AN ABSTRACT OF THE THESIS OF

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Title: An Analysis of Risk Management Strategies for Southern Alberta Feedlots

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Feedlot finishing of beef cattle in Southern Alberta involves income risk due to the variability of prices of feeders, feed and finished cattle. Several strategies are available to reduce this risk, including hedging of cattle on feed, participation in a Federal-Provincial government and producer established income stabilization program for finished cattle (National Tripartite Stabilization Plan) and diversification of production plans.

This study evaluated the efficacy and interaction effects of these strategies in reducing net income variability in cattle feeding in Southern Alberta. Concerns that were addressed included: (1) whether participation in hedging or Stabilization would increase firm-level slaughter cattle output, (2) whether portfolio effects exist between production and marketing alternatives, (3) whether participation in Stabilization would reduce participation in hedging (4) whether hedging performance could be increased by hedging the Canadian dollar, and (5) whether privately supplied hedging versus publicly supplied Stabilization is better able to handle income risk in cattle feeding.

The theory of decision making under uncertainty was reviewed to determine how to best incorporate the risk aspects of the feedlot management problem. Expected Value-Variance (EV)and safety-first risk analyses were identified as frameworks for formulation of the feedlot management problem in a mathematical programming context. Using data from 1976-87, linear risk programming (MOTAD and Target MOTAD) models of the feedlot process were constructed to analyze the alternatives for reducing income risk.

Results for the 1986-87 feeding year suggested that, at moderate levels of risk aversion, feedlot managers should maintain high levels of hedging of both live cattle and the Canadian dollar with moderate participation (25 percent of cattle on feed) in the Stabilization plan. Significant portfolio effects were present. Hedging, but not Stabilization, was found to increase firm-level output by increasing the average weight to which a group of cattle would be finished. Participation in Stabilization was found to reduce hedging participation by an average of 10 percent. Hedging of the Canadian dollar improved the performance of live cattle hedging. Whether hedging was better at reducing risk and maintaining income than Stabilization depended on the definition of risk.

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of
Risk Management Strategies
for Southern Alberta Feedlots

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I INTRODUCTION

The Problem

Feedlot finishing of beef cattle in Southern Alberta is an important enterprise and a major market for feed grains. Beef feeding is usually considered a very risky activity. Large amounts of short term capital are required to buy feeder cattle and feed, and prices of feeders, feed and finished cattle are volatile. In addition, feed availability and quality can be highly variable from year to year. Thus, successful feedlot management requires careful attention to markets, feeds, health of animals and feed preparation.

Several feeding, marketing and pricing strategies are available to reduce risk. For example, feeding of certain breeds, sex of animal (steers, heifers or virgin bulls), or phase of feeder growth (calves, yearlings or long yearlings) may be employed to reduce output variability. Use of the futures market, forward contracting with packers and enrollment in a government stabilization plan may be employed to reduce price risk. Using irrigation to produce feeds may reduce feed quantity and quality variability and input price risk. Two possibilities for reducing marketing risk are the use of maintenance feed regimes to hold cattle at optimum slaughter weight and finish and the marketing of finished cattle into the U.S. market. Both extend the time window of marketing finished cattle. Finally, custom feeding might be used to reduce financial risk.

Specifically, the problem to be addressed by this study is the lack of information available for evaluating the effectiveness of these various strategies for reducing income risk in cattle feeding. Theoretically, participation in hedging or stabilization should reduce financial risk in cattle feeding. There may also be beneficial interactions of these strategies either with each other or with production strategies that may be risk reducing.

Economic models of the feedlot production and marketing process that simultaneously evaluate the portfolio of risk reducing strategies could assist feedlot operators in evaluating the strategies available to reduce risk or the variability in net returns. In addition, such models could address the conventional feedlot optimization questions regarding optimal market weight, length of feeding time, optimal diet and rate of gain. Given the level of microcomputer technology available such models could be constructed in a microcomputer format to allow direct use by extension agents and knowledgeable feedlot operators.

The Beef Industry in Southern Alberta

A brief summary of the structure, history and importance of the beef feeding industry in Alberta is helpful to delineate the setting of the research. The feedlot industry represents the second phase in beef production, the finishing of a feeder calf or stocker animal for slaughter. Feeder animals are produced throughout the province but in Southern Alberta come predominately from cow-calf ranches in the foothills region of Southwestern Alberta and the shortgrass region of Southeastern Alberta. These feeders are transported inward to central south Alberta for finishing on farm and nonfarm feedlot operations in the irrigation and wheat producing areas. Farm feedlots range in size from small enterprises (100 - 500 head capacity) using surplus feedgrains and off-season labor to relatively large feedlots (1,000 - 5,000 head capacity), which provide the major source of farm income. Nonfarm feedlots are more specialized cattle feeding operations (5,000 - 10,000 head capacity) that purchase all feed and either purchase feeder cattle or custom feed cattle for producers and private businessmen on a fee for service basis (Alberta Agriculture, 1981, p. 1).

In the last two decades, Alberta has increased its share of Canada's finished cattle market, and currently produces almost half of the grain-fed beef in Canada and 65 percent of western Canadian production. Table 1 documents the marketings of slaughter cattle in western Canada compared to the Canadian total. Southern Ontario, which has feeding industry based on corn ensilage rather than grain, is Alberta's largest competitor producing about 30 percent of Canadian slaughter cattle. Until 1960 nearly all the grain feeding of beef cattle in Alberta was done in relatively small lots on farms, as promoted since 1938 under The Alberta Feeder Associations Guarantee Act (Horner et al., 1980, p. 105). In the 1960s inexpensive feed grains encouraged rapid development of large commercial feedlots in the area south of Calgary. Until 1974, Alberta enjoyed an absolute advantage over Ontario feedlots with a cost per pound of gain consistently two to three cents below that of Ontario (Environment

Table 1 Slaughter Cattle Marketings in Western Canada and in Canada, 1973 to 1985

Year	Alberta '000 hd	Western Canada '000 hd	Alberta as a percentage of Western Canada	Canada	Alberta as a percent of Canada
1973	1,112	1,743	64	2,878	39
1974	1,132	1,792	63	2,976	38
1975	1,352	2,063	66	3,338	41
1976	1,538	2,305	67	3,676	42
1977	1,590	2,365	67	3,761	42
1978	1,381	2,098	66	3,430	40
1979	1,257	1,808	69	2,954	43
1980	1,251	1,801	69	3,059	41
1981	1,295	1,865	69	3,197	41
1982	1,321	1,974	67	3,294	40
1983	1,308	1,939	67	3,242	40
1984	1,261	1,924	66	3,116	40
1985	1,270	1,973	64	3,159	40

Source: Livestock Market Review, 1973-1985
Agriculture Canada, Marketing and Economics Branch

Council of Alberta, p. 26). With much higher feed grain prices in the late 1970s, the absolute advantage in feed cost per pound of gain switched to Ontario. Only recently have feed grain prices returned to levels low enough for Alberta to regain that advantage. Generally, Alberta feedlots have specialized in backgrounded or stocker feeders weighing 600-800 pounds because lighter cattle and calves require more care, roughage and time on feed (Sibbald Group, p. 33). As grain prices decline, cattle are put on feed at a younger age (Williams, p. 4). During periods of high grain prices, cattle are left on the range longer to maximize the use of forage for cheaper growth. Such considerations have given rise to feedlots specializing in backgrounding, i.e., the feeding of calves on forage or pasture to the yearling or long yearling stage (anywhere from 600 - 900 pounds final weight).

Traditionally the market for Alberta beef has been eastern Canada (Toronto and Montreal) resulting in a West-to-East movement of livestock and meat products. Recent years have seen the West-to-East movement shifting to a North-to-South movement into the western United States. The combination of increased West-to-East freight rates and decreased tariff protection has placed U.S. Midwest finished beef in a preferred position in eastern Canadian markets as compared to Alberta products (Cattlemen, Mar. 1982, p. 70). With the Manitoba and Quebec governments promoting increased finishing of beef in their provinces, many Alberta feedlot operators believe increased growth in the Alberta feeding industry will depend on increased access to the Pacific coast market (Cattlemen, Mar. 1986, p. 46).

Risk Management Alternatives

Risk reducing strategies available to Alberta feedlot operators have increased in recent years. In addition to the traditional strategies of hedging and custom feeding, new alternatives such as government stabilization programs and options futures trading have emerged.

Given the volatility of the beef feeding industry in the late 1970s and high interest rates in the early 1980s, various provincially funded stabilization programs emerged. Saskatchewan introduced a beef returns stabilization plan in 1982 based on a cost of production formula that supports 100 percent of cash costs and 50 percent of noncash costs (Loyns and Martin, 1985). Manitoba implemented a similar program in 1983 aimed at keeping 100,000 calves for finishing in the province. Support levels in 1983 were established at $1.51 per pound of carcass weight and over 72 percent of the beef cow herd was covered under the plan in late 1983 (Cattlemen, Oct. 1983, p. 38). By mid 1985, the Manitoba plan had a 15 to 20 million dollar deficit (Loyns and Martin, 1985). Alberta had a one time assistance program in 1982 that gave a $4 per hundredweight payout for slaughter calves and cattle to producers in 1981 (Cattlemen, Mar. 1982, p. 80). Recently, several provinces have joined the federal government tripartite stabilization plan. The plan offers a guaranteed margin to feeder backgrounders and slaughter cattle producers at varying percentage levels of support (Loyns and Martin, 1985). By August of 1986, over 33 percent, or 4,000 Alberta cow-calf producers and 2,800 slaughter cattle producers, had joined the plan (Cattlemen, Aug. 1986, p. 39). Currently Ontario, Prince Edward Island and Alberta are enrolled in the plan and Saskatchewan and Manitoba are maintaining their own plans.

Hedging on the U.S. cattle futures markets has long been considered a tool for reducing price risk. However, this strategy is limited in Canada due to basis risk, which is complicated by exchange rate movements (Cattlemen, Oct. 1982, p.32). Studies also suggest that the cattle futures market does not perform well and provides downward biased hedging results (Helmuth, 1981; Carter and Loyns, 1985). As an alternative to conventional hedging, the Chicago Mercantile Exchange (CME) introduced options on agricultural commodities in October of 1984. Essentially, options provide insurance protection against downside risk for a premium over conventional futures contracts. The cattle feeder can guarantee a selling price if the cash market moves downward, or if the cash market moves above the futures strike price, the feeder can let the option expire and take a profit in the cash market (Cattlemen, Jun. 1986, p. 14).

Whether the futures market is helpful in reducing risk, given stabilization programs in Canada, is an empirical question that warrants study. Indeed, evaluation of the complementary and substitution effects of all alternative risk reducing strategies in a portfolio framework is necessary before this question can be resolved. For example, an analysis could be undertaken to determine whether participation in the futures market reduces risk given an existing stabilization plan. Also, the complementary effects of price forecasting could be explored in regard to hedging and basis risk. Direct selling to the U.S. market could be examined for effects on basis risk. Price forecasting could be studied for its information value in terms of feed planning, futures market participation and the determination of finished cattle marketing weights. A model that could capture the interaction effects of all such risk reducing strategies could be helpful to beef producers and their advisors.

Study Objectives

The objective of the study is to identify the most effective risk reducing feeding and marketing strategies available to feedlot operators. The specific objectives are to:

1. Determine if firm-level finished cattle output, i.e., feeding to higher weights, will increase as a result of participation in hedging or the Tripartite Beef Stabilization Program.
2. Determine the risk reduction benefits of diversification among the various production and marketing alternatives. Marketing alternatives include: cash marketing, hedging and stabilization. Production alternatives include: the feeding of smaller British versus larger exotic crossbred cattle, and various feeding regimes (low, medium or high energy feeding combinations over the specified feeding stages).
3. Determine if participation in stabilization will reduce the level of conventional hedging.
4. Determine if hedging performance can be increased in Southern Alberta by hedging the Canadian dollar to reduce the live cattle basis risk.
5. Quantify the difference in expected value and variability of distributions of net returns between the privately supplied mechanism of hedging and the publicly supplied mechanism of stabilization.

Organization of the Thesis

The following chapter, chapter two, presents a review of decision theory relevant to the analysis of the beef feedlot management process. Chapter three develops the theory of the firm under uncertainty and uses the theory to deduce testable hypotheses regarding the risk-reducing effects of hedging and stabilization. It also considers the effects of time; in particular, the time considerations of diet specification. Chapter four discusses potential modeling techniques. Chapter five outlines the production and marketing alternatives and develops the planning model used to determine the risk efficient frontiers for the feedlot management problem. Cost and expected gross margin data and input-output parameters for the alternative production-marketing alternatives are developed. Chapter six presents and discusses the risk efficient feedlot plans developed by the analysis. Chapter seven summarizes the analysis, draws conclusions and discusses the implications of the study for management and for further research.

II THE THEORY OF DECISION MAKING UNDER UNCERTAINTY

Introduction

This chapter develops and links several theoretical issues important to an understanding of the beef feedlot management process under risk. First, the nature of the beef feedlot management process is discussed. Risk is defined and related to the decision framework facing the feedlot operator. Sources of risk in the feedlot process are reviewed and those important to the analysis are stated. Second, the theory of choice under uncertainty is developed beginning with the expected value criterion and extending to the foundations and use of expected utility. Alternative methods are presented for implementation of the Expected Utility Theorem. Specifically, portfolio theory or mean-variance analysis, and safety-first decision analysis are developed and justified as the approaches in this study.

The Nature of the Beef Feedlot Management Process

The beef feedlot management process essentially involves decision making in the presence of risk and time effects. Meyer (p. 410) recognized the dynamic aspects of the process by noting:

> Feedlot managers, in seeking to maximize their income, are faced with the task of balancing feed costs, purchase costs of feeders, yardage, handling, maintenance, interest, disease preventatives, and other fixed costs accruing over time, against the selling weight and the beef market. Should he purchase 600 pound animals and

> feed high-energy rations to finish in the shortest time to save time-dependent fixed costs, or 400 pound animals and feed poor rations to minimize feed costs?

Determination of optimal purchase weight, feeding time, slaughter weight and feeding regime is intrinsically tied to existing and expected prices of feeders, feeds and finished animals. Risk arises from the possibility that the actual values of these variables may differ from their expected values. To understand better what risk is, a definition is proposed followed by a discussion of its measurement and importance in the decision process. Sources of risk in the beef feedlot management problem are then detailed.

Uncertain Versus Risky Events

Risk and uncertainty have been defined by several authors. Baumol (p. 458) notes:

> Contemporary theory follows Knight's distinction between risk and uncertainty. Risk refers to situations in which the outcome is not certain, but where the probabilities of the alternative outcomes are known, or can at least be estimated. Uncertainty is present where the unknown outcomes cannot even be predicted in probability terms, that is, it refers to contingencies against which one cannot protect oneself on ordinary insurance principles.

More recent proclamations on risk and uncertainty have noted that decision makers must make probability judgments even with little or no empirical support (Robison and Barry, p. 13). Once such judgments are formed, the decision process is similar whether the decision maker faces Knightian risk or uncertainty. As a result, most economists use the terms risk and uncertainty interchangeably.

Robison and Barry (p. 13-14) suggest a newer distinction between uncertain events and risky events in the following:

> Events are uncertain when their outcome is not known with certainty. Uncertain events are important when their outcomes alter a decision maker's material or social well-being. This definition is broader than the popular concept of risk as involving possible loss or injury and implies that risky events form a subset of uncertain events. The decision maker's response to uncertain nonrisky outcomes is indifference or irrelevance. Only risky events have significance.

While risk in this sense cannot be identified by objective probabilities as Knight suggested, it is recognized that some informational bases are more objectively determined than others. However, given the current state of uncertainty analysis, the Knightian distinction is unwarranted and impractical. For purposes of this study, then, risk is defined according to the Robison and Barry distinction given above.

In empirical studies, the risk modeling task becomes one of adequately representing the subjective probability distribution of risky events within the model structure (McCarl, 1985). Methods range from representation of the entire distribution, as in stochastic dominance techniques, to more compact methods which measure risk on the basis of distribution parameter estimates, such as in mean-variance analysis.

Measures of Risk

Risk arises from the possibility that actual values of certain random variables in the decision process may differ from those expected. Expectations may be formulated from either subjective or objective sources. Subjective expectations are those calculated from probability measures elicited from individual decision-makers. Objective expectations are formulated from probability measures computed from historical or experimental data and may act as input into the formation of subjective expectation values. Regardless whether risk is subjective or objective, the nature and amount of risk present is altered depending on the expectation model.

Expectation models can be simple or complex ranging from mathematical expectation and naive forecasting methods to advanced econometric methods such as those based on ARIMA (autoregressive integrated moving average) processing of historical data. Darcovich and Heady proposed a number of alternative price and yield expectation models. The models included: (1) the average price and yield model, (2) the normal model, (3) the cumulative yield model, (4) the random price and yield model, (5) the current-year price and yield model, (6) the moving-average price and yield model, (8) the trend and reverse-trend price model and (11) the futures price model. The average- or mean-expectation models assume equal weighting of historical observations, whereas more recent observations could be argued as being more relevant and should receive more weight. Another possible problem with the mean expectation model is the selection of the length of the data series. The longer the series selected, the longer the implied memory of the decision maker. For this reason, many studies have based income expectations on average values from recent periods (Halter and Dean, p. 152; Adams et al.). Recently, Young (p. 40) noted that simple forecasting models will generally represent a better forecast of next period's returns than using the average of returns over the past twenty years. He also suggests that more sophisticated forecasting procedures, such as Box and Jenkins (ARIMA) procedures or fundamental econometric equations incorporating exogenous variables for supply and demand will improve the credibility and performance of risk efficient action sets as normative guides.

Regardless of the expected value chosen or estimated, it can be considered a forecast for the next period's returns and the difference between it and any observed value of the variable may be considered a measure of risk. Where the expected value is estimated as the historical mean, the appropriate risk measures are variance and standard deviation as well as lesser used estimators, such as total absolute deviation and mean absolute deviation. Variance and standard deviation are consistent with quadratic programming methods (Markowitz), while total absolute deviation and mean absolute deviation (MAD) are employed in linear risk programming models (Hazell, 1971). Both estimators (variance and MAD) indicate the degree of variability of enterprise returns.

Where the expected value estimated represents a forecast for each successive time period in the historical series (e.g., exponentially smoothed forecast) or where a non-historical based forecast has been employed (e.g., future market prices) the risk measure represents an estimate of forecast error variability.

McSweeny (1987) espoused that past forecast errors are likely to dominate subjective risk perceptions and proposed mean-squared forecast error as a more appropriate risk measure than historical variance. He noted that historical variance assumes that the distribution of realized returns is the same as the distribution of returns anticipated by the decisionmaker at the start of the production process. This study employs simple exponential smoothing to forecast the expected value of slaughter cattle prices that will exist at the end of the finishing period for any year. Risk is measured as the series of forecast error deviations for the historical period (1976-86).

Another important concept of risk notes that variability and risk may not be synonymous. Variability includes returns above the expected level as well as below. Many decision makers do not consider situations risky if return is above the expected level of return. This kind of consideration underlies the use of the semi-variance and the mean negative deviation measures (Hazell, 1971), and the employment of safety-first decision rules.

Safety-first decision rules exist when the decision maker first satisfies a preference for safety, or a risk constraint, in selecting among action alternatives and then pursues a profit oriented objective (Young). The concept assumes that the decision maker is more concerned with the ability to prevent a return below some "disaster level". Formally, the risk constraint indicates the "chance of loss" or the probability (α) that random net income (π) will fall below some critical or disaster level (d). Mathematically it can be expressed as:

$$P(\pi \leq d) \leq \alpha \qquad (1)$$

Young shows that this risk concept will rank distribution 1 more risky than 2 in Figure 1 and distribution 1 more risky than 2 in Figure 2 because $\alpha_1 > \alpha_2$ in both figures. In contrast, the variance concept will rank 2 more risky than 1 in Figure 1 because $\sigma^2{}_1 < \sigma^2{}_2$, and will rank distributions 1 and 2 equally likely in Figure 2 because $\sigma^2{}_1 = \sigma^2{}_2$.

Safety-first concepts of risk have recently found application in Target MOTAD models, where risk is measured as total negative deviations from the target income as opposed to the mean (Tauer; Watts et al.). Watts et al. provide an interesting insight regarding the two approaches to risk in the following:

> The principal purpose of risk-return analysis lies in ranking alternative farm plans on the basis of risk, and examining trade-offs between risk and mean income. However, analyzing trade-offs between "risk" (defined as deviations from mean income) and mean income: is subject to question, since risk is not expressed in a "pure" sense; i.e., such a risk expression is not independent of, but rather dependent on mean income. Furthermore, in most cases the only possible way to reduce (or eliminate) risk in MOTAD (and quadratic programming) is to reduce (or eliminate) income. Yet, from a practical standpoint, it is not "higher income" per se that poses a threat. To the contrary, it is low income yielding negative deviations from a fixed level of acceptable target income.

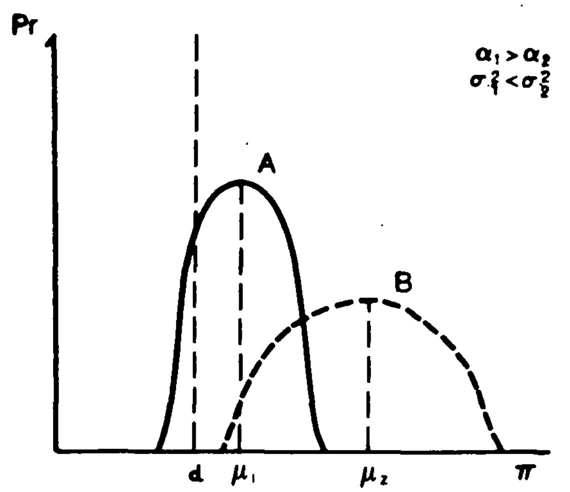

Figure 1 Chance of loss and variance measures of risk for different distributions

Source: Young (p. 33)

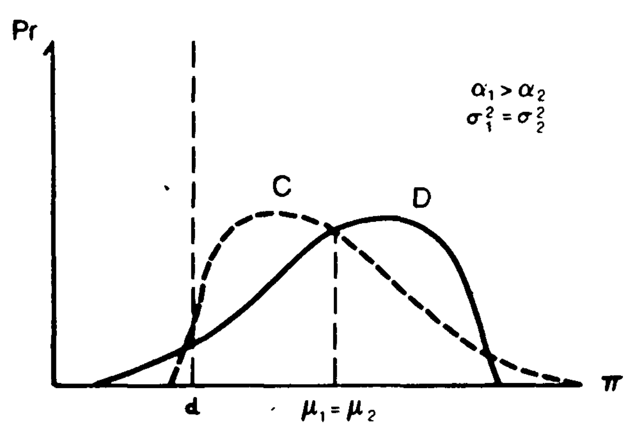

Figure 2 Chance of loss and variance measures of risk with identical but oppositely skewed distributions

Source: Young (p. 33)

They conclude that the safety-first concept of risk, as made operational in the Target MOTAD model, is a more plausible approach for examining risk-return trade-offs. In this study both the forecast error and safety-first concepts of risk are explored for their ability to rank alternative cattle feeding and marketing strategies.

The Importance of Risk in the Decision Process

Regardless of the approach taken to risk, its importance in modeling the decision process should not be automatically assumed. McCarl (1985) addresses this question as follows:

> First and fundamentally, the main reason for considering risk is as follows: If in a modeled solution the solution diverges from reality because the decision maker in reality has somehow considered risk, then it is important to consider risk. So in effect risk must make a difference in the optimal level of the decision variables.

