin. Weight	Pay Weight	Days In Program	Sale or Transfer Date
		---------------- (Lbs) ----------------						
Weaned Steers, Spring-Calving					564	547	210	31-Oct
Weaned Heifers, Spring-Calving					545	529	210	31-Oct
Weaned Steers, Fall-Calving					654	635	285	15-Jul
Weaned Heifers, Fall-Calving					617	599	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	556	1.82		826	801	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	537	1.64		782	758	135	15-Mar
Grazeout Stocker Steers	31-Oct	556	1.79		933	905	195	14-May
Grazeout Stocker Heifers	31-Oct	537	1 61		877	851	195	14-May
Year-Round Stocker Steers	31-Oct	556	0 84		858	833	330	26-Sep
Year-Round Stocker Heifers	31-Oct	537	0 76		812	787	330	26-Sep
Slaughter Options								
1. Feeding Weaned Spring Steers	31-Oct	547	2 81	6 70		1185	227	15-Jun
1 Feeding Weaned Spring Heifers	31-Oct	529	2 47	6 98		1037	206	24-May
2 Feeding Stocker Steers	15-Mar	801	3 30	6 61		1213	125	17-Jul
2. Feeding Stocker Heifers	15-Mar	758	2 90	6.89		1061	104	27-Jun
3 Feeding Grazeout Steers	14-May	905	3 51	6 70		1274	105	27-Aug
3 Feeding Grazeout Heifers	14-May	851	3 09	6 98		1114	85	07-Aug
4 Feeding Year-Round Steers	26-Sep	833	3 22	7 17		1233	124	28-Jan
4 Feeding Year-Round Heifers	26-Sep	787	2 83	7 48		1079	103	06-Jan
5 Feeding Weaned Fall Steers	15-Jul	635	3 05	6 37		1174	177	07-Jan
5 Feeding Weaned Fall Heifers	15-Jul	599	2 68	6 65		1027	160	21-Dec

APPENDIX TABLE X

SYSTEM 8 TERMINAL CROSS ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		----------------	(Lbs)	----------------				
Weaned Steers, Spring-Calving					594	576	210	31-Oct
Weaned Heifers, Spring-Calving					574	557	210	31-Oct
Weaned Steers, Fall-Calving					689	668	285	15-Jul
Weaned Heifers, Fall-Calving					650	631	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	585	1 93		871	845	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	566	1 74		825	800	135	15-Mar
Grazeout Stocker Steers	31-Oct	585	1 90		984	955	195	14-May
Grazeout Stocker Heifers	31-Oct	566	1 70		925	898	195	14-May
Year-Round Stocker Steers	31-Oct	585	0.89		906	878	330	26-Sep
Year-Round Stocker Heifers	31-Oct	566	0 80		856	831	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	576	2 96	6 89		1250	228	15-Jun
1 Feeding Weaned Spring Heifers	31-Oct	557	2 60	7 18		1094	206	25-May
2 Feeding Stocker Steers	15-Mar	845	3 48	6 80		1300	131	23-Jul
2 Feeding Stocker Heifers	15-Mar	800	3 06	7.09		1137	110	03-Jul
3 Feeding Grazeout Steers	14-May	955	3.70	6 89		1375	113	04-Sep
3 Feeding Grazeout Heifers	14-May	898	3.25	7 18		1203	94	15-Aug
4 Feeding Year-Round Steers	26-Sep	878	3 40	7 38		1375	146	19-Feb
4 Feeding Year-Round Heifers	26-Sep	831	2 98	7 69		1203	125	28-Jan
5 Feeding Weaned Fall Steers	15-Jul	668	3 21	6 56		1250	181	11-Jan
5 Feeding Weaned Fall Heifers	15-Jul	631	2 83	6 84		1094	164	25-Dec

APPENDIX TABLE XI

SYSTEM 9 ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		----------	----------	---------- (Lbs)	----------	----------		
Weaned Steers, Spring-Calving					628	609	210	31-Oct
Weaned Heifers, Spring-Calving					607	589	210	31-Oct
Weaned Steers, Fall-Calving					728	707	285	15-Jul
Weaned Heifers, Fall-Calving					687	667	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	619	2.01		917	890	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	598	1.81		868	842	135	15-Mar
Grazeout Stocker Steers	31-Oct	619	1.97		1034	1003	195	14-May
Grazeout Stocker Heifers	31-Oct	598	1.77		973	944	195	14-May
Year-Round Stocker Steers	31-Oct	619	0.93		953	924	330	26-Sep
Year-Round Stocker Heifers	31-Oct	598	0.84		901	874	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	609	3.11	6.79		1275	214	02-Jun
1 Feeding Weaned Spring Heifers	31-Oct	589	2.73	7.08		1115	193	11-May
2 Feeding Stocker Steers	15-Mar	890	3.65	6.70		1500	167	29-Aug
2 Feeding Stocker Heifers	15-Mar	842	3.21	6.99		1312	146	08-Aug
3 Feeding Grazeout Steers	14-May	1003	3.89	6.79		1500	128	18-Sep
3 Feeding Grazeout Heifers	14-May	944	3.42	7.08		1312	108	29-Aug
4 Feeding Year-Round Steers	26-Sep	924	3.56	7.27		1500	162	06-Mar
4 Feeding Year-Round Heifers	26-Sep	874	3.13	7.58		1312	140	12-Feb
5 Feeding Weaned Fall Steers	15-Jul	707	3.38	6.46		1300	176	06-Jan
5 Feeding Weaned Fall Heifers	15-Jul	667	2.97	6.74		1137	159	20-Dec