The fact that risk does make a difference in livestock production is supported by several studies. Patrick et al. surveyed crop and livestock producers as to their perception of sources of risk in their agricultural operations. Livestock prices were considered the most important sources of variability followed by operating input costs. Important conclusions from the study that lend credence to this research are:

1. Decision criteria vary across geographic region and by farm type. Risk modeling techniques should be adapted to the unique conditions of the research domain because standardized modeling can produce spurious results.
2. Risk models that consider only commodity price and yield variability underestimate the importance of risk in the decision-making framework. As a minimum requirement, production (including inputs), marketing and financial considerations should be integrated into a realistic decision-making framework.
3. Agricultural producers view their business in a multiperiod fashion where safety-first considerations are emphasized.
4. Information management for financial and marketing decision making is a significant constraint to the success of many producers.
5. Stabilization of macroeconomic variables such as inflation, interest rates, government farm policies and government regulations do as much as individual management options to improve the risk position of producers.

Given that risk is important in the beef feedlot decision problem, the sources of risk in the feedlot process and those aspects upon which this study will focus are considered next.

Sources of Risk in Beef Cattle Feeding and Finishing

Several classifications of risk are relevant to cattle feeding and finishing. McCarl (1985) categorizes risk in programming models as: objective function risk (c_j's), right hand uncertainty (b_i's) and coefficient uncertainty (a_{ij}'s). Anderson (1985) refers to production risk, market risk and financial risk in instructing producers and extension agents on how to analyze risk. Production risk is the probability of low yields or of high cost per unit of production. In cattle feeding, production risk arises from variability in feeder prices (c_j risk), from variability in feed quality (a_{ij} risk) and costs (c_j risk), from animal response variability (a_{ij} risk) and from variability in morbidity, mortality and treatment costs of animals (a_{ij} and c_j risk).

Market risk arises from fluctuating output prices, which affect both the within year and between year variability of net returns of different marketing strategies. Output price variability in cattle feeding involves price variability, both within and between carcass grades of cattle (c_j risk). Grade price differentials tend to increase when there is an excess of slaughter cattle supply (Hironaka, 1986a). Cattle owners may try to reduce marketing risk by hedging, enrolling in a stabilization plan, or transferring stock to a custom feeder who has more marketing power (Alberta Agriculture, 1984).

Financial risk occurs at two levels: (1) operating loan cost risk, which in the short run is affected by the interest rate and the percentage of operating capital borrowed, and (2) intermediate and long-term loan cost risk. Interest rate variability (c_j risk) may have been a significant factor in the volatile period of the early 1980's, but generally the interest rate remains relatively fixed for the production period. A study by Apland notes the important trade-off between interest rate expense and feed costs. Custom-feeding has become important by allowing the cattle owner (operating loan on cattle) and the feedlot owner (long-term loans on fixed facilities) to share the financial risk (Alberta Agriculture, 1984).

This study focuses on market price risk in the objective function, namely that risk due to slaughter price and carcass grade price differentials. Aspects of production risk and financial risk; such as feed quality variability, animal response variability and morbidity and mortality variability, are assumed to be known with certainty at the time that cattle are purchased and put on feed, and to some extent can be controlled by the manager.

Theory of Choice Under Risk

Prescribing or predicting decision behavior under risk is difficult. It involves choosing from among a number of action alternatives for which the outcomes are represented by probability distributions. The probability distributions represent the information available for ranking the alternatives and combinations of alternatives. A powerful framework for structuring that information is the Expected Utility Theorem (EUT) or Bernoulli's Principle. This section recounts the development of the EUT, beginning with a discussion of expected value and expected utility, and ending with a review of the methods of stochastic dominance and mean-variance analysis.

Expected Value

In the theory of the competitive firm, maximum profit is obtained by producing at an output level where marginal cost equals marginal revenue. Under price uncertainty and perfect competition, the firm faces the problem of what price (price = marginal revenue) to use in setting output. It is unlikely that the output level selected will be one such that the price actually received is equal to the marginal cost of production. However, where the probability distribution of possible outcome prices is known, a logical criterion for determining output level is for the firm to equate marginal cost with the expected value of the price distribution. With this criterion decision-making under risk changes little from the assumption of certainty in that the expected value is simply used for the price.

Several problems have been recognized with the expected value approach. Borch (p. 16) noted that the criterion is valid only if the decision is repeatable, that is, if it recurs so many times such that an averaging process is taking place that eliminates risk. A few very large feedlot operators, for example, have indicated that with the volume and turnover of cattle they handle that output price risk is not a concern (Hironaka, 1986a).

A more fundamental problem with the expected value criterion is known as the St. Petersburg paradox.[1/] Developed by Daniel Bernouilli in 1732 to show that maximization of expected value could not be representative of rational human behavior, the paradox runs as follows. Peter contracts to pay Paul 1 ducat, if, at the first throw, a fair coin falls heads; he will pay 2 ducats if heads first appears at the second throw, 4 ducats at the third, and so on to 2^{n-1} ducats at the n^{th}. The expected value of Paul's winnings is given by:

$$E(\text{winnings}) = (1/2 \times 1)+(1/4 \times 2)+(1/8 \times 4)+ \ldots$$

$$1/2 + 1/2 + 1/2 + \ldots = \infty \qquad (2)$$

Theoretically, there is a potential for unlimited gain; however, if Paul was offered a choice between playing the game or receiving a finite sum of, say, 100 ducats he would opt for the latter. Clearly, maximization of expected value is not a valid criterion in this case.

Expected Utility

As a resolution of the St. Petersburg paradox, Bernoulli proposed expected utility maximization as an alternative to expected value maximization. He postulated that the utility of a risky prospect is a function of existing wealth, and recognized that the utility of an additional unit of gain was worth more to a poor man than a rich man. Von Neumann and Morgenstern provided the necessary theoretical

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[1/] A description of this game appears in several texts. See Deaton and Muellbauer, p. 387 for a concise review.

foundations for Bernoulli's assertion by showing that if a small number of axioms are satisfied then utility is measurable up to a positive linear transformation. The axioms are: (1) Completeness or Ordering, (2) Transitivity, (3) Continuity or Measurability, (4) Strong Independence, and (5) Ranking (Copeland and Weston, p. 79). Implied by the axioms is a utility function that associates a single real number (utility value) with any risky prospect. The power of the utility function lies in its cardinality.[2/] Cardinality allows an analyst to deduce the rankings and associated utility values of all alternative risky prospects on the basis of the decision-maker's revealed utility values for any two risky prospects (Baumol, p. 424). The next section defines the specific axioms of the EUT and employs them to develop the main properties of utility functions and the implied result that decision makers operate to maximize expected utility.

The Expected Utility Theorem

The axioms of cardinal utility provide the minimum set of necessary conditions for consistent and rational behavior under

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[2/]The cardinality referred to here represents an interval-level of measurement in that differences between ranked risky prospects are defined in terms of fixed and equal units. Interval-level measurement allows the study of differences between things but not their proportionate magnitudes. See Baumol (p. 421-424) and Nie et al. (p. 4) for discussions of levels of measurement.

uncertainty and form the basis of the Expected Utility Theorem.[3/]

Axiom 1--Completeness or Comparability or Ordering. For the entire set, S, of uncertain alternatives, an individual can say either that outcome x is preferred to outcome y (written as $x > y$) or y is preferred to x ($y > x$) or the individual is indifferent as to x and y ($x \sim y$).

Axiom 2--Transitivity or Consistency. If $x > y$ and $y > z$ then $x > z$. Also if $x \sim y$ and $y \sim z$, then $x \sim z$.

Axiom 3--Strong Independence. Let a gamble be constructed where an individual has a probability α of receiving outcome x and a probability $(1-\alpha)$ of receiving outcome z. [written as $G(x,z;\alpha)$]. Strong independence says that if $x \sim y$, then $G(x,z:\alpha) \sim G(y,z:\alpha)$.

Axiom 4--Continuity or Measurability. For x, y, z contained in S, where $x \geq y \geq z$, ($\geq$ means weakly preferred to or indifferent to) there exists a unique probability α such that the individual will be indifferent between y and a gamble between x with probability α and z with probability $1-\alpha$, i.e., $y \sim G(x,z;\alpha)$. This states that any outcome can be restated as a function of the most preferred and least preferred outcomes.

Axiom 5--Ranking. If $x \geq y \geq z$ and $x \geq u \geq z$, then if $y \sim G(x,z:\alpha_1)$ and $u \sim G(x,z:\alpha_2)$ it follows that if $\alpha_1 > \alpha_2$ then $y > u$, or if $\alpha_1 = \alpha_2$ then $y \sim u$.

[3/]The notation and conceptual outline follow Copeland and Weston.

Individually, the preceding five axioms do not appear completely unreasonable. Together with the additional assumption that people prefer more wealth to less, the axioms lead to the powerful result that decision makers always seek to maximize their expected utility of wealth. This development follows from the Expected Utility Theorem (EUT) which states that if a decision maker accepts the axioms of ordering, transitivity, continuity, independence and ranking, then there exists a utility function for the decision maker that reflects the decision maker's preferences for outcomes and a subjective probability distribution that reflects the decisions maker's personal judgement of the choices available (Anderson, Dillon and Hardaker, p. 69). The utility function has two properties: (1) it will be order preserving and (2) expected utility can be used to rank combinations of risky alternatives. Order preserving means that if $U(x) > U(y)$, it implies that $x > y$, and the expected utility of a gamble between two risky alternatives is defined by

$$U[G(x,y:\alpha)] = \alpha\, U(x) + (1-\alpha)\, U(y).$$

To show how the axioms give rise to utility functions that are order preserving, consider the set of risky outcomes, S, which is assumed to be bounded above by outcome a and below by outcome b. Next consider two intermediate outcomes x and y such that

$$a \geq x \geq b \text{ and } a \geq y \geq b$$

By using Axiom 4 (Continuity), gambles as illustrated in Figure 3 can be constructed for a and b by choosing unique probabilities for x and y such that

$$x \sim G[a,b:\alpha(x)], \text{ and } y \sim G[a,b:\alpha(y)]$$

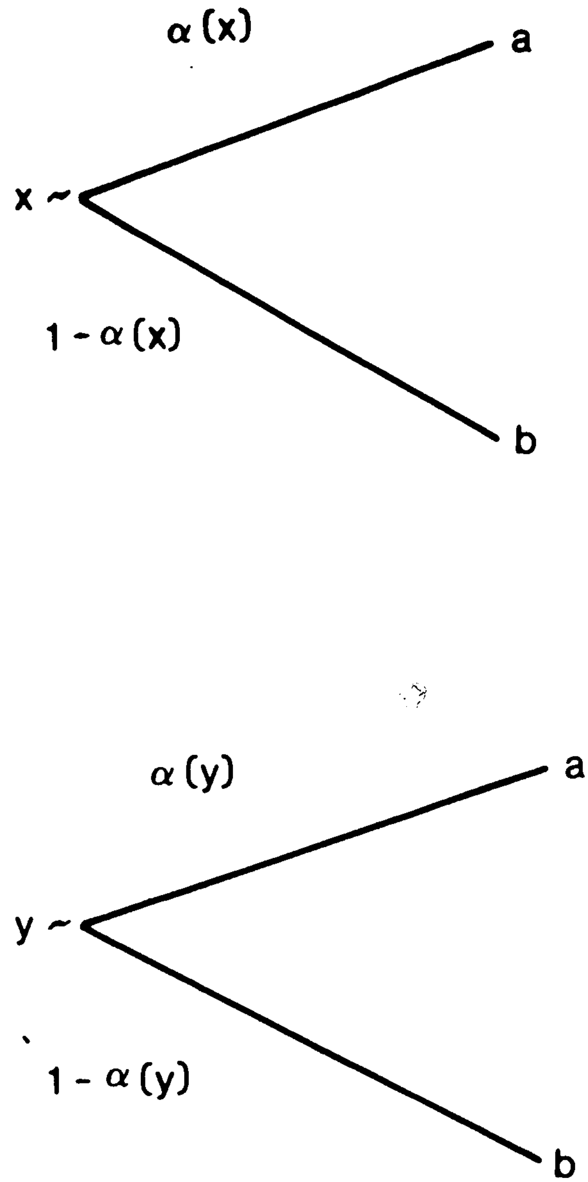

Figure 3 Elementary Gambles

Next using Axiom 5 (ranking) it can be shown that the probabilities $\alpha(x)$ and $\alpha(y)$ can be interpreted as numerical quantities which uniquely rank x and y. By Axiom 5,

If $\alpha(x) > \alpha(y)$, then $x > y$.

If $\alpha(x) = \alpha(y)$, then $x \sim y$.

If $\alpha(x) < \alpha(y)$, then $x < y$.

This proves the order preserving property of utility functions. By assigning any numbers to the upper and lower bound outcomes of a and b respectively, cardinal utility values can be assigned to the intermediate outcomes by the process of forming simple gambles.

Proving the second property of utility functions, that expected utility can be used to rank risky alternatives, involves developing a compound or combination of risky alternatives and showing that the resultant compound lottery can be reduced to an expected utility expression. Consider again the elementary gambles illustrated in Figure 3. Next, consider a third alternative, z. By Axiom 3 (Strong Independence) it is assumed that the alternative z does not affect the relationship between x and y. Thus by Axiom 4 (Continuity) there must exist a unique probability $\beta(z)$ that would make outcome z indifferent from a gamble involving x and y as illustrated in Figure 4. A compound lottery can be expressed by relating z to the elemental prospects a and b. Tracing the branches of the decision tree represented in Figure 4 it can be seen that outcome z will be indifferent to outcome a with probability $\Gamma = \beta(z)\alpha(x) + [1-\beta(z)]\alpha(y)$ and to outcome b with probability $(1-\Gamma)$(see Figure 5). The corresponding gamble can be written as:

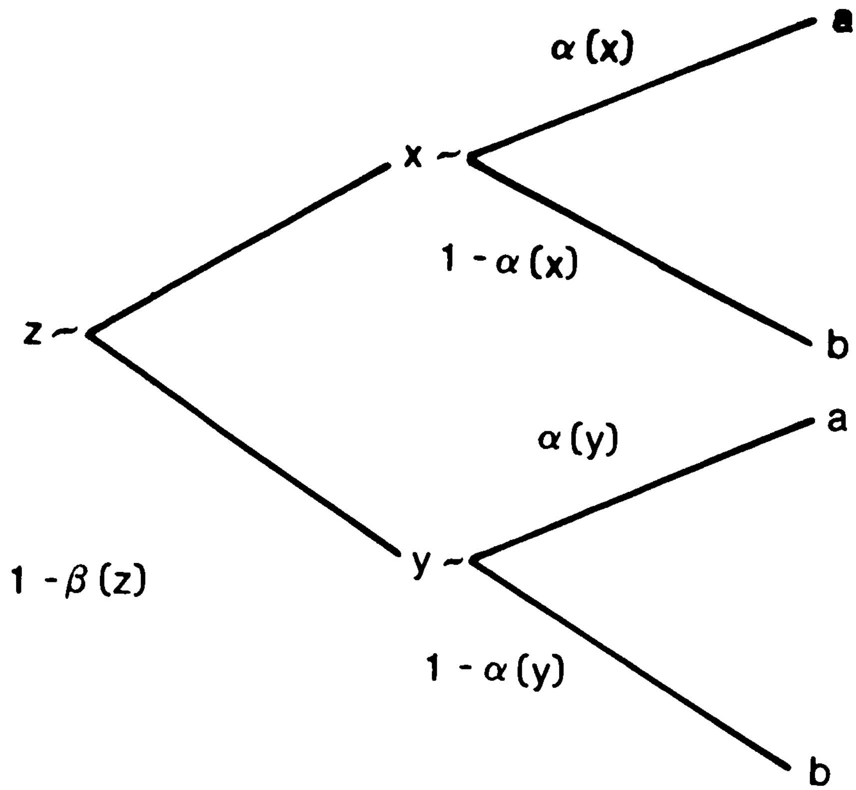

Figure 4 Outcome z compared with a gamble between outcomes x and y.

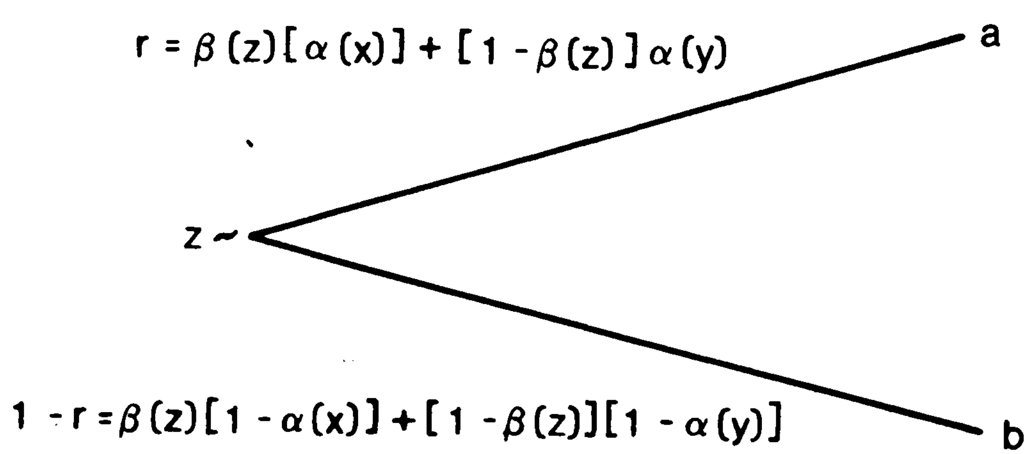

Figure 5 Outcome z related to elementary prospects a and b.

$$z \sim G\,\{a,b{:}\beta(z)\alpha(x) + [1-\beta(z)]\alpha(y)\} \text{ or } z \sim G(a,b{:}\Gamma).$$

From Axioms 4 (Continuity) and 5 (Ranking) it is known that the utilities of x and y can be represented by their probabilities, namely $U(x) = \alpha(x)$ and $U(y) = \alpha(y)$. Thus, the gamble can be rewritten as:

$$z \sim G\,\{a,b{:}\beta(z)U(x) + [1-\beta(z)]U(y)\}. \tag{3}$$

The compound lottery can now be reduced to an expected utility expression by again employing Axioms 4 and 5 which allow the probability of outcome z to be used as cardinal measure of its utility relative to the elemental prospects of a and b. Thus expression 3 can be rewritten as:

$$U(z) = \beta(z)U(x) + [1-\beta(z)]U(y) \tag{4}$$

Equation 4 says that the utility of x is equal to the probability of x times its utility plus the probability of y times its utility, and thus demonstrates that the correct ranking function for risky alternatives is expected utility. The expected utility represents a linear combination of the utilities of the outcomes. In general the expected utility of wealth can be written as:

$$E[U(W)] = \Sigma\, U(w_i)\, f(w_i). \tag{5}$$

If the utility function is continuous and differentiable, expected utility is given by the integral:[4/]

[4/]The notational system is changed to conform with statistical conventions. A capital letter is used to denote random variables and a lower case letter is used to denote continuous outcomes of the random variable.

$$E[U(W)] = \int_a^b U(w)\ f(w)\ dw,\ a < w < b \qquad (6)$$

where

U(w) is the utility function,

f(w) is the probability density function.

With the additional assumption that decision makers prefer more wealth to less, equations 5 and 6 imply that decision makers will calculate the expected utility of wealth for all possible alternative actions and then choose the outcome that maximizes their expected utility of wealth. This is the main result and usefulness of the Expected Utility Theorem. It implies a unified theory of utility (preference) and subjective probability (degree of belief) (Anderson, Dillon and Hardaker, p. 69). The next section explores further the concept of a decision maker's risk attitude, as reflected by the characteristics of the utility function, and looks at the effects of different risk attitudes on decision choices in a risky environment.

Utility Functions and Risk Attitudes

Since the exact characteristics of utility functions are unique to individuals, it would seem that for empirical applications, a detailed specification of the utility function would be necessary. However, meaningful, but more generalized results, are often attainable by classifying decision makers according to the general characteristics of their utility functions. At a high level of generality, attitudes can be ordered into risk-averse, risk-neutral, and risk-preferring categories. More specifically, within the class of risk-averse agents, individuals can be further ordered according to levels of risk aversion and their response to changes in wealth or other objects of utility. Such ordering procedures enrich the capacity to evaluate and predict the responses of decision makers to changes in the risk characteristics of their environments.

The first distinction commonly made in regard to the risk attitudes of individual decision makers is based on the shape of their utility functions defined with respect to wealth. Three types of risk attitudes are generally defined: risk-averse, risk-neutral and risk-preferring. For all three types, it is assumed that the marginal utility of wealth is positive $[MU(W)>0]$ and that utility is non-negative for any outcome. As depicted in figure 6 the possible shapes may be classified as concave (to the horizontal axis), linear, or convex. Concavity (convexity) reflects diminishing (increasing) marginal utility, while linearity reflects constant marginal utility.

The differences between the three utility functions relate to the attitude of a decision maker to a risky outcome as opposed to a certain prospect where both have the same expected value. Consider a gamble between two prospects a and b. Let the probability of receiving a be α, the probability of b be $(1-\alpha)$ and the gamble designated as $G(a,b:\alpha)$. The expected value of the gamble is calculated as:

$$E\,[G(a,b:\alpha)] = \alpha\, a + (1-\alpha)\, b \qquad (7)$$

The decision maker that prefers the certain prospect to the gamble is risk averse, the decision maker that is indifferent is risk neutral

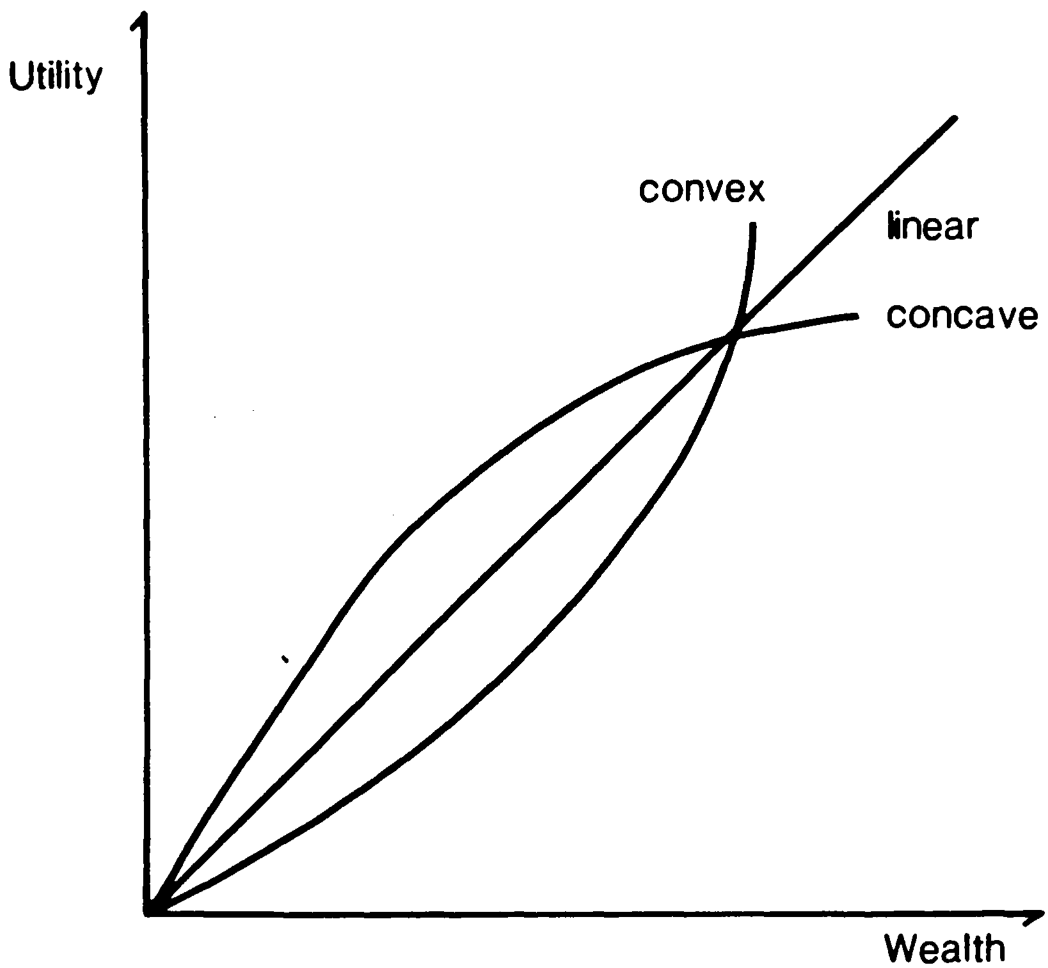

Figure 6 Shapes of Utility Functions

and one that prefers the gamble is risk loving. In general, if the utility of expected wealth is greater than the expected utility of wealth, the individual will be risk averse. Restated, the three definitions are:

$$\text{If } U[E(W)] > E[U(W)] \Rightarrow \text{risk averse} \quad (8)$$

$$\text{If } U[E(W)] = E[U(W)] \Rightarrow \text{risk neutral} \quad (9)$$

$$\text{If } U[E(W)] < E[U(W)] \Rightarrow \text{risk loving} \quad (10)$$

Figure 7 displays equation 8 for the risk averse decision maker.

Most economists agree that the firm under uncertainty displays risk averse behavior.[5/] Within this broad classification of behavior more specific and discriminating measures of risk aversity have been developed. The simplest measure is the risk premium (π), which is defined as the difference between the expected value of a gamble and its certainty equivalent. The certainty equivalent is that value of wealth or income that yields the same amount of utility as the expected value of the gamble. In Figure 8 the expected value of a gamble between outcome y_1 and y_2, $G(y_1,y_2:\alpha)$, is shown as $E(y)$. The expected utility value of the gamble is shown as $EU_i(y)$.

[5/] Friedman and Savage (p. 293-297) argued that decision makers' utility functions should display both concave and convex segments to represent the totality of human behavior. The concave portion may represent risk averse behavior for business decisions, while the convex portion may reflect risk preferring behavior for casino-type gambling. Robinson and Barry (p. 31) note, however, that empirically estimated utility functions have not substantiated the Friedman and Savage claim. For the most part it is typical to consider only the concave portion of a utility function when analyzing behavior.

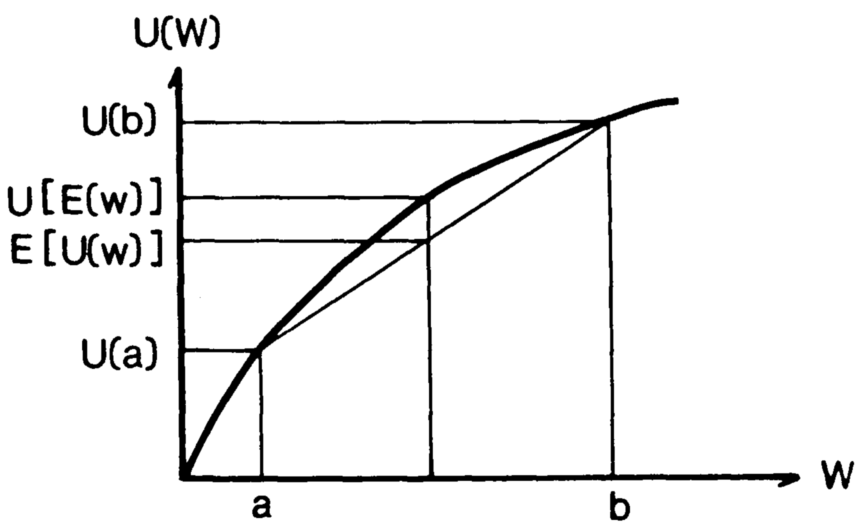

Figure 7 Concave utility function of the risk averse decision maker

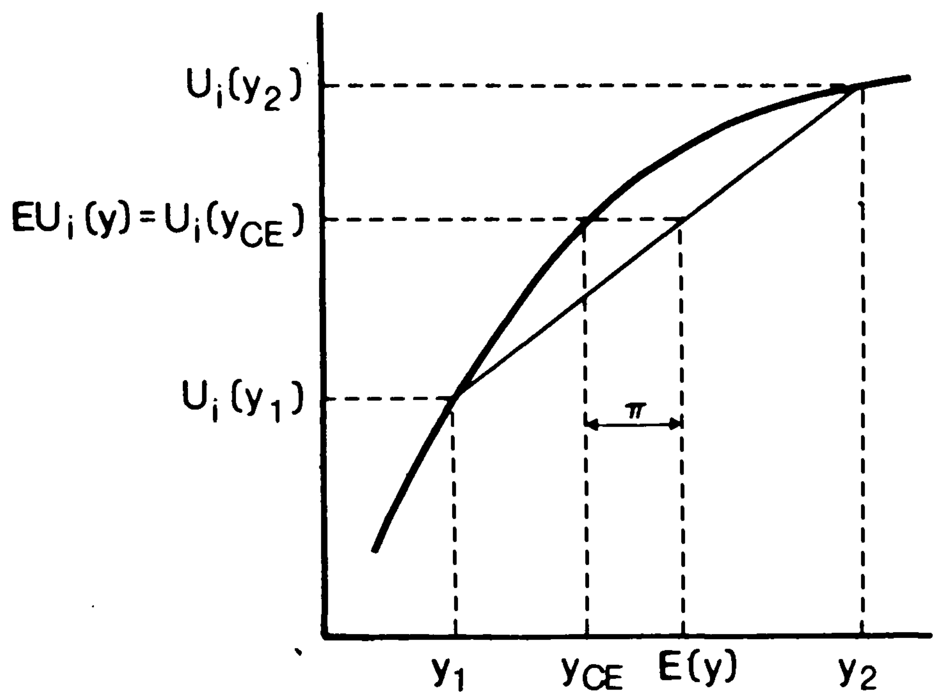

Figure 8 Concave utility function showing the risk premium

The level of wealth that generates the same utility value as expected value of the gamble is y_{CE}, or the certainty equivalent. The risk premium (π) is positive for concave utility functions and represents the maximum amount of wealth an individual would be willing to give up in order to avoid the gamble, and receive the certainty equivalent wealth. The larger the risk premium, the more risk averse the individual, given the choices and the amounts of risk involved. Since the risk premium is only a single parameter description of a utility function and may not be unique to a particular utility function, Robison and Barry (p. 31-32) note that it has limited usefulness in ordering decision makers according to their risk attitudes and serves only as a rough measure of risk aversion. More discriminating measures focus on the slope of the marginal utility function. For example, the Pratt-Arrow absolute risk aversion measure is preferred as a means of ordering decision makers versus using a nonunique utility function. Mathematically, absolute risk aversion is defined as:

$$R(y) = \frac{-U''(y)}{U'(y)} \tag{11}$$

where $U'(y)$ and $U''(y)$ represent the first and second derivatives with respect to income, respectively.[6] Another, but related measure of risk aversion is derived by multiplying absolute risk aversion by the level of income to obtain relative risk aversion or Rr(y). It is defined as:

$$Rr(y) = \frac{- U''(y)\ y}{U'(y)} \tag{12}$$

Constant relative risk aversion implies that an individual will have constant risk aversion to a proportional loss of income even though the absolute loss increases as income does. Both measures have positive values for risk averters, and since they are not affected by linear transformations of the utility function, their uniqueness permits interpersonal comparisons at comparable wealth levels.

More importantly, the sign of R'(y) indicates how risk aversion attitudes change as wealth increases. If $R'(y) < 0$, the most usual assumption, decision makers are said to display decreasing absolute risk aversion (DARA). This means, for example, that a $1,000 gamble would be trivial to a billionaire, but a pauper would probably be very

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[6] U'(y) indicates the slope of the utility function. For von Neumann-Morgenstern utility functions U'(y) is positive, indicating utility increases as wealth increases of the marginal utility of wealth is positive. U''(y) indicates the direction of bending of the utility function. As a function bends less in a downward or negative direction, the risk premium decreases. Risk aversity implies a concave utility function or bending in a negative direction ($U'' < 0$) and a positive risk premium. $U'' < 0$ implies the marginal utility of wealth decreases as wealth increases. Risk neutrality implies a linear utility function or no bending ($U'' = 0$) and a risk premium of zero. Risk preferring implies bending in a positive direction ($U'' > 0$) and a negative risk premium. Thus either U''(y) or the sign on the risk premium can be used to classify decision makers into the risk averse, risk neutral and risk loving categories.

risk averse toward it. In other words, the risk premium for the gamble decreases as the decision maker moves to higher and higher levels of wealth. If $R'(y) = 0$, the decision maker exhibits constant absolute risk aversion (CARA), meaning that the risk premium remains constant regardless of changes in wealth. Lastly, $R'(y) > 0$ implies increasing absolute risk aversion (IARA), meaning that the risk premium for the same gamble increases with increases in wealth.

These more discriminating measures of risk aversion allow closer examination of some of the more commonly used utility functions. The logarithmic utility function, first proposed by Bernoulli, exhibits all the intuitively plausible properties: the marginal utility of wealth is positive and decreases with increasing wealth, the measure of $R'(y)$ decreases with increasing wealth and $Rr'(y)$ is constant. It is written as:

logarithmic utility function $U(y) = \ln y$ (13)

first derivative, marginal utility, $U'(y) = 1/y$

second derivative, change in MU

$$U''(y) = \frac{-1}{y^2} < 0$$

with respect to income

$$R(y) = \frac{-U''(y)}{U'(y)} = \frac{-(-1/y^2)}{1/y} = \frac{1}{y}$$

$$R'(y) = -1/y^2 < 0$$

$$Rr(y) = (1/y)\ y = 1$$

$$Rr'(y) = 0$$

There is no evidence, however, that the logarithmic utility function accurately represents the preferences of all individuals (Robison and Barry, p. 44). Under the assumption that a quadratic function locally approximates any concave utility function[7/], many studies have employed the form,

$$U(y) = y - by^2, \; b > 0 \text{ and } (1-2b) > 0 \qquad (14)$$

as a representation of risk averse decision makers. Unfortunately,

$$R(y-by^2) = \frac{2b}{1-2by}$$

and

$$R'(y-by^2) = \frac{(2b^2)}{(1-2by)^2} > 0$$

imply an increasing absolute risk aversion (IARA) risk attitude, which is rarely observed. Since the quadratic utility function assumption forms one basis for the EV (Expected Value-Variance) analysis approach to expected utility maximization, the IARA result is often cited as a criticism of the EV approach (Johnson, p. 50).

Pratt tied the unique measure of absolute risk aversion, R(y), to the risk premium concept as a means for ordering risk averse individuals facing small gambles and having the same level of wealth. In the small, or at a point, the relationship is:

$$\pi = \frac{1}{2} R[E(y)] \sigma^2 \qquad (15)$$

[7/] A second-order Taylor series approximation would, for example, lead to a quadratic function approximation in a neighborhood.

where $E(y)$ represents a specific value of income y, and π is the risk premium the individual is willing to pay to avoid the uncertainty of the gamble. Equation 15 implies that the risk premium increases directly as the measure of absolute risk aversion increases. Thus on a local basis (i.e., for a specific gamble and specific level of wealth) individuals can be ordered as to their relative risk aversity by their absolute risk aversion function or by the size of their risk premium.

However, on a global basis for one individual to be considered more risk averse than another requires that the individual's utility function bend at a greater rate everywhere than does the utility function of the other individual. If individual i is more risk averse than individual j then $R_i(y)$ must be consistently greater than $R_j(y)$ at all levels of wealth and no matter what the probability distribution of choices.[8/] The difference between risk aversion measured locally and globally is best illustrated by example. Consider two individuals i and j whose absolute risk aversion functions $R_i(y)$ and $R_j(y)$ are described in Figure 9 panel A. Individual i exhibits DARA, while individual j shows IARA. Yet when facing outcomes y_1 and y_2 with mean outcome $E(y)$, individual i is locally more risk averse than individual j since $R_i[E(y)] > R_j[E(y)]$. As the outcomes they face change to y_3 and y_4 with mean outcome $E(y^*)$, individual j is locally more risk averse than individual i,

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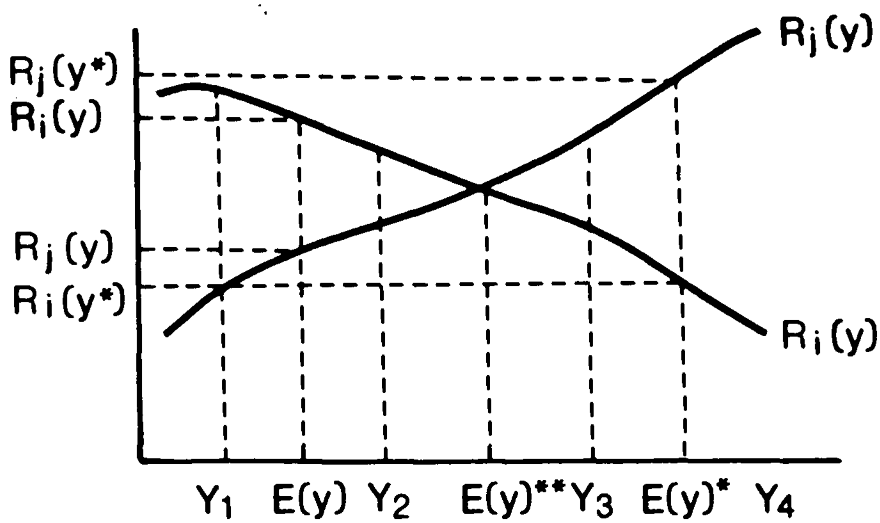
[8/] Robison and Barry (p. 36) prove this condition by showing that if $U_i(y) = g\,[U_j(y)]$, where $g\,(\bullet)$ is a concave transformation and $g'>0$ and $g''>0$, then $R_i(y) > R_j(y)$.

Panel A



Panel B

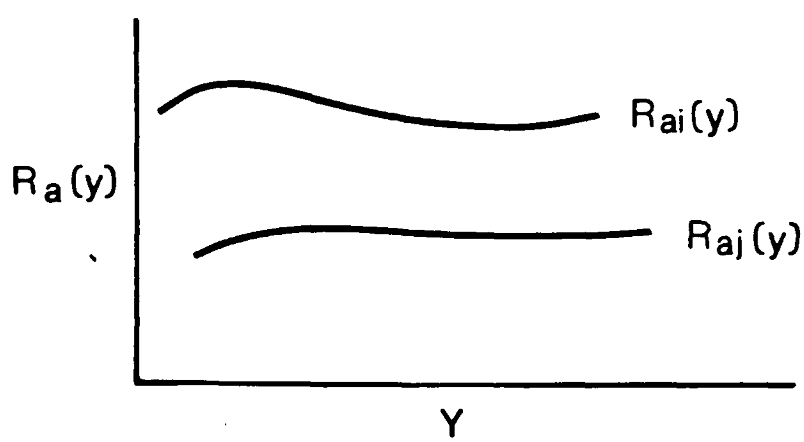


Figure 9 Comparison of absolute risk aversion functions $R_i(y)$ and $R_j(y)$ over outcomes y for individuals i and j

since $R_j[E(y^*)] > R_i[E(y^*)]$. At $E(y^{**})$ the local risk aversion result will be indeterminate and will vary with the probability weights assigned to the outcomes. Only if $R_i(y)$ is consistently greater than $R_j(y)$ (as in Figure 9 Panel B) can individual i be considered, globally more risk averse than the j^{th} individual.

Robison and Barry (p. 36) cite several important consequences arising from individual i being globally more risk averse than individual j. The consequences have importance in the later consideration of responses to risk. For example, the degree of hedging, or the degree of participation in a stabilization program reflect the extent to which "safe" assets are held in preference to "risky" assets when production is undertaken in the face of price uncertainty. The consequences cited are:

1. For every lottery faced by individuals i and j, individual i will pay a larger risk premium (π_i) than individual j (π_j) in order to eliminate uncertainty.
2. Equivalently, since $\pi = E(y) - y_{CE}$, where y_{CE} is the certainty equivalent income, the certainty equivalent income for individual j exceeds the certainty equivalent income for individual i.
3. Individual i's utility function curves at a greater rate than individual j's; that is, i's marginal utility declines at a faster rate. This is true if $U_i(y) = g[U_j(y)]$, where $g(\bullet)$ is a concave transformation.
4. A lottery exists that would be acceptable to individual j, but not to individual i.

5. When facing choices that combine a certain choice and a single risky asset, individual i's preferred choice contains more of the safe asset than individual j's.

It is important to note that these consequences can only be inferred where risk aversion is assured on a global basis. Yet the above conditions for global risk aversion are so strict that in practice few decision makers could be considered more risk averse than others at all levels of wealth. As an alternative, Robison and Barry (p. 37-38) propose a general risk aversion measure called the average risk attitude measure. This measure is important as it provides a link from expected utility theory to the assumptions made under which EV analysis is proffered as an approximation to the expected utility approach. Essentially the average risk aversion measure orders decision makers in reference to their risk aversion for a particular utility function. The referencing utility function proposed by Robison and Barry is:

$$U(y) = -e^{-\alpha y} \tag{16}$$

where α is a constant and an average risk attitude measure.[9/]

To see how the referencing parameter α can be used as index of risk aversion attitudes of decision makers facing a particular probability distribution of outcomes $g(y)$, consider the k^{th} individual's utility function, $U(y)$. Recall that the utility of a certainty equivalent of wealth, $U[(y_{CE})]$, is equivalent to the

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[9/] For $U(Y) = -e^{-\alpha y}$, $U'(y) = \alpha e^{-\alpha y}$ and $U'' = -\alpha^2 e^{-\alpha y}$. Forming the ratio $R(y) = -U''(y)/U'(y)$ and cancelling give $R(y) = \alpha$.

expected utility of a gamble, $E[U(y)]$, where $E[U(y)] = \Sigma\, U(y)f(y)$, as per equation 5. Thus:

$$U(y_{CE}) = \Sigma\, U(y)f(y) \quad \text{or} \quad U(y)f(y)\, dy. \qquad (17)$$

Taking the inverse the certainty equivalent is:

$$y_{CE} = U^{-1}[\Sigma\, U(y)f(y)] \qquad (18)$$

The average risk aversion coefficient, α, is now determined by referencing the certainty equivalent calculated in equation 18 to the reference utility function of equation 16 and solving for the value of α that satisfies the following equation:[10/]

$$y_{CE} = \frac{-\ln \Sigma\, e^{-\alpha y} f(y)}{\alpha} \qquad (19)$$

For any k^{th} individual, given that a certainty equivalent can be calculated for a particular gamble, a value of α_k can be determined and used to compare the degree of risk aversion to other individuals. The relationship between α and y_{CE} is inverse. If y_{CE} for individual is greater than y_{CE} for individual j, then $\alpha_i < \alpha_j$. The ordering of individuals by the average risk aversion coefficient provides a more general measure than local comparisons of absolute risk aversion functions, R(y)'s. However, it is still limited to comparison of decision makers' risk attitudes where they face a particular distribution of outcomes. When the particular distribution of outcomes is normally distributed with mean E(y) and variance σ^2, the average risk aversion concept provides a

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10/ the equation is determined by substituting $U(y) = e^{-\alpha y}$ into equation 17.

result useful in the expected value-variance (EV) approach to expected utility maximization. In equation 17, substituting in the constant absolute risk averse utility function $-e^{-\alpha y}$ for U(y) and the normal distribution $(2\sigma^2\pi)^{-1/2}e^{-(y-\bar{y})^2/2\sigma^2}$, where $\bar{y}$ = E(y), for f(y) yields:

$$U(y_{CE}) = \int [-e^{-\alpha y}(2\sigma^2\pi)^{-1/2}\ e^{-(y-\bar{y})^2/2\sigma^2}]\ dy$$

$$= -\int [(2\sigma^2\pi)^{-1/2}\ e^{-(y-\bar{y})^2/2\sigma^2-\alpha y}]\ dy \qquad (20)$$

The solution as developed separately by Freund and Hildreth yields:

$$y_{CE} = E(y)\ -(\alpha\sigma^2/2)$$

which, since $\pi = E(y) - y_{CE}$, can be rearranged to:

$$\pi = \frac{\alpha\sigma^2}{2} \qquad (21)$$

This is essentially Pratt's approximation, as given in equation 15. Since the average risk coefficient α is constant and no moments above the second exist, the expression is an exact equality and no longer just a local measure. In other words, at all levels of wealth, the decision maker's average risk averse coefficient is constant. If the further assumption is made that all decision makers have constant absolute risk aversion functions, one could make global inferences about their relative degree of risk aversion. Another implication is that, at least locally, variance can be traded for expected returns at the rate of $\alpha/2$ without affecting the well-being of the decision maker, or the decision maker's certainty equivalent income. This is an important result in the EV approach to expected utility maximization, which is considered again in later sections.

This section on utility functions and risk attitudes established concepts for identifying risk dispositions and for ordering individuals according to their risk attitudes when faced with similar probability distributions. The next section relates this information and the main result of the Expected Utility Theorem, that individuals act to maximize their expected utility, to the concepts and methods of ordering risky choices. Specifically, expected value-variance analysis is introduced as a valid empirical approximation to expected utility maximization.

Ordering Risky Choices

The focus of decision theory is to develop rules for ordering risky alternatives. The discussion thus far has developed the approach of the expected utility theorem (EUT), which advances a set of reasonable axioms about how an individual ought to order risky prospects. It then uses the axioms to deduce a cardinal utility function[11/] which reflects all that is known about the effects of monetary outcomes on the decision maker's risk attitudes. Given information on the probability distributions of the outcomes of the various risky alternatives, the main result of the EUT is that the

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[11/]"Cardinal" utility here should not be confused with the cardinal utility of neoclassical economics. It is not a measure of "strength of feelings" or pleasure intensity, but rather an operational measure for ranking risky alternatives in the absence of the decision-maker. Since it only predicts rankings of alternatives some theorists have called it an ordinal measure. Baumol (p. 431-432) discusses the difference in greater detail.

decision maker should act to maximize his expected utility over all the alternatives. Implied in this process is a complete ordering of all alternatives based on the absolute differences between the various expected utility indexes calculated for each of the risky alternatives. For the individual decision maker, the ordering process reveals a specific answer. The answer, however, has no applicability to other decision makers unless the underlying utility function is deemed to be representative of a class of decision makers. Herein lies the trade off that exists in empirical applications of the EUT. A complete ordering of risky choices requires substantial information about the risk attitudes of the class of decision makers being studied, but increases the chances of ordering errors if the attitudinal information is wrong and not really representative. Cochran refers to this inaccurate ranking of alternatives as Type I error. A partial ordering of choices requires less information on risk preferences but increases the chance of Type II error, that is, where the analysis does not detect a difference between two alternatives, when in fact the class of decision makers prefers one alternative over the other. This section discusses the methods employed to extend the results of the EUT beyond the individual decision maker; first by commenting briefly on the more general approach of stochastic dominance, and lastly on the method of expected mean-variance (EV) analysis which is employed in this study.

Stochastic Dominance

Stochastic dominance techniques rank alternative risky strategies by focusing on the explicit representation of the probability distributions. Implementation of the EUT requires that both probability distributions and risk preferences be included in the analysis. Rather than imposing any functional restriction on the shape of a representative utility function, stochastic dominance methods only implicitly depict the risk preferences of the class of decision makers being considered. For example, first degree stochastic dominance (FSD), assumes only that the class of decision makers prefers more income to less ($U' > 0$). Second degree stochastic dominance (SSD), adds the assumption that decision makers are risk averse ($U'' < 0$), and third degree stochastic dominance (TSD) further assumes that risk aversion decreases as wealth increases ($U''' > 0$). Stochastic dominance with respect to a function (SDWF), places upper and lower bounds on the value of the absolute risk aversion coefficient $R(y)$.