APPENDIX TABLE XII

SYSTEM 10 ASSUMPTIONS

	Date Entering Program	Weight In	Average Daily Gain	DM Feed Per Lbs Gain	Fin Weight	Pay Weight	Days In Program	Sale or Transfer Date
		---------------- (Lbs) ----------------						
Weaned Steers, Spring-Calving					578	561	210	31-Oct
Weaned Heifers, Spring-Calving					559	542	210	31-Oct
Weaned Steers, Fall-Calving					670	650	285	15-Jul
Weaned Heifers, Fall-Calving					633	614	285	15-Jul
Wheat Pasture Stocker Steers	31-Oct	569	1 94		857	831	135	15-Mar
Wheat Pasture Stocker Heifers	31-Oct	550	1 74		810	786	135	15-Mar
Grazeout Stocker Steers	31-Oct	569	1 91		970	941	195	14-May
Grazeout Stocker Heifers	31-Oct	550	1 71		912	884	195	14-May
Year-Round Stocker Steers	31-Oct	569	0 89		891	864	330	26-Sep
Year-Round Stocker Heifers	31-Oct	550	0 81		842	817	330	26-Sep
Slaughter Options								
1 Feeding Weaned Spring Steers	31-Oct	561	3 00	7 48		1275	238	25-Jun
1 Feeding Weaned Spring Heifers	31-Oct	542	2 64	7 80		1115	217	05-Jun
2 Feeding Stocker Steers	15-Mar	831	3 53	7 39		1500	190	20-Sep
2. Feeding Stocker Heifers	15-Mar	786	3 10	7 70		1312	170	31-Aug
3 Feeding Grazeout Steers	14-May	941	3.76	7 48		1500	149	09-Oct
3 Feeding Grazeout Heifers	14-May	884	3 30	7.80		1312	130	20-Sep
4 Feeding Year-Round Steers	26-Sep	864	3 44	8 01		1500	185	29-Mar
4 Feeding Year-Round Heifers	26-Sep	817	3 03	8 35		1312	164	08-Mar
5 Feeding Weaned Fall Steers	15-Jul	650	3 26	7 12		1300	199	30-Jan
5 Feeding Weaned Fall Heifers	15-Jul	614	2 87	7 43		1137	183	13-Jan

APPENDIX C

MONTHLY AVERAGE CHOICE YIELD GRADE #3

PRICE OVER SELECT YIELD GRADE #1-3

PRICE, OMAHA-CENTRAL U.S.,

600-700 LBS.

APPENDIX TABLE XIII

MONTHLY AVERAGE CHOICE YIELD GRADE #3
PRICE OVER SELECT YIELD GRADE #1-3
PRICE, OMAHA-CENTRAL U.S.,
600-700 LBS.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	3.68	4.19	1.85	1.51	1.64	4.92	5.49	6.10	5.19	4.61	3.50	2.72
1981	2.43	2.04	2.92	2.11	1.72	5.24	6.48	5.49	3.08	1.13	1.21	2.07
1982	3.50	4.61	2.84	2.19	4.08	4.92	6.36	2.72	3.32	2.66	2.95	1.44
1983	2.67	2.84	2.40	2.55	2.73	6.14	6.79	8.17	7.28	4.55	3.35	2.43
1984	4.10	2.90	3.96	2.71	1.64	6.37	8.96	5.71	3.90	4.84	3.43	3.29
1985	2.30	1.19	1.11	0.92	1.76	3.44	4.01	4.32	5.16	5.96	5.45	4.24
1986	3.56	5.38	1.53	2.26	2.64	5.18	8.55	3.15	4.91	5.23	7.33	6.11
1987	4.10	2.77	2.10	4.20	10.35	14.19	8.81	3.16	4.02	4.01	4.37	3.45
1988	3.63	3.28	3.77	4.53	10.96	12.75	4.37	8.46	7.45	4.22	5.74	5.64

2

VITA

Randall Dean Little

Candidate for the Degree of

Doctor of Philosophy

Thesis: ECONOMIC ANALYSIS OF ALTERNATIVE CATTLE BREEDING SYSTEMS WITH RETAINED OWNERSHIP THROUGH THE STOCKER AND FEEDER PHASES

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Boise City, Oklahoma, August 24, 1960, the son of Howard R. And Christine J. Little.

Education: Graduated from Socorro High School, Socorro, New Mexico in May 1978; received Bachelor of Science degree in Agricultural Economics from New Mexico State University in May 1982; received Master of Science degree in Agricultural Economics from the University of Illinois in May 1985; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in December 1990.

Professional Experience: Graduate Research Assistant, Department of Agricultural Economics, University of Illinois, November 1982 to December 1983; Graduate Teaching Assistant, Department of Agricultural Economics, University of Illinois, January 1984 to May 1984; Research Assistant, Department of Agricultural Economics, North Dakota State University, December 1984 to July 1986; Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, August 1986 to August 1990; Assistant Professor of Agricultural Economics, Department of Agricultural Economics, Mississippi State University, August 1990 to present.