Details regarding stochastic dominance procedures are available elsewhere[12/], but several problems limit their empirical use. Cochran (1986) reviews the empirical limitations in five areas: 1) generation of probability distributions, (2) selection of preference intervals and scaling of outcome variables, (3) diversification

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[12/] See Anderson, Dillon and Hardaker (p. 282-298); Copeland and Weston (p. 92-101); Cochran; and Robison and Barry (p. 43-54).

issues, (4) the lack of statistical tests for differences in expected utility, and (5) the validity of the EUT. Most limiting in the context of this study is the diversification or portfolio building problem. Because the cumulative probability distributions used by stochastic dominance do not take into account any covariances, optimal combinations of the various strategies cannot be investigated. Although McCarl et al. (1987) offer a series of guidelines to determine when convex combinations of the strategies may need to be considered, the choice set still has to be articulated prior to the analysis and probability distributions constructed before the rankings can be completed. Another limitation is simply computational. Stochastic dominance requires pairwise comparison of all alternatives and the development of numerical integration algorithms specific to the functional forms of the cumulative probability distributions determined in the empirical problem. For these reasons, expected value-variance (EV) analysis remains the most often employed empirical technique for implementation of the expected utility theorem with continuous decision variables.

Expected Value-Variance Analysis

Expected value-variance (EV) analysis approximates the specific methods of expected utility maximization and is an alternative to the generalized methods of stochastic dominance for ordering risky choices into efficient and inefficient sets. Essentially, the EV criterion assumes that the decision maker's preferences among alternative risky prospects are based on expected income, E(y), and on the associated income variance, σ^2. Justifications for the EV approach range from theoretical assumptions, such as quadratic utility or normality, to its ability to approximate expected utility model efficient sets. In addition, the EV approach offers the advantage of ease of computation, being solvable by quadratic or linear programming formulations. Utility functions with preferred theoretical properties often have expected values that are difficult to evaluate numerically, and higher order polynomials that might be used to approximate more desirable functions can lead to nonconvex programming problems (Hazell and Norton, p. 80). Furthermore, EV analysis has the ability to examine portfolio problems. This section reviews the approach and justifications of EV analysis and extends the procedural aspects to the portfolio problem.

The EV Analytical Approach

The methodology of EV analysis can be illustrated by employing one of its simplest justifications; that of assuming the decision maker or class of decision makers are risk averse and represented by a quadratic utility function of the form:

$$U(y) = y - by^2 \quad (22)$$

where $b > 0$ must hold. If y is stochastic with mean E(y) and variance σ^2, then according to the decision rule of the EUT, the expected utility is given as:

$$E[U(y)] = E(y) - b\, E(y^2)$$
$$= E(y) - b\, \{ Ey^2 - [E(y)]^2 + [E(y)]^2 \}$$
$$= E(y) - b\, \{ \sigma^2 + [E(y)]^2 \} \qquad (23)$$

equation 23 implies that risk is based on expected values and variances of choices. For $b > 0$, an increase in σ^2 while holding $[E(y)]^2$ constant increases the risk of choices and reduces their expected utility. The decision maker will prefer strategies having higher expected income and lower variances of income.

Graphically, the decision maker's preferences between expected value of income and variance of income can diagrammed as in Figure 10. Each dot describes the expected value and variance of an alternative action, or plan or choice. Choices A_i and A_j have the same expected value, but A_i has a lower variance. Thus A_i is preferred according to the EV criterion. Choices along BC represent an efficient set, that is, they have equivalent expected values but smaller variances than corresponding choices interior to BC. Choices below the efficient set yield lower utility to the decision maker and are thus inefficient. The optimal choice is revealed by introducing an isoutility map onto the efficient set or EV boundary. The utility map reflects the risk averse nature of the individual decision maker or class of decision makers in that isoutility curves are concave to the vertical axis, indicating that higher variance of returns must be accompanied by higher expected returns to yield the same utility as lower variance, lower expected return choices. The optimal choice at point A_i represents the highest achievable level of utility.

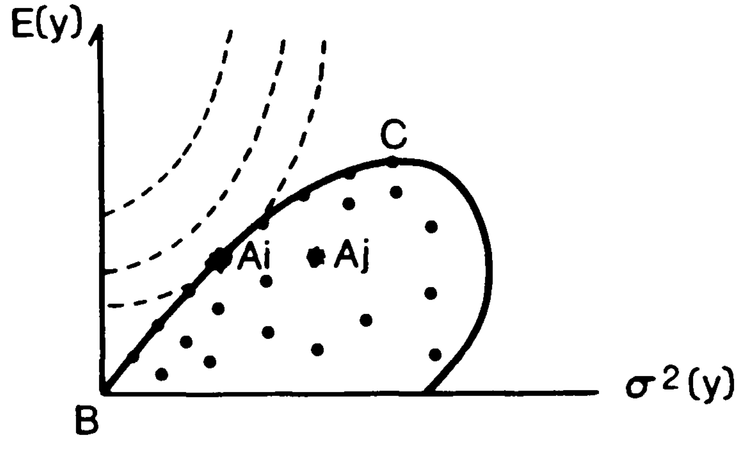

Figure 10 Expected value-variance efficient choice set

Extension of the EV Approach to the Portfolio Problem

An extension of the above concepts of EV analysis can be made to the problem of portfolio selection. Instead of considering choices of an all of this or all of that nature, portfolio selection is concerned with situations where combinations of risky prospects are feasible and pertinent. In the context of the feedlot problem this implies, for example, that rather than having a decision problem of hedge or no-hedge, that various combinations of hedging and partial hedging would be considered. Another example would be that it may be risk reducing (through the capture of time and grade effects) to simultaneously produce different types of finished cattle as the result of different feeding programs. The objective is to select the portfolio that maximizes the decision maker's expected utility. In reference to Figure 10 each of the points along BC now represent either combinations of risky prospects, or some individual prospects that are EV efficient by themselves. The optimal choice at point A_i thus either portrays a single prospect or a portfolio of risky prospects which maximizes utility.

Although the analytical shift from the all or nothing choice problem to the portfolio problem appears straightforward, an important theoretical difference remains. In the portfolio problem, the shape of the EV efficient set or boundary is the result of imperfect correlations between risky prospects in the portfolios and the assumption that decision makers are risk averse. To see this result clearly, consider the case of two risky prospects x and y. In Figure

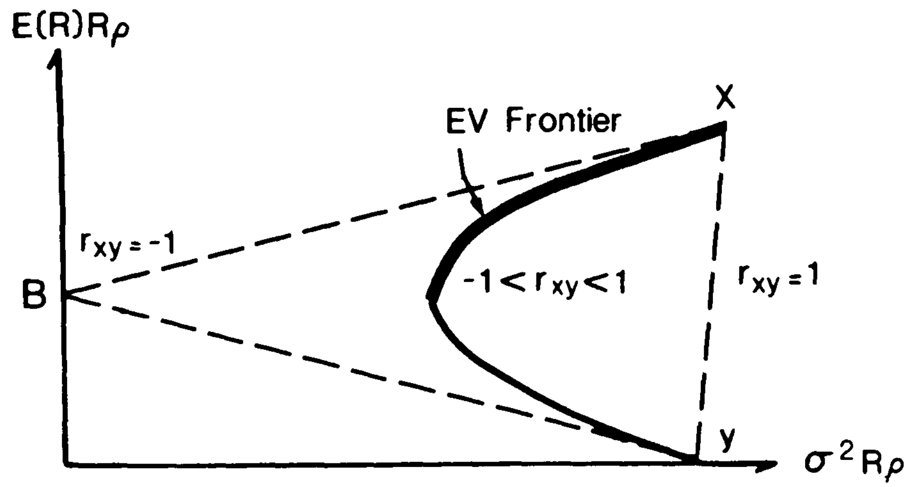

Figure 11 Effect of diversification on the distribution of portfolio returns with varying degrees of correlation

Source: Anderson, Dillon and Hardaker (p. 193)
Copeland and Weston (p. 159)

11, points x and y, respectively, denote single prospect portfolios where all of the units of investment funds are devoted to x or to y. In the context of the feedlot problem, x could represent a production-marketing strategy of feeding calves a high rate of gain to a target weight of 950 pounds with a no hedge plan; whereas y could represent a strategy of feeding calves to a target weight of 1050 pounds with participation in the Canadian Tripartite Beef Stabilization Plan. For combinations of x and y, let b represent the proportion of the investment budget devoted to x, and let (1-b) be the proportion devoted to y. The expected return of a portfolio will be:

$$E(R_p) = a\,E(R_x) + (1-a)\,E(R_y), \text{ where} \quad (24)$$

R_p is the return on the two prospect portfolio,

R_x is the return on prospect x, and

R_y is the return on prospect y.

The variance of a portfolio will be:

$$\sigma_p^2 = a^2\,\sigma_x^2 + (1-a)^2\,\sigma_y^2 + 2a(1-a)\,r_{xy}\,\sigma_x\sigma_y, \text{ where} \quad (25)$$

σ_p^2 is the variance of the portfolio,

σ_x is the standard deviation of prospect x,

σ_y is the standard deviation of prospect y, and

r_{xy} is the correlation coefficient between x and y.

Figure 11 illustrates the possible shapes of the EV boundary for combinations of $E(R_p)$ and σp^2 at various levels of correlation of the returns between prospects x and y. For the case of perfect positive correlation ($r_{xy} = 1$), the portfolio combinations lie on a straight line joining x and y. If x and y are perfectly negatively correlated (rxy = -1), the various combinations of x and y are shown by two straight lines that intersect at point B, which represents a mixed portfolio with zero variance. If x and y are less than perfectly correlated ($-1 < r_{xy} < 1$), which is the usual case, the variance reducing effect of diversification is partially realized and shown by the curve joining x and y. This is the typical shape of the EV frontier for the risk averse decision maker.

Generalizing these results to n risky prospects gives the following portfolio expected value and variance results:

$$E(R_p) = \sum_{i=1}^{n} b_i R_i \quad (26)$$

$$\sigma^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} b_i b_j \, r_{ij} \, \sigma_i \sigma_j \quad (27)$$

With n risky prospects the EV efficient set has the same shape as in the two prospect case. The only difference is that with many alternatives some will fall in the interior of the opportunity set. The EV frontier will be composed of various portfolios and some individual prospects that are mean-variance efficient by themselves (Copeland and Weston, p. 172). Determination of the optimal portfolio requires estimation of all the means, variances and covariances of risky prospects, and would be located at the point of tangency between the EV frontier and the highest utility indifference curve.

Alternative Justifications of the EV Approach

As discussed earlier in the section on risk aversion, the assumption of a quadratic utility function implies that the decision maker is characterized by increasing absolute risk aversion (IARA) and that at some level of income marginal utility becomes negative. Both are implausible conclusions in terms of economic theory. An alternative justification for the EV approach to the EUT exists if the choices facing the risk averse decision makers have outcomes that are normally distributed. For most agricultural situations this is not an unrealistic assumption. Johnson (p. 73) tested detrended price series data for several agricultural commodities and found they did not deviate too badly from normality. However, slaughter cattle, corn and alfalfa price distributions were slightly skewed and showed a mild kurtosis. Often though, the choice variable, e.g., wealth or net income, represents a composite of different price series and the Central Limit Theorem[13/] may ensure normality. The assumption of normality then justifies the EV approach as a special case of second degree stochastic dominance (SSD). No functional restrictions are imposed on the shape of the utility function other than risk aversity, $U''(y) < 0$, and normality essentially implies that one choice can only be dominated by another choice when it has a lesser mean and precisely

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[13/] The Central Limit Theorem states that if a random variable arises as the sum of a (large) number of independently and identically distributed random variables, its distribution will tend to normal (Mood, Graybill and Boes, P. 195).

the same variance, or the same mean and greater variance. Specifically, a normal cumulative density function (cdf), F, dominates a normal cdf, G, in the sense of SSD if $E_F(y) \geq E_G(y)$ and $V_F(y) \geq V_G(y)$ with at least one strong inequality, where E is the expectation operator and V is the variance operator (Anderson, Dillon and Hardaker, p. 287). But this is exactly the EV criterion discussed above.

This same argument for justification of the EV approach can be extended to the portfolio problem if the distributions of returns offered by the risky prospects in the portfolios are jointly normal. Even if the individual risky prospects have outcomes that are not normally distributed, application of the Central Limit Theorem ensures that the portfolio returns are normally distributed if the individual risky prospects have outcomes that are independently and identically distributed.

Despite the strong arguments for justification of the EV approach on the basis of normality, criticisms remain. Tsaing (p. 355) suggested that the normality assumption may be highly restrictive since returns on investments are more apt to be lognormally distributed. Johnson (p. 50) noted that institutional practices such as progressive taxation and hedging may cause skewness in returns. Robison and Barry (p. 72) comment that few variables take on values that range from negative to positive infinity as normality implies, or are symmetrically distributed. However, without the assumption of normality or quadratic utility, the EV approach can still be justified, albeit with some error, by showing that a Taylor series expansion of an assumed risk averse utility function can be expressed in terms of the mean and a series of higher moments of the associated probability distribution. If convergence of the series expansion is sufficiently rapid, terms involving moments higher than the variance can be ignored.

Specifically, given a general utility function, U(y), a Taylor Series expansion about the mean $\mu = E(y)$, yields:

$$U(y) = U(\mu) + U'(\mu)(y-\mu) + U''(\mu)(y-\mu)^2/2! + U'''(\mu)(y-\mu)^3/3! + \ldots \quad (28)$$

Using the expected utility theorem and taking the expectation of equation 28, the utility of the risky prospect y is:

$$E[U(y)] = U(\mu) + U'(\mu)\ E(y-\mu) + U''(\mu)\ E(y-\mu)^2/2! + U'''(\mu)\ E(y-\mu)^3/3! + \ldots \quad (29)$$

Recall that $E(y-\mu) = 0$, and that the k^{th} moment about the mean $M_k(y) = E(y-\mu)^k$, equation 29 can be simplified to:

$$E[U(y)] = U(\mu) + U''(\mu)\ M_2(y)/2! + U'''(\mu)\ M_3(y)/3! + \ldots \quad (30)$$

Thus the expected utility of a risky prospect can be evaluated in terms of the mean and a series of higher moments of the associated probability distribution. Anderson, Dillon and Hardaker (p. 97) note that it is usually found that $U_k(\mu)/k!$ becomes smaller at a rather faster rate than $M_k(y)$ becomes larger as k increases, therefore, terms beyond those involving the third moment usually add insignificantly to the approximation of equation 26. For several specific utility functions Tsiang (p. 356-362) showed that terms beyond the quadratic were quite small numerically. Consequently, although a EV analysis would not give precise results under this justification, the solutions are apt to be accurate enough for decision making purposes.

Related to the above, and perhaps the most important justification of the EV approach in empirical studies, is its ability to approximate results obtained with more general models consistent with the EUT. For example, Porter and Gaumnitz compared the application of stochastic dominance rules and EV analysis to the ordering of stock portfolios and concluded that, except for the highly risk averse investor, the choice between the EV analysis and the theoretically superior stochastic dominance approach for selecting efficient stock portfolios was not critical. Tsaing demonstrated that various restrictions on skewness could yield a close correspondence between EV and EUT efficient sets. Futhermore, Samuelson has commented:

> ... in practice where crude approximations may be better than none, the 2-moment models may be found to have pragmatic usefulness.

Lastly, Levy and Markowitz showed that regardless of the utility function and distribution of profits that maximization of a mean-variance objective function provides a reasonable approximation of the true objective function. In summary, the EV approach can justified and employed in this study on the basis of any (or combinations of) of the following assumptions:

1. Utility functions for feedlot operators in Southern Alberta are all quadratic.
2. Output price risk and the associated return variable, e.g., net income, are normally distributed.

3. Portfolio combinations of the various production marketing strategies tend to have normally distributed return variables because of the applicability of central limit theorems; or because individual production-marketing choices are normally distributed, yielding multivariate normal portfolio return distributions.
4. A truncated Taylor series is sufficient to estimate the expected utility of production-marketing portfolios facing feedlot operators.
5. The EV efficient set is a good approximation of the EUT efficient set.
6. The EV approach facilitates investigation of the portfolio problem and the effects of diversification.
7. Computational advantages of the EV model more than offset its theoretical limitations.

Summary

This chapter examined the theory of decision making under uncertainty to justify an empirical methodology appropriate for analysis of the feedlot management problem. The nature of risk was examined and the EUT advanced as the most theoretically consistent and powerful approach to model the ordering of risky prospects by individual decision makers. Risk attitudes and methods for quantifying such attitudes were explored to establish a framework for extending the results of the EUT to classes of decision makers. Finally, the EV approach was proposed as a valid approximation of the EUT for analysis of the feedlot decision problem. Each of these areas of discussion yielded insights into how to approach the analysis of the feedlot decision problem.

Based on the developed EV approximation of the EUT, the next chapter details a framework for analysis of the firm under conditions of uncertainty. In addition, the risk reducing strategies of hedging and stabilization are introduced. Testable hypotheses are generated regarding the effects of finished cattle output price risk on input and output levels, with and without the above risk reducing strategies employed alone or in combination.

III THE THEORY OF THE FIRM UNDER UNCERTAINTY

Introduction

This chapter sets the stage for empirical analysis of the feedlot planning problem by extending the conclusions of Chapter II into an analytical framework consistent with economic theory of the firm under uncertainty. The expected value-variance criteria (EV) is used to examine the effect on optimal choice solutions from changes in some, or all, of the relevant moments of the probability distributions for choice variables. In the context of the feedlot planning problem, such changes could occur from the risk reduction techniques of: participation in the Tripartite beef stabilization scheme or hedging on the futures market. Employing the developed economic theory, testable hypotheses are constructed that predict the effect and interaction of these various risk response techniques on the efficient choice set in the feedlot management problem.

The EV Analytical Model

Chapter II advanced expected value-variance (EV) analysis as a legitimate approximation to expected utility maximization. Not only does the approximation facilitate empirical research, it has merit as an analytical tool for deducing the relationships between variables in the decision environment. For example, a change in investor wealth resulting from a change in fixed costs or taxes may cause varied changes in the optimal portfolio depending on the risk attitudes of the decision maker. Thus, the EV framework accommodates a theoretical analysis of how decision makers determine the trade offs between expected returns and variance of returns by showing the changing positions of the EV frontier and optimal portfolio due to changes in the decision environment.

The basis for the EV analytical model derives from the fact that solutions to the EV set can be characterized by a linear tangent line to the efficient set (Tobin; Copeland and Weston, p. 172-175); (Anderson, Dillon and Hardaker, p. 92). From equation 21, where $\pi = E(y) - y_{CE}$ and $\pi = \alpha\sigma^2/2$, it can be shown that the tangent line has an arbitrary slope of $\alpha/2$. This indicates that variance can be traded off for expected returns at a rate of $\alpha/2$ without affecting the well being, or certainty equivalent income, of the decision maker. Thus, the tangent line is termed the certainty equivalent line (Robison and Barry, p. 73). Since y_{CE} is the certainty equivalent return to the risky expected return E(y), the optimal risky solution can be obtained by maximizing the certainty equivalent such that:

$$\text{Max } y_{CE} = E(y) - \frac{\alpha\, \sigma^2(y)}{2} \tag{31}$$

Using the construct inherent in equation 31, an analytical framework can be developed to show how changes in variables in the decision environment shift or rotate the EV frontier and subsequently alter the slope of the certainty equivalent line. Essentially, such changes affect the demand for risky assets, which in turn change the location of the EV set. Robison and Barry (p. 75-79) define the resulting adjustment in terms of an income effect and a substitution effect. The income effect is defined as the change in demand for a risky asset resulting from a change in risk-free wealth while holding the probability distributions constant for the prices of the risky assets. The income effect results in a parallel shift of the EV frontier in the direction of change in risk free wealth. The substitution effect is defined as the change in quantity demanded of a risky asset from a change in the probability distribution of its price after compensating for income. Total change in demand for an asset is given by addition of the two effects.

Mathematically these two effects can be expressed as:

$$\frac{dx}{d\phi} = \frac{(\partial x)}{(\partial \phi)\alpha \text{ constant}} + \frac{\partial x}{\partial \alpha}\frac{\partial \alpha}{\partial \phi} \tag{32}$$

where x is a risky asset and ϕ is any parameter defining the EV set location, such as; E(y), $\sigma^2(y)$, σ_e^2, or risk-free wealth. The substitution effect is given by the first term on the right, and the income effect is given by the second term on the right.

Theory of the Firm Under Uncertainty

Sandmo was one of the first to detail the theory of the firm under uncertainty by assuming that the firm's attitude toward risk is characterized by a von Neumann-Morgenstern utility function. Important conclusions from his paper were: (1) that output is smaller under price uncertainty, (2) that increasing (decreasing) fixed costs result in decreasing (increasing) output for DARA firms under uncertainty, and (3) that DARA is a sufficient condition for an upward sloping supply curve. Similar conclusions are reached using an EV approach, as first developed by Hawawini. Consider a firm facing a risky price for the product it produces. Under risk conditions, let p be the expected output price such that:

$$E(p + e) = p \qquad (33)$$

where the random variable $e \sim (0,\sigma_e^2)$. Profit can be defined as:

$$y = (p + e)q - C(q) - B \qquad (34)$$

where q is output, C(q) is variable costs as a function of output, and is fixed costs. Expected profit is given by:

$$E(y) = pq - C(q) - B \qquad (35)$$

and variance of profits is:

$$\sigma^2(y) = q^2\sigma_e^2 \qquad (36)$$

Substituting equations 35 and 36 into 31 yields the certainty equivalent of the profit equation:

$$y_{CE} = pq - C(q) - B - \frac{\alpha}{2} q^2\sigma_e^2 \qquad (37)$$

Maximizing with respect to q the first order condition becomes:

$$p - C'(q) - \alpha q \sigma_e^2 = 0. \qquad (38)$$

Since C'(q) represents the marginal costs of production (MC_q) and $\alpha q \sigma_e^2$ represents the marginal costs of risk (MC_{risk}), equation 38 can be rewritten as:

$$p = MC_q + MC_{risk}.$$

As C'(q) > 0, the result implies that the optimum output level under risk occurs where expected price (marginal revenue) is equal to the marginal costs of output ($MC_q + MC_{risk}$). This means that output is less under uncertainty by the cost of risk ($\alpha q \sigma_e^2$).

Under certainty, the theory of the firm concludes that fixed costs do not play a role in the determination of optimal output. Under uncertainty conditions, however, changes in fixed costs result in an income effect by increasing or decreasing the E(y) at each level of output. Figure 12 illustrates the income effect of a decrease in fixed costs. The decrease causes an upward parallel shift in the EV frontier. Depending on the firm's absolute risk aversion coefficient, output may rise, fall or remain constant. Since α=R[E(y)] on a local basis, (α/2), the slope of the certainty equivalent line may change as the decrease in fixed costs causes E(y) to change. If R'[E(y)] < 0 (i.e., DARA) the demand for risky assets will increase, and the optimal portfolio will shift to C''. The new portfolio represents an increased production of q in response to a declining aversion to risk in the presence of increased wealth. If R'[E(y)] = 0 (i.e, CARA) the demand for risky assets remains the same and output q

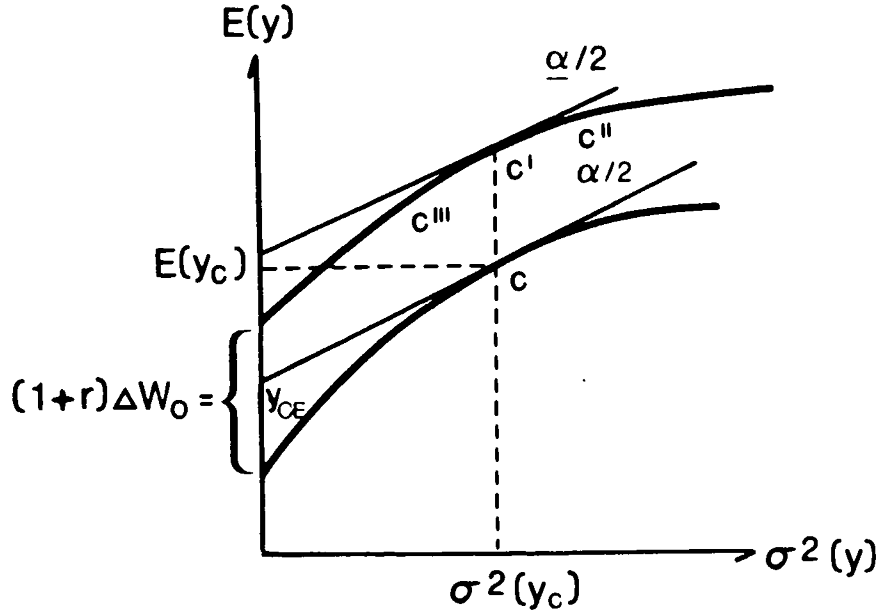

Figure 12 The Income Effect of Decreasing Fixed Costs on the EV Frontier
Source: Robison and Barry (p. 77)

does not change. If $R'[E(y)] > 0$ (i.e., IARA) output will fall as aversion to risk increases and the portfolio shifts to C'''. Mathematically the result is derived by total differentiation of equation 38 as follows:

$$[C''(q) + \alpha\sigma_e^2]\ dq + (\partial\alpha/\partial B)\ q\sigma_e^2\ dB = 0$$

$$\frac{dq}{dB} = \frac{-(\partial\alpha/\partial B)\ q\sigma_e^2}{[C''(q) + \alpha\sigma_e^2]} \qquad (39)$$

Since the denominator is positive to satisfy the second order condition for expected utility maximization and the sign of $(\partial\alpha/\partial B)$ depends on the sign of $R'[E(y)]$, i.e.,:

$$\frac{\partial\alpha}{\partial B} \gtreqless 0 \text{ as } R'[E(y)] \lesseqgtr 0 \qquad (40)$$

then for DARA firms output will increase as fixed costs decrease. Sandmo notes that this result would imply that a lump sum subsidy would be a more appropriate policy to increase output than a lump sum tax.

Under certainty the supply curve for an output slopes upward as price increases. Under uncertainty it may do the same, but under some conditions it may slope downward. Taking the total differential of equation 37 with respect to p and q yields:

$$[1 - (\partial a/\partial p)\ q\sigma_e^2]\ dp - [C''(q) + \alpha\sigma_e^2]\ dq = 0$$

$$\frac{dq}{dp} = \frac{1-(\partial\alpha/\partial p)\ q\sigma_e^2}{[C''(q) + \alpha\sigma_e^2]} > 0 \quad \text{for} \quad \frac{\partial\alpha}{\partial p} \leq 0 \qquad (41)$$

This implies that the supply curve will be upward sloping for DARA or CARA firms, but may be downward sloping for IARA firms. The results are seen graphically in Figure 13. As the expected value the of output price increases[14/], the EV frontier rotates and shifts upward. With CARA the slope of the certainty equivalent line remains the same but the optimal portfolio shifts from C to C', representing an increase in q as $\sigma^2(q_1)$ shifts to $\sigma^2(q_2)$. With DARA, an increase in the demand for risky assets causes the certainty equivalent line to become less steep and the optimal portfolio to shift to D, representing an even further increase in q as $\sigma^2(q_1)$ shifts to $\sigma^2(q_3)$. Under IARA, the slope of the certainty equivalent line becomes more steep and q may or may not increase depending on whether the optimal portfolio is between F and C', or below F, respectively. Thus, the potential exists under uncertainty for a downward sloping supply curve. For DARA firms, Sandmo suggests that these results imply that to increase output the government should consider a per unit subsidy, rather than a per unit tax, as the appropriate policy measure. The above results provide a framework for the analysis of behavior of the firm under uncertainty and allow the prediction of changes that occur as the firm adopts available risk-reducing strategies. Such strategies could include (Robison and Barry, p. 65):

14/ Sandmo considers this increase in the probability distribution of price as being an increase in the mathematical expectation of the price with the higher central moments constant.

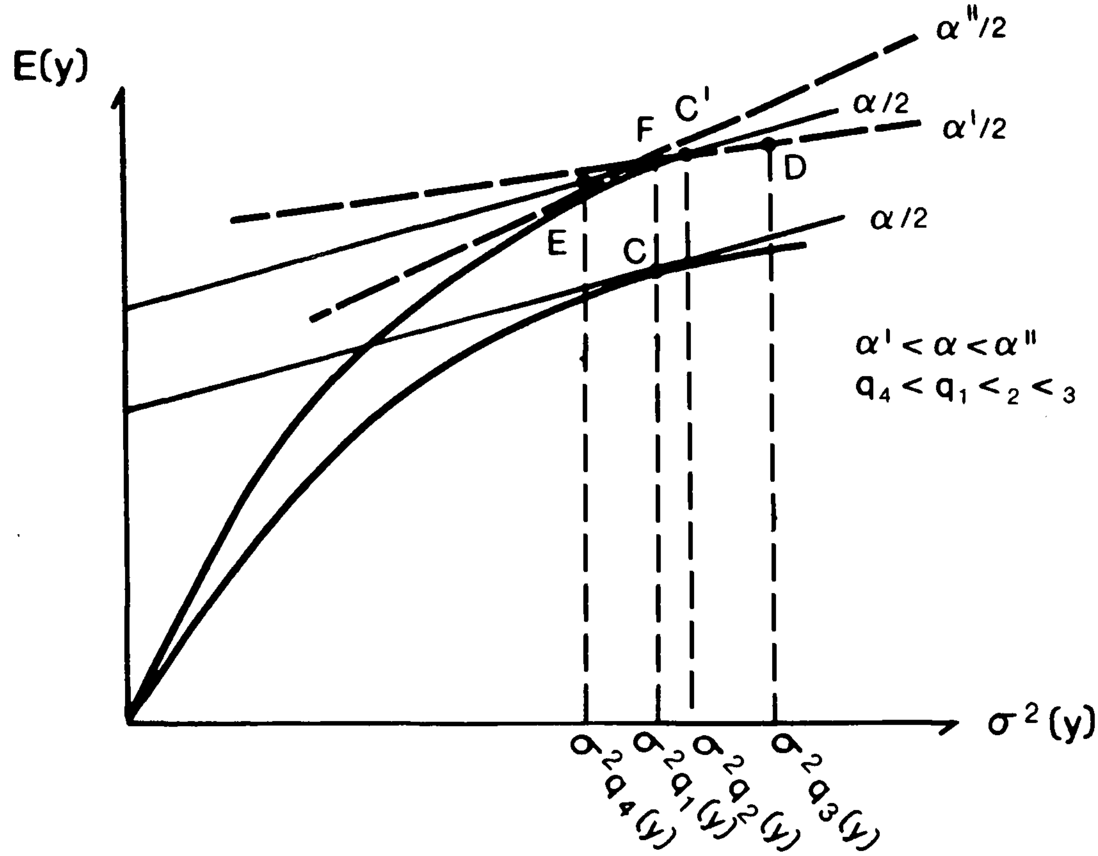

Figure 13 Effect of an increase in Expected Price on Output

"1. Adjusting input levels $x_1, \ldots, x_n$ and output q
2. Holding reserves
3. Holding credit reserves
4. Holding reserves of inputs $x_1, \ldots, x_n$
5. Integrating vertically
6. Gathering information
7. Postponing decisions
8. Forward-contracting
9. Hedging
10. Diversifying enterprises, that is, integrating horizontally to produce products in addition to q
11. Acquiring risk-reducing inputs
12. Investing in production processes with a flat average cost curve
13. Buying flexible inputs
14. Buying insurance
15. Specializing
16. Adjusting financial leverage
17. Diversifying operations spatially
18. Spreading transactions over time
19. Participating in public programs designed to reduce risk
20. Utilizing share leasing of resources."

Since this study focuses on output price risk in feedlot slaughter cattle operations, the available risk-reducing strategies of hedging and stabilization are next described and analyzed in the context of the EV analytical model. Testable hypotheses are constructed about their likely effects and interactions on variables in the feedlot decision process.

Hedging

The theory of the firm under uncertainty predicts reduction of output as the primary response to risky output price. However, in many production situations, reduction of output may be impractical. Contract commitments or vertical integration with feeder production may dictate specific numbers of cattle to be fed. Output, then, can only be reduced by decreasing the target finishing weights of the feeders. In such situations one appropriate response to risk is the trading of a risky asset for a certain one by hedging on the futures market.

Feder, Just and Schmitz were among the first to incorporate participation in the futures markets into the theory of the firm under uncertainty. Using an expected utility framework, they assumed perfect competition, an uncertain output price and a certain output as determined by optimal input levels through a production function. Although the assumption of certain output is questionable for most agricultural products, it fits well with slaughter cattle production since output is known with a high degree of certainty and death losses are usually small and have limited variability. A main conclusion of their model was that production decisions do not depend on the expected cash price or its variability, but rather on the certain futures price. Chavas and Pope later refuted this and other conclusions when the model (in an EV framework) allowed for production uncertainty and hedging costs. Both models, however, failed to consider basis risk, which Carter and Loyns concluded is a major limitation to the employment of the U.S. futures markets for hedging Canadian feeder cattle.

To explore the risk reducing effects of hedging cattle on the futures market, a simplified hedging model is constructed employing the EV theory of the firm framework, followed by a discussion of empirical studies and the formulation of hypotheses.

Abstracting from the complex mechanics of the futures market, the following assumptions are made:

1. Perfect competition--a reasonable assumption given that feedlot operators are not large enough to affect price and the flow of cattle is determined on a large number of farms and ranches.
2. Uncertain output price and certain output.
3. Divisible product--futures contacts for cattle are indivisible in lots of 40,000 pounds, but the assumption of divisibility permits a marginal analysis of risk changes.
4. Risk averse decision maker.
5. Durable product with established grades--finished cattle are "durable" for the length of the futures contract period and have established grades.
6. Zero transactions costs, margin requirements, and exchange rate effects.
7. Effect of the basis is insignificant--this assumption is relaxed after establishing some simplified hedging conclusions.

For notational purposes, let

q = output

$C(q)$ = variable costs, where $C'(q) > 0$ and $C''(q) > 0$

B = fixed costs

e = a random variable with expected value 0 and variance σ_e^2.

p = the expected spot price, where $E(p+e) = p$

f = price of the futures contract

h = volume of the futures contracts sold ($h \geq 0$)

$z = q-h$ = amount sold at spot price $(p + e)$ (p, σ_e^2)

y = profits and E(y) is expected profits

d = interest rate or discount rate

The profit is given by $y=(p+e)(q-h)+[fh-C(q)-B](1+d)$ and is the value of output unhedged, plus cash receipts from the sale of futures contracts, minus variable and fixed costs. Expected profit is:

$$E(y) = p(q-h) + [fh - C(q) - B](1+d) \tag{42}$$

and variance of profits is:

$$\sigma^2(y) = (q-h)^2 \sigma_e^2 \tag{43}$$

Substituting equations 42 and 43 into 31 gives the certainty equivalent model:

$$\text{Max } y_{CE} = p(q-h) + [fh - C(q) - B](1+d) - (\alpha/2)(q-h)^2 \sigma_e^2$$

The first order conditions (FOC) for maximization are:

$$\frac{\partial y_{CE}}{\partial q} = p - C'(q)(1+d) - \alpha(q-h)\sigma_e^2 = 0 \tag{44}$$

$$\frac{\partial y_{CE}}{\partial h} = - p + f(1+d) + \alpha(q-h)\sigma_e^2 = 0 \tag{45}$$

The optimal output q is found by adding equations 44 and 45:

$$f = C'(q) \tag{46}$$

Expression (46) is the solution under risk and implies that transferring risk allows the firm to act as a profit maximizer under certainty. The level of output is adjusted to the point where the futures price is equal to the marginal variable costs of production. The result is a larger output since the firm is not paying risk costs along with production costs. Feder, Just and Schmitz conclude that this result means:

1. The production decision is not affected by changes in the subjective probability distribution of the spot price or by the degree of risk aversion (α).
2. Output will increase as the futures price increases, ($dq/df > 0$), and output will decrease as costs increase, ($dq/dC < 0$).

They further conclude that, given the determination of an output q, risk attitudes and output price uncertainty play a role in the determination of the volume and direction of futures hedging. Solving equation 45 with respect to h gives:

$$h = q - \{[p-f(1+d)]/\alpha\sigma_e^2\} \qquad (47)$$

Since $\alpha > 0$ for the risk averse firm, equation 47 indicates:

1. if $p/(1+d) < f$ the firm will speculate and $h > q$,
2. if $p/(1+d) = f$ the firm will completely hedge and $h = q$, and
3. if $p/(1+d) > f$ the firm will partially hedge and $h < q$.

Furthermore, differentiating equation 47 with respect to the variance of the spot price reveals the substitution and income effects of an increase in the variance of the spot price on the hedging decision. As per the format of equation 32, the substitution effect equals:

$$\frac{\partial h}{\partial \sigma_e^2} = \frac{p - f(1+d)}{\alpha(\sigma_e^2)^2} > 0 \quad \text{for } p/(1+d) > f \qquad (48)$$

The income effect is:

$$\frac{dh}{d\sigma_e^2} = \frac{p - f(1+d)}{\alpha(\sigma_e^2)^2}\,\frac{\partial \alpha}{\partial \sigma_e^2} > 0 \quad \text{for } p/(1+d) > f \text{ and DARA} \qquad (49)$$

This implies that as the degree of uncertainty relating to the future spot price decreases, the hedging volume decreases as long as the current futures contract price is less than the discounted expected future spot price. As σ_e^2 decreases, the EV set rotates upward, since for each level of E(y) the variance has decreased, and the slope of the certainty equivalent line will decrease if the firm exhibits DARA. Thus, if a beef stabilization program reduced the variance of the spot price, a testable hypothesis would be that the EV frontier will rotate upwards and the level of hedging will decrease, but that the level of output would not be affected since it depends on the futures price.

The hedging decision can also be affected by changes in the fixed costs, B. Since output is only affected by the futures price and variable costs, changes in fixed costs alter the level of hedging via an income effect and a change in the slope of the certainty equivalent line as affected by the firm's risk attitude. Differentiating equation 46 with respect to B yields:

$$\frac{dh}{dB} = \frac{p - f(1+d)}{\sigma_e^2\alpha^2} \frac{\partial\alpha}{\partial B} > 0 \quad \text{for } p/(1+d) > f \text{ and DARA} \qquad (50)$$

Thus, another testable hypothesis would be that stabilization policies involving lump sum subsidy payments, would reduce fixed costs, and shift the EV line upward by giving a higher level of E(y) for each level of variance. Assuming p/(1+d) > f and DARA, the certainty equivalent line would become less steep and the level of hedging would decline.

Basis Effects

Relaxing the assumption of insignificant basis risk complicates the hedging problem. The basis for a commodity arises as the difference between the cash and futures price at any point in time, and reflects the costs of storage, handling, transportation, and interest. Storage costs are irrelevant for live cattle; however, the basis can be viewed as a product transformation cost, or the market price of feedlot services (Ward and Fletcher). A fundamental principle about the basis is that the cash and futures prices converge at the market location as the futures contract approaches maturity. As time goes on, the carrying charges on the futures contract diminish and the basis narrows. Even under uncertainty where the cash and futures prices fluctuate, the basis pattern normally remains the same. Figure 14 illustrates the theoretical basis pattern under uncertainty. When conditions exist that affect the futures markets differently than the current cash markets (or vice-versa), the basis may diverge from a constant pattern. Only if the basis variability is less than the price variability will hedging be risk reducing and conclusions discussed above hold. In addition, determination of the hedge level becomes more complicated and can be shown to depend on both the basis variance and the covariance between the basis and the output price.

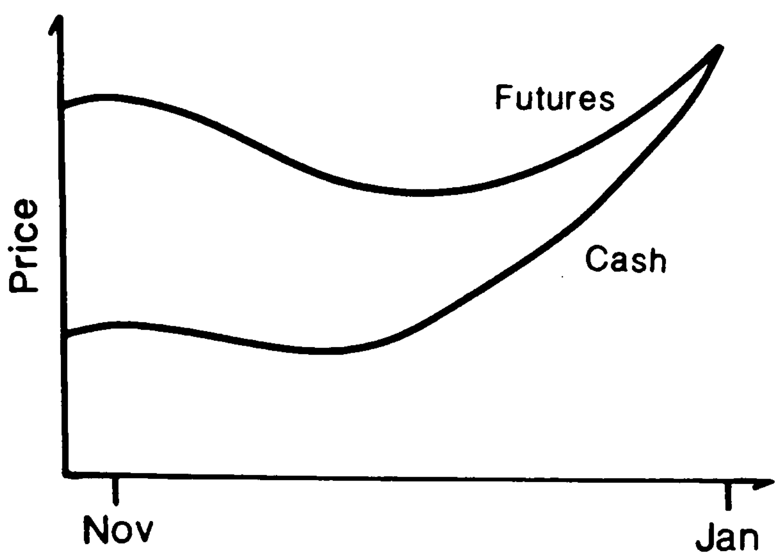

Figure 14 Theoretical Basis Pattern Under Uncertainty
Source: Alberta Agriculture, 1982

To analyze the effect of basis risk on the above hedging conclusions, the feedlot firm is assumed to take a short position in live beef futures contracts, with an delivery date of time t. Because it is likely that the firm will lift its hedge before the delivery date of the contract[15/] the futures price at the time the contract is lifted can be given as f_{t-i}, reflecting the fact that the hedge is lifted i periods before the delivery date. Returns to the firm can be expressed as:[16/]

$$y = (p+e)(q-h) + [(f+\delta)h - C(q) - B](1+d) \qquad (51)$$

where

d = discount rate,

δ= basis = $f_{t-i} - (p+e)$, e $(0,\sigma_e{}^2)$, δ $(0,\sigma_\delta{}^2)$, and

$cov(e,\delta) = r\sigma_e\sigma_\delta$ for $(-1 < r < 1)$, $E(f_{t-i}) = f$

Expected profit is:

$$E(y) = p(q-h) + [fh - C(q) - B](1+d) \qquad (52)$$

and variance of profits is:

$$\sigma^2(y) = (q-h)^2 \sigma_e{}^2 + h^2\sigma_\delta{}^2 + 2(q-h)h\, r\sigma_e\sigma_\delta \qquad (53)$$

Substituting equations 52 and 53 into 4 gives the certainty equivalent model:

$$\text{Max } y_{CE} = p(q-h) + [fh - C(q) - B](1+d)$$
$$-(\alpha/2)(q-h)^2 \sigma_e{}^2 + h^2\sigma_\delta{}^2 + 2(q-h)h\, r\sigma_e\sigma_\delta$$

[15/] Delivery dates of futures contracts rarely correspond with marketing dates of finished cattle.

[16/] This section draws on models presented by Ward and Fletcher, Kahl, and Robison and Barry.

The first order conditions (FOC) for maximization are:

$$\frac{\partial y_{CE}}{\partial q} = p - C'(q)(1+d) - \alpha(q-h)\sigma_e^2 - \alpha h\, r\sigma_e\sigma_\delta = 0 \qquad (54)$$

$$\frac{\partial y_{CE}}{\partial h} = -\,p + f(1+d) + \alpha(q-h)\sigma_e^2$$

$$-\,\alpha h\sigma_\delta^2 - \alpha q r\sigma_e\sigma_\delta + 2\alpha h\, r\sigma_e\sigma_\delta = 0 \qquad (55)$$

Letting $C(q) = kq$[17/] and $C'(q) = k$, equations 54 and 55 can be written in matrix notation as:

$$\begin{matrix} \alpha\sigma_e^2 & \alpha(r\sigma_e\sigma_\delta - \sigma_e^2) & q & p-k(1+d) \\ \alpha(r\sigma_e\sigma_\delta - \sigma_e^2) & \alpha(\sigma_e^2+\sigma_\delta^2-2r\sigma_e\sigma_\delta) & h & f(1+d)-p \end{matrix}$$

Using Cramer's Rule, the solutions for q and h are as follows:

$$q = \frac{[p-k(1+d)](\sigma_e^2+\sigma_\delta^2-2r\sigma_e\sigma_\delta)-\{[f(1+d)-p](r\sigma_e\sigma_\delta-\sigma_e^2)\}}{\alpha[\sigma_e^2(\sigma_e^2+\sigma_\delta^2-2r\sigma_e\sigma_\delta) - (r\sigma_e\sigma_\delta - \sigma_e^2)^2} \qquad (56)$$

$$h = \frac{\{\sigma_e^2[f(1+d)-p] - (r\sigma_e\sigma_\delta - \sigma_e^2)[p-k(1+d)]\}}{\alpha[\sigma_e^2(\sigma_e^2+\sigma_\delta^2-2r\sigma_e\sigma_\delta) - (r\sigma_e\sigma_\delta - \sigma_e^2)^2} \qquad (57)$$

Thus, the optimal output and quantity hedged will depend on the risk aversion coefficient, α, the variances of the cash price and the basis and their covariance. Despite the ambiguity of these results, an interesting finding is that the optimal hedge ratio (h/q) will not depend on the level of risk aversion. Since both denominators are the same, the optimal hedge ratio is given as:

[17/] This assumes that the relationship between costs and output is a linear trend, which is a plausible assumption where inputs are purchased at fixed prices.

$$\frac{h}{q} = \frac{\{\sigma_e^2[f(1+d)-p] - (r\sigma_e\sigma_\delta - \sigma_e^2)[p-k(1+d)]\}}{[p-k(1+d)](\sigma_e^2+\sigma_\delta^2-2r\sigma_e\sigma_\delta) - \{[f(1+d)-p](r\sigma_e\sigma_\delta - \delta_e^2)\}}$$

This means that regardless of their levels of risk aversion, feedlot managers who have the same expectations regarding returns and variances of the cash and futures positions should employ the same hedging ratio.

In summary, the presence of basis risk complicates the determination of optimal output and hedging levels. If the basis variance, σ_δ^2, is less than the cash price variance, σ_e^2, output will likely be higher with hedging.

Empirical Hedging Studies

Most studies that have examined the risk-reducing effects of hedging have considered hedging in the context of portfolio effects. Typically, hedging strategies are designed that involve methods for developing future spot price expectations, selective hedging techniques and management objectives. Variances and covariances are established from historical data and EV frontiers are generated by mathematical programming. Results have indicated the superiority of partial hedging portfolios. Few studies have examined the effects of alternative risk reducing strategies on hedging. This next section reviews recent articles on hedging as a prelude to summarizing testable hypotheses that draw on both the theory of the firm under uncertainty and empirical studies.

Bobst et al. recognized the potential of hedging to shift price risk, and determined to investigate the question of whether hedging was worthwhile in cattle backgrounding operations given the additional costs and financial obligations involved. Two price expectation functions were used in the analysis together with mean returns as a comparison. One function forecasted future cash prices based on current cash prices, while the other function forecasted future cash prices based on current futures prices. Results indicated that complete hedging was an expected value maximizing strategy but that, because of diversification effects, partial hedging was more efficient for marketing backgrounded cattle.

Assuming a stocker operation large enough to handle a 40,000 pound cattle futures contract, Russell and Dickey examined complete hedge or no hedge alternatives against partial hedging strategies for three backgrounding production scenarios: small grain grazing, small grain grazeout and summer stocker. They concluded that partial hedging strategies generally outperformed complete hedging in increasing the mean and reducing the variance of returns for the stocker operator.

Peterson examined the optimal futures position for a cattle hedger, given a cash market position and degree of risk aversion. As suggested by portfolio theory, he found that considering basis risk in addition to price risk in the hedging decision reduced total risk compared to hedges that considered only price risk. Generally, the hedging results confirmed the predictions of financial theory, i.e., high risk aversion hedges were grouped at the low risk, low return end of the spectrum, while the low risk aversion hedges were located at the high risk, high return end. Of special interest was his insight that by combining optimal hedging with non-naive forecasting one might be able to produce hedges with lower risk, higher returns or both and thereby improve performance over that attained in the study (Peterson, p. 184).

Application of hedging procedures entails special problems for the Canadian feedlot operator. Since the 1975 withdrawal of a live cattle contract from the Winnipeg Commodity Exchange, producers have been able to hedge feeder or slaughter cattle only on the Chicago Mercantile or Mid-American Commodity Exchanges. Caldwell, Copeland, and Hawkins note that since U.S. prices, tariffs and transfers are exogenous variables to the Canadian market system, the Canadian beef price is not a function of the U.S. price, but rather is constrained by the U.S. price. The upper constraint is U.S. price plus Canadian tariff plus transfer costs (all in $Cdn); whereas the lower constraint is U.S. price minus U.S. tariff. The basis, which is defined as the Chicago futures price in Canadian dollars minus the Calgary cash price, is essentially free to fluctuate between the two limits without regard to movements in the U.S. cash price. In addition to this source of basis variability, the Canadian dollar adds further variability by affecting Canadian prices and profits. Hedging of the Canadian dollar may remove some of the variability in the Calgary basis, but usually, basis risk can be as large or larger than the cash price risk.

To explore the efficacy of hedging Canadian cattle, Caldwell et al. used simulation analysis to investigate eight hedging strategies:

(1) no hedge, (2) routine hedge on feeder cattle, feed barley, and slaughter cattle, (3) routine hedge only on feeder cattle, (4) routine hedge only on barley, (5) routine hedge only on finished cattle, (6) hedge finished cattle when the current futures price is greater than, or equal to, the current cash price, (7) hedge finished cattle when the current basis is less than the historical mean of the basis and (8) hedge finished cattle when the current basis is less than the mean of the basis minus one standard deviation. Major conclusions were: (1) that an Alberta operator could increase his expected income level by hedging, but only at the expense of greater income variation, (2) that the Calgary, Alberta basis for finished cattle was subject to considerable variation and that the only solution for the Canadian producer would be to monitor the basis daily and lift or place the hedge according to unfavorable or favorable shifts in the basis, (3) that the bases for feeder cattle and feed barley are more related to exchange rate movements and that hedging of the Canadian-U.S. exchange rate may be beneficial and (4) that the current futures price was a better indicator of the forthcoming cash price than was the current cash price.

Carter and Loyns also investigated hedging of Canadian cattle on U.S. futures exchanges. Utilizing data on approximately 100,000 custom fed cattle, they examined four basic hedging strategies: (1) a routine insurance or "classic" hedge, (2) a naive selective hedge that was placed a hedge if profit conditions were favorable, (3) a selective hedge that was placed at any time within the first six weeks of the feeding period, provided critical profit levels were assured, and (4) a "threshold" strategy that only placed cattle on feed and hedged them if threshold levels of price and profit were met. The strategies were evaluated under the actual exchange rate risk that existed for the data period of 1972 to 1981. Although the threshold strategies resulted in higher realized returns and decreased variances versus the no hedge or other hedging alternatives, they were deemed impractical. Routine hedging resulted in unexpected and dramatic reductions in mean returns, which were negative in some cases. Exchange rate risk was also a significant source of hedging loss. Generally, the results suggested limited usefulness of U.S. futures markets for hedging Canadian finished cattle. Explanation for the poor hedging results was attributed to the erratic behavior of the finished cattle basis. This suggested that more appropriate hedging strategies might be designed if the demand and supply factors affecting the basis could be understood.

In summary, participation in the futures market can be expected to increase output as the firm responds to the certain futures price by producing to the point where marginal costs equal the futures price. A complete hedge will occur when the discounted expected futures spot price is equal to the futures market price. Partial hedging will occur when the discounted expected futures spot price is greater than the futures market price or if diversification of the firms cash and futures positions permits a reduction in risk. A stabilization plan should affect hedging participation by the DARA firm by decreasing the level of hedging involvement either by reducing the variance of the spot price or by decreasing the fixed costs of the firm. Empirical studies indicate that future spot price expectation formulae based on current futures market prices yield more accurate results than those based on current spot prices or mean future spot prices. Hedging results in Canada may also be improved by accounting for exchange rate risk and by incorporating supply and demand factors that affect the basis. All of these conclusions represent testable hypotheses.

Stabilization

To prevent a continuing decline in livestock numbers and feedlot production, the Canadian government established a national tripartite price stabilization plan for feeder calves, feeder cattle and slaughter cattle in November of 1985. Implementation of the plan began in January of 1986, with a scheduled termination date of December 31, 1995. Basic principles of the subsidy program are (Agriculture Canada, 1986):

1. All producers shall receive the same level of support per unit of production, after all relevant provincial stabilization plans are fully phased-in;

2. The costs of the schemes shall be shared equally by the Government of Canada, the governments of the participating provinces and participating producers.

3. Producer participation is voluntary.

4. The schemes are designed to be financially sound. The premiums of governments and producers should equal the total payment over time.

5. The schemes shall not provide an incentive to over-produce.

6. A comparable level of support will be provided in all commodity schemes established under the national tripartite program.

In terms of slaughter cattle, the program takes a guaranteed margin approach by announcing at the end of each quarter a national support price for that quarter. The support price equals the current cash costs of production for the quarter plus 90 percent of the difference (margin) between the cash costs and the national average market price of slaughter cattle in the same quarter for the preceding five years. The national costs of production are estimated from production models of the cash costs of raising short-keep and long-keep heifers and steers weighted by the number of federally inspected heifers and steers slaughtered in eastern and western Canada. The national average market price is the average price of all cattle grading A, B or C in regionally representative markets and weighted by the number of heifers and steers slaughtered in the various regions of Canada. Stabilization payments are triggered in any quarter that the national average market price falls below the support price. Table 2 details calculation of the stabilization payment for the third quarter of 1985. Premiums under the plan are shared equally by the federal and provincial governments and producers and announced at the beginning of each quarter. Producers must register at the beginning of a quarter and pay premiums on the number of animals they plan to sell for slaughter each quarter. Coverage is limited to 2,000 head per quarter or 8,000 per year.

To determine the risk-reducing effects of the Tripartite Stabilization Plan the EV analytical model developed in equations 33 to 38 is extended to include a stabilization option.[18] Recall that income was defined as $y = (p + e)q - C(q) - B$ where $e \sim (0,\sigma_e^2)$. For the risk averse firm, the expected utility-maximizing output was the solution to the equation $p - C'(q) - \alpha q\, \sigma_e^2 = 0$. For the feedlot participating in the stabilization plan and paying a premium of π, the output price received will be $(p + e_s)$ when price outcomes of $e < e_s$ occur.[19] The stabilized income (y_s) now becomes:

$$y_s = \begin{cases} (p + e)q - C(q) - B - \pi & e > e_s \text{ or} \\ (p + e_s)q - C(q) - B - \pi & e \leq e_s \end{cases} \tag{58}$$

Letting f(e) be the probability density function (pdf) for e, the expected value of the stabilized income becomes:

$$E(y_s) = pq - C(q) - B - \pi + \bar{e}q \tag{59}$$

where

$$\bar{e} = e_s\, F(e_s) + \int_{e_s}^{\infty} e\, f(e)\, de > 0 \tag{60}$$

The variance of the truncated distribution of e values is:

$$\sigma_s^2(y_s) = q_s^2\, \sigma_s^2 \tag{61}$$

where

$$\sigma_s^2 = e_s^2\, F(e_s) + \int_{e_s}^{\infty} e^2\, f(e)\, de - \bar{e}^2 \tag{62}$$

Under stabilization the price error term distribution becomes truncated to $e \sim (\bar{e},\sigma_s^2)$. Thus, it follows that $\sigma_s^2 < \sigma_e^2$ and $\bar{e} > e > 0$.

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[18] This proof is adapted from material in Robison and Barry (p. 228-229) on insurance as a risk response.

[19] e_s represents the amount of the stabilization payout.

Table 2 Calculation of Slaughter Cattle Stabilization Payment

Year and quarter	Market Price ($/cwt)	Cash Costs of Production ($/cwt)	Margin ($/cwt)	Average 5-year Margin ($/cwt)
1980 Q3	74.61	67.03	7.58	
1981 Q3	72.76	67.10	5.66	
1982 Q3	73.26	58.00	15.26	
1983 Q3	68.83	59.90	8.93	
1984 Q3	75.46	66.09	9.37	9.36
1985 Q3	67.42	65.80		

Support Price ($/cwt) = $65.80 + 90% ($9.36) = $74.22

Stabilization Payment ($/cwt) = $74.22 - $67.42 = $6.80

Source: Agriculture Canada (1986)

It can now be determined that output will increase under the stabilization plan ($q_s > q$). An expression for maximizing the certainty equivalent income of the feedlot is developed by substituting equations 59 and 61 into equation 31 to give:

$$y_{CE} = pq_s - C(q_s) - B - \pi + q_s\bar{e} - \frac{\alpha}{2} q_s^2 \left[e_s^2 F(e_s) + \int_{es}^{\infty} e^2 f(e)\, de - \bar{e}^2\right] \quad (63)$$

The FOC are:

$$\frac{dy_{CE}}{dq_s} = p - C'(q_s) + \bar{e} - \alpha q_s \sigma_s^2 = 0) \quad (64)$$

The conclusion that output under stabilization (q_s) is greater than output without stabilization (q) can be seen by substituting q for q_s in equation 64 which gives:

$$p - C'(q) + \bar{e} - \alpha q \sigma^2{}_s > 0$$

The fact that this result is greater than zero can be seen by considering the FOC that determines output under risk. Recall equation 38 determined that:

$$p - C'(q) - \alpha q \sigma_e{}^2 = 0$$

Since $\sigma_s{}^2$ is a truncated version of $\sigma_e{}^2$, which implies that $\sigma_s{}^2 < \sigma_e{}^2$ and $\bar{e} > 0$, the result must be that: $p - C'(q) + \bar{e}\ \alpha q \sigma_s{}^2 > 0$. Therefore, the result can only be made to equal zero if q is increased to q_s. Thus, another testatable hypothesis would be that, contrary to the objectives of the National Tripartite Stabilization program (TSP), slaughter cattle output will increase under the plan.

The effect on hedging of participation in the stabilization plan can also be deduced. Extending the certainty equivalency model of equation 63 to reflect participation in the futures markets gives:

$$\text{Max } y_{CE} = p(q_s-h_s) + (q_s-h_s)\bar{e} + [fh_s - C(q_s) - B - \pi](1+d) - (\alpha/2)\ (q_s-h_s)^2\ \sigma_s{}^2 \qquad (65)$$

where d = discount rate.

The first order conditions (FOC) for maximization are:

$$\frac{\partial y_{CE}}{\partial q_s} = p + \bar{e} - C'\ (q_s)\ (1+d) - \alpha(q_s-h_s)\sigma_s{}^2 = 0 \qquad (66)$$

$$\frac{\partial y_{CE}}{\partial h_s} = - p - \bar{e} + f(1+d) + \alpha(q_s-h_s)\sigma_s{}^2 = 0 \qquad (67)$$

The optimal output under stabilization, q_s, is found by adding equations 66 and 67:

$$f = C'(q_s) \tag{68}$$

Expression (68) is the same solution that was obtained under hedging, and implies output will not increase under stabilization since hedging allows the firm to behave as if in a certain world. Changing the probability density function of prices, then, does not affect the output level, which depends on the futures price.

However, the stabilization program will affect the level of hedging. Solving the FOC of equation 60 for h_s gives:

$$h_s = q_s - \{[p + \bar{e} - f(1+d)]/\alpha\sigma_s^2\} \tag{69}$$

Comparing the level of hedging without stabilization and with stabilization $(h - h_s)$, yields:

$$h - h_s = \left\{q - \frac{[p-f(1+d)]}{\alpha\sigma_e 2}\right\} - \left\{q_s - \frac{[p + \bar{e} - f(1+d)]}{\alpha\sigma_s 2}\right\}$$

As $(q > q_s)$, $(\bar{e} > 0)$ and $(\alpha\sigma_e^2 > \alpha\sigma_s^2)$, the result, $h-h_s$, will be positive. Since stabilization already reduces risk, hedging is partially redundant, and as a consequence, the level of hedging is decreased.

In summary, participation in the National Tripartite Beef Stabilization Program may: (1) increase slaughter cattle output at the firm level and (2) decrease the level of slaughter cattle hedged. Empirical analysis may also quantify the extent to which stabilization substitutes for futures market hedging.

Comparison of Cash, Hedging and Stabilization Marketing Alternatives

A comparison of the mechanics of the three strategies of cash marketing, hedging and stabilization is illustrated by the example in Table 3. The example assumes that an Alberta feedlot producer places short keep cattle on feed in early January and plans to sell them in the second week of May. Assuming a constant exchange rate of .81 Cdn$ per U.S.$, and an expected basis calculated from a five year average of the Calgary basis, the expected and realized selling prices per hundredweight (CWT) are determined. Although the example is contrived from 1979-1984 data[20/], it depicts the case where the producer would employ either of the risk reducing tools to protect from an expected fall in prices.

A general, graphical comparison of the three strategies is shown in figure 15. Assuming a basis of $5.51 under June futures, line A plots the expected cash sale price at slaughter. Line B shows the expected return from a hedge in June futures which will yield Cdn$ 70.97 if the basis is $5.51 under the June futures when the hedge is lifted. Lastly, line C shows the stabilization option, which assures an expected return of Cdn$ 70.35. The difference between the sloping portion of line C and line A reflects the size of the producer portion of the levy under the Tripartite Stabilization Plan.

20/ The data are contrived using 1983 prices, and estimates of the TSP levy, and the Calgary basis.

Table 3. A Comparison of Cash Sales, Stabilization and Hedging Risk Reduction Strategies

Forward Pricing Strategies	Date	
	January 1	May 14
Cash Sale	Do nothing. Expected price = futures - exp basis = Cdn$ 76.54 - Cdn$ 5.51 = Cdn$ 71.03	Sell to Packer at Cdn$ 68
TSP Stabilization	Be enrolled in TSP Exp. Price = MAX [futures price- levy - exp. basis, TSP sppt p. - levy] = MAX {[Cdn$ 76.54 - ($1.80/3) - $5.51], [$70.95 -($1.80/3)]} MAX {$70.43,$70.35}= $Cdn 70.43	Sell to Packer at Cdn$ 68. Net Price = Cdn$ 68- levy+TSP payout = Cdn$68-($1.80/3)+ $2.95 = $70.35
Hedging	Sell JUN futures at US$ 62(Cdn$ 76.54) - historical basis estimated at $5.51. Exp. price = futures - exp. basis -transaction costs = $76.54 - $ 5.51 - $ 0.06 = $70.97	Sell to Packer at $68 and Buy JUN futures at US$ 60 (Cdn$ 74.07). Net selling price=$68 -($76.54-$74.07) - $0.06 = $ 70.41

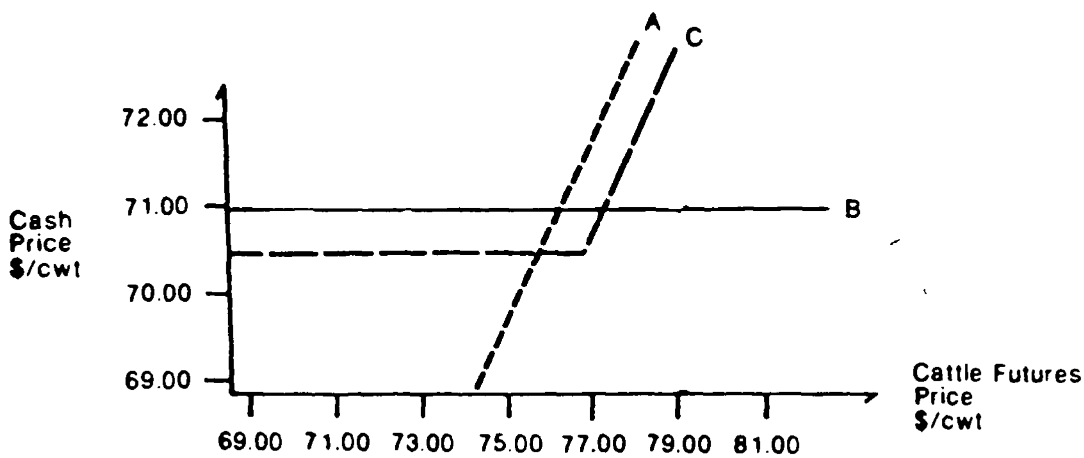

Figure 15 Relationship between Cash Sales, Stabilization and Hedging
Source: Chicago Board of Trade, 1984, p. 16

Time and Risk Effects on Price and the Objective Function

Dillon (p. 66) notes three effects of time on prices and the objective function. The first time effect has to do with the opportunity cost of employed resources. This opportunity cost depends on the availability of alternative uses of the resources over time. In feedlots where finished beef production is a continuous process, the time opportunity cost of carrying a lot of cattle another week is the contribution which that week could make to profit if it were used for a new lot of cattle. In this study, feedlot production is modeled as a yearly process, that is, the feedlot is filled in early fall and emptied some time before the next fall. Thus, the replacement issue of how quickly one lot of cattle should be finished and another started is not considered. Rather, the focus of the analysis centers on the risk reducing effects of hedging, stabilization and diversification of feeding regime.

The second time effect is known as the time preference effect and relates to the need to compound present costs or discount future returns to make them comparable. Given the alternative feeding regimes and length of feeding times involved in modeling finished beef production, returns must be made comparable by discounting. Since the model in this study evaluates production-marketing alternatives in one production cycle, a simple interest cost calculation is employed in the objective function rather than discounting to make returns comparable.

The third time effect is that input and output prices vary over time in either a predictable, or subjectively assessable probabilistic, fashion. Risk and time interact in the beef feedlot problem in that alternative feeding regimes dictate varying finishing times and corresponding probability distributions of output and grade prices. The two aspects that are important in this regard, are grade output distributions and seasonal price effects. Grade output distributions relate to the fact that beef animals finished on different feeding regimes and length of feeding periods will grade differently. For example, Agriculture Canada research results show that Hereford steers on a LMH feeding regime and finishing in 283 days had a carcass grade output distribution of 31.25 percent A1, 25.00 percent A2, 31.25 percent A3 and 12.5 percent A4. In contrast, Hereford steers on a LLH feeding regime and finishing in 303 days had a carcass grade output distribution of 13.30 percent A1, 46.70 percent A2, 33.30 percent A3 and 6.70 percent A4 (Hironaka, Sonntag and Kozub, 1979). Seasonal price effects are accounted for in this study by linking them to specific feeding alternatives. For example, the LMH feeding alternative finishes steers in approximately 280 days. If the feeding model is initialized on October 1, then the average slaughter grade price distributions for the first week in July are employed to budget net returns for that alternative. For the first week of July 1985, carcass prices ($/lb) were: $1.39 for A1 & A2 carcasses, $1.24 for A3 carcasses, and $1.19 for A4 carcasses (Alberta Agriculture, 1986). Detrended historical prices are employed this study to determine the price mean and variance for each grade of each feeding the model. With such time-grade price effects it is possible that portfolio effects would exist. The next section explores the diversification issue.

Diversification Effects

As indicated at the end of chapter two, if the decision maker faces choice alternatives that are not perfectly positively correlated, the diversification effect results in a reduction in returns variability. The diversification effect depends on the degree of correlation among activities, the number of activities in the portfolio and the economies of size in production.

Economies of size, which reduce average cost as production increases, favor specialization. Assets that experience increases in output per unit of input over a given range give rise to economies of size which give incentive to specialize and offset the loss in risk reduction that would have resulted with diversification. In terms of cattle feeding, economies of size would exist for any particular feeding regime if costs decreased significantly at progressively higher levels of output through the use of that feeding regime. The cost reductions might be associated directly with feeding, such as, diet preparation, labor and marketing. These economies of size should not be confused with the economies of size associated with the entire feedlot operation. It is well recognized that substantial economies of size exist for the entire feedlot operation. Rosaasen and Schmitz (p. 57) present data on Southern Alberta feedlots that suggest that the most efficient size appears to be 1,000 head capacity with per-unit costs dropping until at least 10,000 head is reached. Cost reductions occur because of the spreading of fixed costs (feed mill, forage and silage storage facilities, hospital pens, feed and water delivery systems), marketing power (ability to bid on feeder cattle and bargain with packer) and specialized management (better price forecasting, preventative veterinary care, nutritional information). The costs associated with a particular feeding regime, however, represent a smaller portion of total feedlot expenses. Thus, diversification of the feeding program may be a valid response to reduce risk and its associated costs, particularly for feedlots that do not feed cattle on a continuous basis. For feedlots that buy and sell cattle on an ongoing basis and feed continuously, the opportunity costs of resources involved in carrying cattle longer periods of time may, however, direct specialization of the feeding program to high concentrate diets.[21/] Given that this study focuses on feedlots that operate a single production cycle, the hypothesis is advanced that diversification of the feeding program will be risk-reducing.

[21/] For example, Monfort's feedlot in Colorado, U.S.A. continuously feeds over 240,000 head of cattle per year on a high concentrate ration which finishes heavier calves in a 120 day feeding period.

Summary

The feedlot management problem of deciding what type of animals to feed, for how long and on what diet is complicated by price risk and time considerations. This chapter dealt with the risk aspect by employing economic theory of the firm under uncertainty in an EV context to deduce the possible output and substitution effects of the available risk-reducing techniques of hedging and stabilization. Other factors, such as seasonal price trends, time opportunity costs of resources, the time preference effect, and feeding regime-time interaction were also considered. Several testable hypotheses were generated from the discussion, which gave insight into how to construct and analyze the empirical portion of the study.

The next chapter discusses modeling approaches used to represent the feedlot management problem and proposes a modeling methodology for analysis of the study objectives.

IV RISK MODELING TECHNIQUES

Introduction

Various modeling approaches have been used to represent and analyze the feedlot management problem. They include dynamic programming, linear programming, quadratic programming and linear risk programming variants, such as MOTAD and target-MOTAD models. This chapter considers each of these techniques and their appropriateness for modeling the beef feedlot management problem specific to Southern Alberta.

Empirical studies which have employed these techniques to model the beef feedlot management problem are reviewed and the reasons given for choosing linear risk programming as the method for this study.

Dynamic Programming

Dynamic Programming (DP) has been employed in several studies to model beef production systems (Nelson, Meyer, Kennedy, Clark, Yager, van Poollen. DP is essentially a multistage algorithm for optimally selecting a sequence of interrelated decisions. An example of a simple, discrete DP model formulation is (Perry):

$$\text{Maximize} \quad \sum_{t=1}^{n} F(u_t, w_t, t)(1 + r)^{-t}$$

$$\text{subject to} \quad w_{t+1} = h(u_t, w_t, t)$$

$$0 \leq x_t \leq d_t$$

where n is the number of stages being analyzed, F(•) is the returns function, u_t is the decision or control variable in stage t, w is the state variable in stage t, r is the discount rate, h(•) is the equation of motion, and d_t is the resource constraint in stage t. In respect to continuous feedlot production, the production period could be divided into one month stages; the states of nature could be defined by feeder and finished beef prices and liveweight levels; and the decision variables might be feeding program and animal placement, that is, animals to sell, buy or continue feeding.

Although an effective technique for finding the optimal times and liveweights at which to sell and buy cattle, DP has serious limitations with respect to the objectives of this study. Specifically, DP would not be effective in determining the impact and interaction of risk-reducing strategies available to feedlot operators because, probabilistic DP models which consider risk tend to be very complex and potentially suffer from the "curse of dimensionality" (McCarl, 1985). In addition, DP requires development of a solution algorithm specific to the problem under consideration; a difficult and time consuming process from the researcher's point of view. For these reasons, DP was not considered the best approach given the objectives of this study.

Previous DP studies of the beef production process, however, provide useful insights and suggestions for future research. Nelson, in an effort to determine the value of an information system to feedlot operators, constructed a three-part model of the beef feeding process. His model consisted of a naive cattle price forecasting subsystem, a least-cost ration formulation subsystem and a dynamic programming feedlot operations scheduling subsystem. Statistical decision theory techniques were incorporated into the dynamic programming algorithm along with price forecasting information to determine decision actions on number of cattle to buy, number of cattle to sell and the feeding program to follow for each sequential one month period in the model. The states of nature in each period were various levels of cattle prices and the choice criterion was the present value of net returns to the fixed resources over the planning horizon.

A suggestion for future research was development of a more reliable price predicting method, such as a quarterly price predicting formula based upon cattle-on-feed data. Another suggestion was a more accurate specification of nutrient requirements (mainly energy) in the beef feed formulation subsystem and validation of those requirements by feeding experiments. It was also felt that the beef feed formulation subsystem should be expanded to consider a larger set of feedstuffs.

Meyer constructed a deterministic dynamic programming feedlot model and suggested that available least cost rations at each stage be formulated by a linear programming model based on the net energy system. His algorithm, however, required only the parameter values of net energy available for gain, net energy available for maintenance and cost per unit of energy for each of the assumed least cost rations.

Kennedy also formulated the feedlot optimization problem in the framework of dynamic programming but was the first to add a linear programming subroutine to calculate least cost rations. Based on the British Metabolizable Energy (M.E.) system, the Kennedy model had the advantage of being able to provide information on the optimal composition of the ration to be fed in each time period. More importantly, by integrating a liveweight sequencing system (the DP model) with a ration composition system (the LP model) the Kennedy model was better able to capture the interactions of feeding regime, feed costs, cattle prices and interest charges. Kennedy also introduced pasture grazing management alternatives into the LP model and specified as a constraint available forage as function of stocking rate and grass growth. Although his study was a deterministic analysis of the effects of stocking rate changes, he proposed that if data on seasonal variation in grass growth and digestibility were available a stochastic analysis could be undertaken. Also of interest is Kennedy's suggestion of using the model to evaluate the effect of government altered feed and/or cattle prices on optimal feeding and marketing policies.

Clark, also constructed a deterministic dynamic programming model for analysis of feeding and marketing strategies for pasture fed beef cattle. Clark extended Kennedy's model by assuming that liveweight gains were dependent on the time of year and breed of cattle. In addition, saleyard prices were made dependent on liveweight and time of year. Rather than comparing a range of grassland management policies, the Clark model recommended an optimal grassland policy. However, Clark proposed that future research consider a stochastic dynamic programming analysis employing data on pasture yield as a function of rainfall and fertilizer coupled with short-term forecasting of cattle prices.

Yager combined a first-order autoregressive model for forecasting monthly cow prices with a price-stochastic dynamic programming analysis of optimal policies for marketing cull cows. Van Poolen incorporated all segments of the overall beef production system (i.e., feedlot, pasture finishing, or culled cows) to examine feed-beef price relationships on beef production strategies in Hawaii.

The major limitation of the above studies is the inability of the DP approach to easily accommodate risk. Stochastic DP problems were solved using an expected value criterion, which ignores variance. For Yager's analysis of the cull cow-marketing problem, the assumption of a linear utility function, as implied by the expected value criterion, was considered appropriate since returns from cow marketing were small relative to the entire ranching operation (Yager). For the feedlot operator, however, risk is an important variable since a large component, if not all his entire income, is dependent on finished cattle marketings. Thus, risk optimization techniques such as quadratic programming or MOTAD (minimization of total absolute deviations) linear programming, which are designed to handle risk directly are considered more appropriate to the objectives of this study.

Linear Programming

Resource allocation problems under certainty may be formulated in a linear programming framework as follows:

Maximize $C'X$

subject to $AX \leq b$

$X \geq 0$

where

C is a 1 x n vector of objective function coefficients

X is an n x 1 vector of decision variables

A is an m x n matrix of resource usages

b is a m x 1 vector of initial resource endowments

Several linear programming (LP) models have been constructed to model the beef growing and finishing process. Most have been extensions of well-known least-cost ration programs where the objective functions have been altered to accommodate profit maximization. Despite the fact that such models do not consider risk, they provide a useful design basis for this study. Two models, by Apland and by Sonntag and Hironaka, have a direct influence on the model employed in this study.

Apland used dynamic linear programming to model the growing-finishing feedlot process. Unique to the Apland model versus other minimum-cost or maximum-profit ration-formulation linear programming models was the endogenous specification of rate of gain in various stages of growth. Specifically, the model was used to find the maximum profit feeding strategies for target marketing weights of 950, 1,000, 1,050 and 1,100 pounds for medium-framed steers with an initial weight of 500 pounds. The number of growth stages specified ranged from four for the 950-pound target weight to seven for the 1100-pound weight. For each stage, seven different rates of gain were specified ranging from 2.2 to 3.0 pounds per day.

Apland focused on the impacts of interest rates on optimal feeding strategies for beef cattle. However, he noted that by parametrically altering the maximum total days on feed and marketing weights that alternate solutions could be combined with expectations of slaughter price movements over time to determine optimal feeding and marketing strategies. He also proposed that as new research in cattle nutrition (e.g., alternate estimates of nutrient requirements and feed intake equations) was completed that the model could be employed to examine their economic implications compared to previous formulations. Lastly, he proposed that microcomputer versions of the model should be constructed with user-oriented matrix and solution report generators as described by McCarl (1982). The incorporation of risk aspects into the model was not discussed.

Sonntag and Hironaka (1976) developed a maximum-profit feedlot LP model for Agriculture Canada Research Branch, based on experiments and data from Southern Alberta. Unique features of the model were linking the feeding program alternatives with carcass grade output distributions and grade pricing and determinating the optimal rations for each of three stages of production based on animal digestible energy requirements. The growing and finishing process was arbitrarily split into three stages of twelve weeks duration for stages 1 and 2, and an undefined length for stage 3, depending on the rate of gain, low (L), medium (M) or high (H), specified in each stage by feeding alternatives. For example, the feeding alternatives of LLH and HHH had stage 3 feeding periods of 132 days and 67 days, respectively. The structure of the diet formulation component of the model was set up so that digestible energy (DE) requirements for alternative feeding programs were specified in Mcal per head for each stage of the feeding period (e.g., 892 Mcal for stage 1 for LLH). Requirements were then met from a combination of alternative feeds where the DE content was specified in Mcal per kilogram of feedstuff. The risk programming models developed in this study are based, for the most part, on the Agriculture Canada model developed by Sonntag and Hironaka.

Quadratic Programming

The general form of a quadratic risk programming model is given by Musser et al. (1984) as:

$$\text{Maximize } C'X - \beta X'\sigma X$$

$$\text{subject to} \quad AX \leq B$$

$$X \geq 0$$

where X = activity levels; C = expected returns associated with each activity; B = resource restrictions; σ = variance-covariance matrix of activity returns; and β equals the quadratic programming (QP) risk aversion coefficient. For each level of ß a unique optimum exists. Parameterizing ß and solving the model repetitively allows for determination of an E-V (expected value-variance) frontier.

Within this general form, Musser et al. (1984) propose a generalized risk programming model (GRPM) structure of activity and constraint sets, and the variance-covariance matrix. The activity sets defined are (1) production-marketing activities, (2) activities for acquiring operating inputs and (3) financial activities. The constraint set can include upper limits on beginning and ending cash balances, operating inputs, capital, credit capacity, consumption and taxation. The variance-covariance matrix as a fundamental component of the model, links the activities in the activity set via their correlations to provide a complete picture of the firm's total risk.

McCarl and Tice (1982) have noted that computer codes for solving QP models have limitations as to size and can be expensive to solve. However, recent advances in both computer codes and microcomputer hardware have relaxed such limitations (McCarl, 1986).

Few beef production studies have employed quadratic programming because of problems in linking the activities for feed and animal production in a manner that would preserve the risk attributes of variable feed production. However, several QP studies that examine risk management strategies in livestock and crop production are important in relation to the objectives of this research.

Recognizing the substantial variation in equity and income of cattle producers and feeders in the 1970's due to wide variations in prices of cattle and purchased feed, Whitson et al. (1976) developed a multiperiod QP model to examine the potential for vertical integration (retention of calf ownership through to finishing) to reduce income variability. Whitson concluded that using vertical production alternatives in ranch planning was an effective response to risk, but that such alternatives should not be evaluated independently of other risk responses.

Falatoonzadeh, Conner and Pope (1985) conducted a portfolio analysis of risk management options available to farmers to determine which strategy or strategies were most effective in reducing variability in net farm income. Specifically, they simultaneously examined five risk management strategies: crop diversification, futures market hedging, forward pricing, cotton seller's call option and the federal crop insurance program (FCIP) for a representative dryland farm in Knox County, Texas. Participation in FCIP at high production-guarantee and price-election levels was found to motivate futures market participation and production uncertainty appeared to have a greater effect on income than price uncertainty. This result is opposite from that predicted by the theory presented in chapter three. Such interactions can only be uncovered if farmers and researchers are encouraged to look at the whole portfolio management picture.

In comparison to the Falatoonzadeh et al. crop production study, portfolio QP studies of risk management strategies in livestock production are limited, with most studies investigating only one or two alternatives for handling risk. Since Stabilization is not an option for cattle feeders in the U.S., the alternatives have typically involved retention of calf ownership to the stocker or finishing phases, and hedging with or without price forecasting.

Angirasa (1981) and Angirasa et al. (1985) conducted long run and short run analyses of cow-calf management strategies but made the variables of fertility level, death loss and rates of gain endogenous in the production process by linking the various LP and QP models to a beef production simulation model. Their results showed that relatively small increases in slaughter cattle prices make stocker or finishing enterprises profitable and that producers who are moderately averse to risk also tend to partially integrate through the stocker phase.

Linear Risk Programming

Because of the wide availability and ease of use of linear programming algorithms, several LP formulations have been devised to accommodate risk analysis (Hazell, 1971; Thomas et al.; Chen and Baker; Tauer). The most popular and widely used approximations of EV analysis are the MOTAD (Minimization of Total Absolute Deviations) formulation developed by Hazell (1971), and the more recent Target MOTAD formulation developed by Tauer. Because of the availability of LP algorithms, linear risk programming was chosen as the solution methodology for this study. Both the MOTAD and Target MOTAD linear risk programming formulations were employed in the study.

MOTAD Model Structure

In the MOTAD model, risk is measured as linear deviations from the expected value. Implicitly, due to the assumption of risk aversion, risk is undesirable and, hence is minimized. The trade-off occurs between expected value returns (E) and absolute deviations (AD). The E-AD frontier is developed by parametrically solving the model with respect to expected value returns, or in the formulation below, by parametrically solving the model for different values of the risk aversion coefficient, α. The E-AD frontier has been found to closely approximate the corresponding EV efficient set (Hazell, 1971; Musser et al., 1984). The MOTAD model can be formulated as (Hazell, 1971):

$$\text{Maximize} \quad \sum_j C_j X_j - \alpha \sum_k (d_k^+ + d_k^-)$$

$$\text{subject to} \quad \sum_j a_{ij} X_j \leq b_i \qquad \text{for all } i$$

$$\sum_j e_{kj} X_j - d_k^+ + d_k^- = 0 \qquad \text{for all } k$$

$$X_j,\ d_k^+,\ d_k^- \geq 0$$

where

e_{kj} is the deviation from the value expected for the jth variable under the k^{th} observation = $c_{kj} - c_j$

d_k^+ is the total summed positive deviation from the k^{th} observation

d_k^- is the total summed negative deviation from the k^{th} observation

α is the risk-aversion coefficient

Since the sum of the negative deviations below the expected value must always equal the sum of the positive deviations above the expected value, a more compact version of the MOTAD model is possible:

$$\text{Maximize} \quad \sum_j C_j X_j - \alpha \sum_k d_k^-$$

$$\text{subject to} \quad \sum_j a_{ij} X_j \leq b_i \quad \text{for all } i$$

$$\sum_j e_{kj} X_j + d_k^- \geq 0 \quad \text{for all } k$$

$$X_j, d_k^- \geq 0$$

Covariance is approximated within the deviation equations. As the deviation is summed across all of the activities, variation in one activity will cancel out opposite variation in other activities. Thus, in minimizing deviation the model has an incentive to "diversify" taking into account negative covariance. Use of deviations from the expected value also allows for accounting within activities of higher moments. For example, an activity with a large negative skewness would enter the optimal solution in a reduced quantity over what it would in a quadratic programming solution. Thomson and Hazell showed that the MAD (mean absolute deviation) estimator may outperform the sample variance in explaining producer behaviour when income deviations are skewed. The MAD estimator may also be transformed into standard deviation if returns are normally distributed. Thus, it is possible to derive a trade-off frontier between expected return and standard deviation.

Several important studies of beef production have used the MOTAD formulation. For example, Gebremeskel noted that budgeting and linear programming techniques used to evaluate cow-calf management options failed to consider risk due to forage yield and calf price variability. He employed a modified multiperiod MOTAD model, which maximized expected net returns subject to parametric restrictions on mean absolute deviations in net returns due to calf price and forage yield variation. Interesting aspects of his analysis were the conversion of deviations in forage supplies between years into dollars through purchase and sale of hay less harvesting and transportation costs and the estimation of E-AD efficient sets for long run farm plans (re: forage system, herd size, calving season) coupled with a decision theory framework to analyze short run calf marketing strategies.

A major result from his study was that E-AD efficient sets appear steeper for livestock producers than for crop producers, implying that it would be difficult to conceive of a personal utility function that would cause a producer to prefer a solution other than the lowest risk E-AD efficient plan.

Target MOTAD Model Structure

As mentioned in Chapter two, another approach to the examination of risk-return relationships involves a variation of the safety-first concept of risk. Tauer proposed a two-attribute risk and return model designed to minimize the expected sum of the negative deviations of the solution results below a target-return level. Risk is varied parametrically so that a risk-return frontier is traced out. The model is formulated as:

$$\text{Maximize} \quad \sum_j C_j X_j$$

$$\text{subject to} \quad \sum_j a_{ij} X_j \leq b_i \quad \text{for all } i$$

$$T - \sum_j C_{kj} X_j - y_k \leq 0 \quad \text{for all } k$$

$$\sum_k p_k y_k = \Omega \quad \text{for all } k$$

$$X_j,\ y_k \geq 0$$

where

$C_j X_j$ is the expected return of the plan or solution,

C_{kj} is the return of activity j for the k^{th} observation,

T is the target level of return,

y_k is the deviation below T for k^{th} observation,

p_k is the probability that the kth observation will occur,

Ω is a constant parameterized from some large number to zero.

The Target MOTAD formulation is useful since decision makers may wish to maximize expected return but are concerned about net returns falling below a critical target. By defining risk as the negative deviations below a target income, comparisons of the risk-return trade-offs between alternatives become more valid. Risk is measured at a standard reference point (target income) between alternatives, as opposed to the MOTAD formulation where the risk-determining reference point of expected income varies between alternatives. Thus, in most cases with MOTAD models, the only way to reduce risk is to reduce income. Moreover, alternatives which generate higher relative incomes and higher relative standard deviations are risk-increasing in MOTAD models, but may be risk-decreasing in Target MOTAD models. Tauer adds the additional rationale that Target MOTAD solutions conform to the second degree stochastic dominance requirements (SSD), whereas MOTAD solutions may not. McCamley and Kliebenstein, however, point out the difficulty of selecting an appropriate target level, and suggest the need for other criteria for selection of an optimum strategy from the complete set of target MOTAD solutions.

Summary

Linear risk programming was selected as the modeling technique of choice in this study. Its ability to deal with alternative risk definitions (standard deviation versus negative absolute deviation below a target) and the availability LP solution algorithms, made it the preferred technique. Alternative risk modeling approaches reviewed included dynamic programming and quadratic programming. DP was rejected because of its limited ability to examine portfolio effects, its tendency to cause stochastic models to become large and unwieldy, and its algorithmic specificity, which generally requires development of a solution algorithm each time a new problem is created.

Non-risk linear programming models of the feedlot management problem were reviewed for insight into how to model the feedlot process to meet the objectives of this study. Both the Apland (1985) and Sonntag and Hironaka (1976) models divided the growth and feeding process into stages and specified alternative rate of gain feeding activities. The next chapter details the design of the feedlot model employed in this study and outlines and describes the data development.

V DESCRIPTION OF THE MODEL AND DATA DEVELOPMENT

Introduction

This chapter outlines the production and marketing alternatives that form the basis of the decision set inherent in the beef feedlot management problem. A description of the linear risk programming models is given followed by an outline of essential data development. Input-output parameters and data required to specify the production-marketing alternatives are described.

Representative Production and Marketing Strategies

To explore the portfolio effects of hedging, Stablization, and feeding regime, specification of a representative set of production and marketing altenatives was requisite. Production alternatives are described first, followed by marketing alternatives, which are then detailed as linked production-marketing activities in the linear risk programming models (MOTAD and Target MOTAD models).

Production Alternatives

The production alternatives in the feedlot models are based on experimental data (Hironaka et al., 1979, 1984, 1985). Feeding activities are essentially as defined in the original Agriculture Canada LP feedlot model (Sonntag and Hironaka, 1976). The alternatives represent particular combinations of eight feeding regimes, three slaughter weight possibilities and two breed types. The two breed types represent the smaller framed British cattle (e.g., Hereford steers) and the larger framed exotic crossbred cattle (e.g, Charolais crossbred steers), respectively. Slaughter weights for British breed steers are 386 kg (850 lb), 432 kg (950 lb) and 477 kg (1050 lb). For crossbred cattle the slaughter weights are 523 kg (1150 lb), 568 kg (1250 lb) and 614 kg (1350 lb). The feeding alternatives are limited to eight choices (i.e., LLH, LMH, LHH, MMM, MMH, MHH, HML, and HHH) as defined in the previous Agriculture Canada model (Sonntag and Hironaka, 1976).[22/] The low and medium rates of gain simulate stocker programs in which the low rates of gain are achieved through either feed restriction or low diet energy concentration such as hay diets (Hironaka, Sonntag and Kozub, 1979). The resulting breed, target weight and feed regime combinations represent 2 x 3 x 8 = 48 different production alternatives, of which 17 are considered in the model (table 4).

Notation convention for the production alternatives is described as follows. In alternatives HHH1, HHH2, HHH3; "1", "2", and "3" represent the target slaughter weights of 386 kg (850 lb), 432 kg (950 lb) and 477 kg (1050 lb), respectively. When no number is specified e.g. LLH, HML, etc. the target slaughter weight is 477 kg (1050 lb) for the British feeder steer. The "C" in feeding regimes CLLH etc.

[22/]"H", "M" and "L" refer to high, medium and low rates of gain.

refers to "crossbred", implying a heavy feeder calf. In feeding regimes CHHH1, CHHH2, CHHH3, USCHHH3; "1", "2", and "3" represent the slaughter weights of 523 kg (1150 lb), 568 kg (1250 lb) and 614 kg (1350 lb), respectively.

Table 4 Production Alternatives Included in the Linear Risk Programming Models

Production Alternative	Days on Feed				Finishing Date[23/]
	Stage 1	Stage 2	Stage 3	Total	
LLH	84	84	132	300	August 30
LMH	84	84	109	277	August 7
LHH	84	84	90	258	July 19
MMM	84	84	128	296	August 26
MMH	84	84	88	256	July 17
MHH	84	84	77	245	July 6
HML	84	84	122	290	August 20
HHH1	84	83	0	167	April 19
HHH2	84	84	22	190	May 12
HHH3	84	84	67	235	June 26
CLLH	84	84	120	288	August 18
CLMH	84	84	108	276	August 6
CMMM	84	84	114	282	August 12
CHML	84	84	123	291	August 21
CHHH1	84	84	80	248	July 9
CHHH2	84	84	126	294	August 24
CHHH3	84	84	178	346	October 15
USCHHH3	84	84	178	346	October 15

The USCHHH3 alternative is the same as CHHH3 except that the finished live animal is shipped and marketed into the United States (e.g., Pasco, Washington).

[23/] Starting date on feed is assumed to be November 4, for all production alternatives.

Since cattle in different production alternatives finish on different days, their associated net income returns should reflect differences in seasonal slaughter prices, interest charges on money tied up in feeders and feed, yardage charges and health costs.

For the production alternatives, nutrient specifications other than energy and protein are based on literature values and industry practices (Sonntag and Hironaka, 1976). Digestible energy (DE) requirements are determined from expericmental data (Hironaka et al., 1986) and allow the rate of gain in each of the three stages of production to be endogenous to the linear risk programming models. The rate of gain specified (L, M or H) for each stage, the initial weight, type of feeder and target slaughter weight define the length of the feeding period and the DE requirement for each stage.[24/] The linear risk programming models then maximize profit subject to the risk constraints by selecting, for each stage of production, an optimal production alternative or combination of production alternatives, and a least cost diet from available feed constituents to meet the determined DE requirements. The least cost diet selected represents a linear interpolation of the diets that would be determined for each of the production-marketing alternatives in solution separately had the model been formulated with a set of nutritional constraints for each production-marketing

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[24/]The rates of gain, "L", "M" and "H" specified for each production alternative are detailed in Table 7.

alternative.[25/] The amount of each feed constituent used times its unit cost is subtracted as a cost in the objective function. In addition, as an approximation of the feed interest costs, a prorated interest charge is included within each feeding activity based on the barley equivalent value of total energy used times the annual interest rate times the number of days on feed divided by the number of days in a year (365), all divided by 2.[26/] Also included as costs of each feeding activity are yardage, buying and selling costs, mortality losses and a prorated interest charge on the feeder cost.

Marketing Alternatives

Superimposed on the production alternatives is a set of marketing alternatives. Specification of the variance of net income in risk programming methodologies requires that the activities be additive rather than multiplicative. Since separate production and marketing activities, as specified in a linear programming framework, have a multiplicative effect on net income, they must be combined in a risk programming formulation (Musser, Mapp, and Barry, 1984, p. 135). The

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[25/]This type of block diagonal formulation of the feedlot problem greatly expands the size of feedlot LP matrix, but is the more correct formulation as it determines a diet for each of the production-marketing alternatives in solution. The compact model formulation was selected since it yielded nearly identical results in terms of total feed constituents used, feed costs and the relative proportions of the production-marketing alternatives in solution. A detailed discussion of the two formulations and comparison of their solutions results is given in Appendix B.

[26/]The investment in feed inventory is assumed to be one-half of the amount of feed required for the entire feeding period.

production-marketing activities are formulated to facilitate investigation of the portfolio effects of various feeding, hedging and Stabilization regimes. Specifically the marketing alternatives form a representative "set" of hedging and Stabilization strategies available to Southern Alberta feedlot operators. Hedging strategies for feeder cattle, principal feeds e.g., barly and interest rates are not included since the major problem of focus is finished cattle price risk. The basic "set" includes hedging of the Canadian dollar to determine if the variability in the basis can be reduced.

The set of hedging alternatives are: (1) no hedge, (2) routine hedge and (3) routine hedge with a Canadian dollar hedge. In addition to the hedging alternatives, a Stabilization alternative was defined following specifications and guidelines of the existing Tripartite National Beef Stabilization Plan (Agriculture Canada, 1986).

Feedlot Linear Risk Programming Models

To construct the feedlot MOTAD and Target MOTAD models, previous linear programming models of beef cattle feeding (Apland; Sonntag) were modified using research data available from Agriculture Canada (Hironaka, 1979, 1984, 1985, 1986). Base data and parameters, such as feedstuff nutrient values, historical futures market and live cattle prices, feed constraint limits and Canadian Tripartite Beef Stabilization plan prices and levies, are linked into the models via a matrix generator developed using (GAMS) (Kendrick and Meeraus).[27/] The components of the MOTAD model are described below in the format of objective function and deviation rows, input acquisition activities, production-marketing activities and constraint set. Figure 16 displays a diagram of the MOTAD model structure for the LLH-CASH alternative in stage one of the feeding program. Modifications to the MOTAD model, to formulate the Target MOTAD model, are also detailed.

The MOTAD Objective Function and Deviation Rows

Formulation of the feedlot MOTAD model objective function required consideration and in corporation of the two aspects of EV analysis, namely, expected value and variance of returns to cattle feeding. The specific calculation of expected value is discussed first, followed by a discussion of variance (or standard deviation). Lastly, the complete objective function is defined.

The expected value of net revenue per head for the i^{th} production-marketing alternative, $E(NR_i)$, for any time period in the series 1976-87 was determined using simple exponential smoothing of in-sample data.[28/] For each production-marketing alternative a smoothing constant was determined based on the minimum mean squared error criterion for the associated historical (1976-86) net revenue (gross revenue minus feeder and estimated feed costs) series (Table 5).

[27/] A complete GAMS listing of the MOTAD model is given in Appendix A.

[28/] See Abraham, Bovas and Ledolter, p. 85-89.

	$/LG GRAIN ONE BARLEY	$/LG GRAIN ONE ALFALFA	$/HD LAG-CASH	$/100KG BUY FEEDER	$/100KG HICOST STC ONE	$/LG FEEDCOST STC ONE	$/HD 1976 PDEV	$/HD 1976 NDEV	$/HD 1977 PDEV	$/HD 1977 NDEV	$/HD 1978 PDEV	$/HD 1978 NDEV	$/HD 1979 PDEV	$/HD 1979 NDEV	$/HD 1980 PDEV	$/HD 1980 NDEV	$/HD 1981 PDEV	$/HD 1981 NDEV	$/HD 1982 PDEV	$/HD 1982 NDEV	$/HD 1983 PDEV	$/HD 1983 NDEV	$/HD 1984 PDEV	$/HD 1984 NDEV	$/HD 1985 PDEV	$/HD 1985 NDEV	$/HD 1986 PDEV	$/HD 1986 NDEV		RHS
$/LG OBJECTIVE FUNCTION	-0.004	-0.074	1099.93	-200.00	-6.25																								E	OBJ
MCAL/LG ENERGY BAL Stg 1	-3.42	-2.25	895.73																										E	0.00
DM KG/LG DUFT BAL Stg 1	0.00	0.92	-307.76																										L	0.00
CP KG/LG CP BAL Stg 1	-0.11	-0.15	50.44																										L	0.00
CA GM/LG Ca BAL Stg 1	-0.40	-16.90	1119.66																										L	0.00
P GM/LG P BAL Stg 1	-3.40	-1.90	859.90																										L	0.00
GM/LG Ca P BAL Stg 1	-4.02	12.43																											G	0.00
GM/LG Ca P BAL Stg 1	-23.40	1.60																											L	0.00
GM/LG SALT BAL Stg 1	-0.0025	-0.0025																											L	0.00
KG/LG Mixing BAL Stg 1	-1	-1			1000.00																								L	0.00
KG/HD Feeder BAL			210.00	-100.00																									E	0.00
HD/HD CAPACITY			1																										E	1.00
$/LG FEEDCOST Stg 1	0.004	0.074				-1																							E	0.00
$/YR DEVIATIONS 1976			0				-1	1																					E	0.00
$/YR DEVIATIONS 1977			-32.16						-1	1																			E	0.00
$/YR DEVIATIONS 1978			166.54								-1	1																	E	0.00
$/YR DEVIATIONS 1979			62.36										-1	1															E	0.00
$/YR DEVIATIONS 1980			-153.51												-1	1													E	0.00
$/YR DEVIATIONS 1981			-152.95														-1	1											E	0.00
$/YR DEVIATIONS 1982			39.21																-1	1									E	0.00
$/YR DEVIATIONS 1983			-54.60																		-1	1							E	0.00
$/YR DEVIATIONS 1984			-9.65																				-1	1					E	0.00
$/YR DEVIATIONS 1985			-103.00																						-1	1			E	0.00
$/YR DEVIATIONS 1986			-200.30																								-1	1	E	0.00

Figure 16 Diagram of the MOTAD Feedlot Model

In calculating net revenue per head for any year of the data period 1976-86, the feed costs (as represented by the barley equivalent energy cost), feeder cost, interest rate and slaughter prices existing in that year were used.

Implicit assumptions in the exponential smooting process are that the feedlot manager forecasts the next year's net revenue per head based on a weighted average of the last year's net revenue per head and the last period's forecast of net revenue per head, and is familiar with the historical pattern of net revenue per head for each of the production-marketing alternatives under consideration. Also assumed is the fact that mean net revenue per head changes slowly over time due to the effects of the cattle cycle. Thus, it is reasonable to give more weight to the most recent observations and less to observations in the distant past.

The technique of simple exponential smoothing facilitated a determination of the exact weights for calculation of $E(NR_i)$ (table 5). The higher the smoothing constant, the more rapidly the weights decline into the past. Since the smoothing constants obtained range all the way from 0.99 to .01, one could argue that the producer would have to be relatively sophisticated to have separate forecasting models for each production-marketing alternative. Since the attempt, in using the expontial smoothing model, is to model the producer's "naive" forecasts, an alternate approach would be to use a constant smoothing value for all of the production and marketing alternatives (e.g., 0.5). However, since producer's involved in hedging have large

Table 5 Simple Exponential Smoothing Constants by Production-Marketing Alternative

Production Alternatives	CASH	SHEDG	CHEDG	TSP
	Marketing Alternatives			
LLH	0.31	0.49	0.44	0.46
LMH	0.01	0.62	0.55	0.32
LHH	0.01	0.29	0.30	0.37
MMM	0.34	0.43	0.39	0.36
MMH	0.01	0.54	0.43	0.38
MHH	0.01	0.01	0.34	0.36
HML	0.36	0.83	0.68	0.50
HHH1	0.45	0.96	0.93	0.50
HHH2	0.29	0.99	0.99	0.32
HHH3	0.01	0.32	0.01	0.05
CLLH	0.39	0.99	0.87	0.53
CLMH	0.23	0.53	0.43	0.45
CMMM	0.29	0.99	0.55	0.47
CHML	0.39	0.94	0.79	0.53
CHHH1	0.25	0.36	0.29	0.40
CHHH2	0.31	0.99	0.95	0.47
CHHH3	0.01	0.50	0.49	0.25
USCHHH3	0.99	0.17	0.21	

operations and in some cases employ market analysts and consultants, the more sophisticated model was employed in this study.

The variance component of the E-V model was estimated as the mean-squared forecast error of the series (1976-86) of one-year ahead forecasts of net revenue per head. McSweeny notes that this measure of risk relies totally on past forecast errors, recognizing that they are likely to dominate subjective risk perceptions of the decision maker. In the MOTAD model this risk is estimated by the deviation matrix of 1976-86 observed net revenues per head minus the (forecasted) expected value net revenues per head.

The detailed objective function is:

$$\text{MAX } Z = \sum_{z=1}^{3} \sum_{i=1}^{72} E(NR_i)\, Y_i - \sum_{j=1}^{2} PF_j F_j - \sum_{z=1}^{3} \sum_{s=1}^{m} C_{zs} Q_{zs} - \sum_{z=1}^{3} M_z B_z - \alpha\phi \sum_{k=1}^{11} (d_k^{+} + d_k^{-})$$

where Z = risk adjusted net returns over feeder animal, feed, feed processing costs; marketing charges; other specific feedlot operation costs and interest charges on feed and feeders

$E(NR_i)$ = expected value forecast of net revenue per head for the i^{th} production-marketing alternative per animal for the current (1986-87) feeding year[29/]

Y_i = number of animals fed under i^{th} feeding-marketing program

PF_j = feeder price (\$/kg) for j^{th} type of feeder(e.g., British breed, Exotic breed) at point of sale.

F_j = weight (kg) of j^{th} type of feeder

C_{zs} = cost (\$/kg/hd/stage) of s^{th} feedstuff used for the z^{th} stage at point of sale.

Q_{zs} = quantity (kg) of s^{th} feedstuff used in the z^{th} stage

M_z = feed mixing charge (\$/tonne) for z^{th} stage

B_z = quantity of feed mixed (tonnes) in z^{th} stage

α = risk coefficient

ϕ = conversion factor (converts deviates to standard normal deviates[30/]

[29/]Calculation details are explained under the description of the production-marketing activities. NR_i is a estimated net revenue per head of the i^{th} production-marketing alternative since feed costs are estimated by the energy requirement cost of barley. The 72 production-marketing alternatives result from 18 production alternatives times 4 marketing altenatives.

[30/]ϕ is defined as the square root of $((12 \times \pi)/YR(YR-1)))$ where $\pi = 22/7$ and YR = the number of years of observations, and the variable transformed is assumed to be normally distributed.

d_k^+ = positive deviation value for the k^{th} year

d_k^- = negative deviation value for the k^{th} year

Linked the objective function is a set of deviation rows as follows:

$$\sum_{i=1}^{72} NRDEV_{ik} - d_k^+ + d_k^- = 0 \quad \text{for } k = 1 \text{ to } 11 \text{ rows}$$

where $NRDEV_{ik}$ = the calculated deviation (net revenue for the i^{th} production-marketing alternative for the k^{th} year minus the expected value forecast of net revenue for the k^{th} year)

Input Acquisition Activity Set

The structure of the input acquisition activity set in the MOTAD model is designed to facilitate diet formulation in each of the three feeding stages implied by the production (feeding) alternatives. To accommodate the possibility that three different diets may be required, ingredient options and diet specifications appear in the model in sets of three. For example, digestible energy (DE) requirements for the alternative feeding programs are specified in Mcal per head for each stage of the feeding period.[31/] The crude protein, calcium and other nutrient requirements are calculated in a similar manner except that they are specified as minimum levels rather than as an equality. Feedstuffs considered in the model are specified

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[31/]For example, 892 Mcal for stage 1, for stage 1, 1028 Mcal for stage 2 and 3894 Mcal for stage 3 of the LLH feeding alternative.

in sets of three; for example, oats1, oats2, oats3, as defined by the stages of the feeding program. A mixing charge activity and a vitamin A treatment charge activity are specified for each stage.

Production-Marketing Activity Set

The production and marketing alternatives described above define 72 production-marketing activities in the model.[32/] For each marketing alternative a unique formula is defined for the determination of its estimated net revenue per head contribution to the objective function, i.e., NR_i, as defined above. The activities and their NR (net return) formulae are defined as follows:

1. Cash Marketing Production-Marketing Alternatives (i = 1 to 18)

$$NR_i = [\sum_{g=1}^{4} P_g G_g]_i - V_i - (rB_i T_i/2)$$

where P_g = price ($ per kg) for the gth grade of carcass

G_g = quantity (kg) of g^{th} grade of carcass

V_i = non-feed variable costs[33/] of i^{th} activity

r = interest rate per day

T_i = number of days on feed for i^{th} activity

[32/]Eighteen production alternatives times four marketing alternatives equals 72 production-marketing activities.

[33/]Includes yardage, buying and selling charges, death loss and interest on feeder cost.

B_i = barley equivalent energy cost of the feed used per day for the i^{th} production-marketing alternative

2. Routine Hedge Production-Marketing Alternatives (i = 19 to 36)

$$NR_i = [\sum_{g=1}^{4} P_g G_g]_i - V_i - (rB_i T_i/2)$$

$$+ \{ (RI_i * EI_i) - (RO_i * EO_i) \} \{18,182 * C_i\}^{34/}$$

where RI_i = closing futures price (U.S. \$/kg) on date cattle placed on feed for a contract near to the selling date (in cents per kg) for the i^{th} activity

EI_i = exchange rate (\$ Can/\$ U.S.) on date cattle placed on feed for the i^{th} activity

EO_i = exchange rate (\$ Can/\$ U.S.) on date cattle sold for the ith activity

RO_i = closing futures price (U.S. \$/kg) when cattle sold for slaughter for the i^{th} activity

C_i = number on contracts hedged which equals number of cattle fed divided by 40 and rounded down to the nearest integer (assumes a 1,000 lb steer)

3. Routine Hedge with Canadian Dollar Hedge Production-Marketing Alternatives (i = 37 to 54)

$$NR_i = [\sum_{g=1}^{4} P_g G_g]_i - V_i - (rB_i T_i/2)$$

$$+ \{ (RI_i * EI_i) - (RO_i * EO_i) \} \{18,182 * C_i\}$$

$$+ \{TEI_i - TEO_i\} * D_i$$

where TEI_i, TEO_i = futures price on Canadian Dollar (\$ Can/ U.S. \$) at time cattle are put on feed and soild, respectively.

34/ 18,182 represents the kilogram weight of a 40,000 pound live cattle futures contract.

D_i = number of Canadian dollars hedged = approximated value of cattle to be sold

4. Stabilization Production-Marketing Alternatives (i = 55 to 72)

$$NR_i = [\sum_{g=1}^{4} P_g G_g]_i - V_i - (rB_iT_i/2) + S - \pi$$

where S = stabilization payout per finished animal
π = producer portion of the stabilization levy

Constraint Set

The constraint section of the model divides into nutrient (e.g., DE, CP, Calcium, etc.) balance constraints, ingredient limit constraints and ingredient ratio constraints.[35/] The balance constraints for energy, protein, calcium and phosphorus ensure that the nutrient requirements of each production alternative are met or exceeded. The constraints impose limits on certain diet ingredients to ensure palatability and to prevent digestive problems (toxicity, bloat) and to stay within industry guidelines. These are based largely on industry experience, and are:

1. Urea $\leq$ 0.5 percent of the diet,
2. Salt $\leq$ 0.25 percent of the diet,
3. Beet pulp $\leq$ 5 percent of the diet,
4. Canola meal $\leq$ 10 percent of the diet,
5. Molasses $\leq$ 2.5 percent of the concentrate portion of the diet and plus 5.0 percent of the forage portion of the diet,

35/The individual constraints are detailed in Appendix A.

6. Vitamin A = 30, 35, and 40 thousand I.U. per day in stages one, two, and three, respectively,

7. Limestone $\leq$ 1.5 percent of the diet.

The ingredient ratio constraints specify that one ingredient or nutrient be set in a certain proportion to another. For example, a minimum calcium to phosphorus ratio in the diet is set to 1.3 to 1, meaning that the gram weight of calcium supplied by the diet must be greater than or equal to 1.3 times the gram weight of phosphorus supplied by the diet.

Target MOTAD Model Adjustments

Only minor adjustments to the MOTAD model were necessary to accommodate a Target MOTAD formulation. The input acquisition activity set, the production and marketing activity set, and the constraint set remain unchanged. The objective function was changed to:

$$\text{MAX } Z = \sum_{z=1}^{3} \sum_{i=1}^{72} E(NR)_i Y_i - \sum_{j=1}^{2} PF_j F_j - \sum_{z=1}^{3} \sum_{s=1}^{m} C_{zs} Q_{zs} - \sum_{z=1}^{3} M_z B_z$$

The deviation rows of the MOTAD model were dropped, and replaced by the following risk rows, and an expected shortfall from the target row:

$$50 - \sum_{z=1}^{3} \sum_{i=1}^{72} E(NR)_i Y_i - \sum_{j=1}^{2} PF_j F_j - \sum_{z=1}^{3} \sum_{s=1}^{m} C_{zs} Q_{zs} - \sum_{z=1}^{3} M_z B_z - y_k \leq 0$$

where y_k = the deviation below the target net revenue per head of \$ 50 for the k^{th} year (k = 1 to 11 for years 1976 to 1986)[36/]

$$\sum_{k=1}^{11} (1/11)\, y_k = \Omega,$$ where Ω is set to some acceptable level for the expected sum of the deviations below \$ 50 and (1/11) defines the probability associated with each k^{th} or yearly observation.

Data Development

Data from a variety of sources are used in this study. Cattle growth data and nutrient requirements were obtained from Agriculture Canada Research Branch experiments conducted at Lethbridge, Alberta, Canada (Hironaka, 1979, 1984, 1985, 1986) and from personal communication with scientists at the Lethbridge station. Representative feedlot statistics and information on the distribution, size and feeding practices of Southern Alberta feedlots were obtained from several sources. These included: a University of Saskatchewan feedlot study (Rosaasen, 1985), Alberta Agriculture publications (Alberta Agriculture, 1980, 1981), a set of studies prepared by Lakeside Research (Lakeside Research, 1986, 1987a, 1987b) and personal communication with livestock specialists and feedlot operators in Southern Alberta.

[36/]All other variables are as previously defined. The target net revenue per head value of \$ 50 was selected because it approximates mean net revenue per head values determined for each of the production alternatives for the cash marketing alternative. The mean net revenue per head values generally ranged from about \$ 30 to \$ 70 (see table 18).

Information on the National Tripartite Beef Stabilization Plan was obtained from Agriculture Canada Policy Branch staff (Agriculture Canada, 1986). Grading and marketing information, including historical time series data on price-grade differentials were obtained from the Alberta Cattle Commission Canfax services, and from Canada Livestock and Meat Trade Reports (Agriculture Canada, 1976 to 1987). Information on feed barley, feeder, stocker and slaughter cattle prices was obtained from Alberta Agriculture IP Sharp database. Data on interest rates were obtained from Statistics Canada CANSIM database. Information on futures market was obtained from Wall Street Journal editions (1976-87) and from the University of Guelph Agricultural Economics database. The following sections detail the feedstuff data, production data, historical financial data and current financial data used in the models.

Feedstuff Data

Feedstuffs made available in the models included those typically available to Southern Alberta feedlot operators. Reported feed composition values were employed in the models (Agriculture Canada, 1981). Table 6 details the feedstuffs available in the models and their feed composition values, which are similar to those determined for Saskatchewan feedstuffs (Christensen and Steacy, 1980).

Table 6 Composition of Southern Alberta Feedstuffs

	Digestible Energy Mcal/kg	Crude Protein g/kg	Calcium g/kg	Phosphorus g/kg	Dry Matter %
Feed Barley	3.42	10.6	0.4	3.4	88
Feed Wheat	3.44	13.7	0.4	3.5	88
Feed Oats	3.13	9.9	0.6	3.1	88
Grain Corn	3.47	9.0	0.3	3.0	88
Beet Pulp	3.22	9.0	6.7	1.0	90
Molasses	2.65	6.7	1.6	0.3	77
Soybean Meal	3.44	47.0	3.0	6.5	90
Canola Meal	3.26	38.0	4.0	9.4	90
Dehy Alfalfa	2.40	17.0	13.0	2.3	90
Alfalfa Hay	2.25	15.2	14.9	1.9	92
Brome Hay	2.20	7.98	3.9	1.3	90
Grass-Legume Hay	2.42	11.8	10.0	1.7	90
Cereal Hay	2.74	8.0	2.5	1.9	90
Barley Straw	1.75	4.1	2.8	0.9	90
Oat Straw	1.87	3.9	2.2	0.9	90
Wheat Straw	1.70	3.6	1.9	0.7	90
Cereal Silage	2.78	14.3	4.6	3.5	31
Supplement	2.86	32.0	30.0	10.0	90
Corn Silage	2.89	9.3	9.7	2.2	30
Urea	0.0	262	0.0	0.0	100
Dicalcium	0.0	0.0	230	185	95
Rock Phosphate	0.0	0.0	300	181	95
Limestone	0.0	0.0	380	0.0	95
Salt	0.0	0.0	0.0	0.0	95
Vitamin A	0.0	0.0	0.0	0.0	100

Source: Hironaka and Sonntag, 1976.

Production Data

Much of the production data employed by the models was derived from experiments conducted by the Lethbridge Research Station (Hironaka, 1979, 1984, 1985, 1986). Basic production data generated for each of the 17 production alternatives (e.g., LLH, HHH1, CHHH3, etc.) included: rates of gain in each feeding stage (kg per day), days on feed, dressing percentages, grade distributions (% A1, A2, A3 and A4), digestible energy requirements (Mcal per day) and crude protein requirements (grams per day).

Table 7 displays the rates of gain (kg per day) per feeding stage associated with each of the production alternatives. Feed was restricted to achieve goals of 0.5 kg per day gain for the "L" (low) rate of gain designation, and 0.8 kg per day for the "M" (medium) rate of gain designation. Diets were fed ad libitum for the "H" (high) rate of gain designation (Hironaka, 1979).

Table 7 Rates of Gain (kg per day) by Production Alternative and Stage of Feeding

	Stage 1	Stage 2	Stage 3
LLH	0.50	0.50	1.39
LMH	0.50	0.80	1.45
LHH	0.50	1.50	1.10
MMM	0.80	0.80	1.04
MMH	0.80	0.80	1.51
MHH	0.80	1.40	1.07
HML	1.65	0.80	0.50
HHH1	1.0	1.11	0.0
HHH2	1.0	1.3	1.31
HHH3	1.0	1.3	1.10
CLLH	0.53	0.82	1.28
CLMH	0.53	0.97	1.40
CMMM	0.63	1.02	1.12
CHML	0.87	0.95	0.91
CHHH1	0.87	1.32	0.94
CHHH2	0.83	1.29	1.02
CHHH3	0.89	1.33	0.98
USCHHH3	0.89	1.33	0.98

Table 8 details the beginning and ending weights, dressing percentages and grade distribution experimental results by production alternative. Approximately 94 percent of cattle marketings in Alberta grade into the "A" grade categories (Considine, 1986).

Table 8 Dressing Percentages and Grade Distributions (Percent in "A" Grade Categories) by Production Alternative

	Dressing	------- Grade	Distribution	------		- Weight -	
	Percent	A1	A2	A3	A4	END kg	BEG kg
LLH	56.9	6.5	29.7	36.1	27.7	477	210
LMH	57.4	15.8	31.9	32.6	19.7	477	210
LHH	58.6	0	0	63.8	36.2	477	210
MMM	56.8	20.1	53.2	26.7	0	477	210
MMH	58.4	6.4	25.8	33.5	34.2	477	210
MHH	59.3	0	7.0	56.7	36.3	477	210
HML	56.8	21.1	42.5	36.3	0	477	210
HHH1	56.0	25.0	56.3	0	18.75	386	210
HHH2	55.8	25.0	37.5	31.25	6.25	432	210
HHH3	59.0	3.1	6.2	34.9	55.8	477	210
CLLH	57.3	62.5	37.5	0	0	523	250
CLMH	58.0	62.5	37.5	0	0	523	250
CMMM	56.7	88.5	12.5	0	0	523	250
CHML	56.8	81.2	18.8	0	0	523	250
CHHH1	57.6	18.8	56.2	25.0	0	523	250
CHHH2	59.6	26.7	40.0	33.3	0	568	250
CHHH3	60.4	21.4	28.6	28.6	21.4	614	250
USCHHH3	60.4	21.4	28.6	28.6	21.4	614	250

Table 9 displays a comparison of the Canadian beef grading system with that of the United States. Table 8 data on the "CHHH3" grade distribution, dressing percentage and ending weight, and table 9 data comparing U.S. grade categories to the Canadian A1 to A4 categories formed the basis for pricing decisions of overweight "CHHH3" steers marketed in the United States (USCHHH3). Essentially, the CHHH3 steers grading Canadian A1 or A4 were assumed to grade U.S. Good, while those grading Canadian A2 or A3 were assumed to grade U.S. Choice. Thus, according to the CHHH3 grade distribution, approximately 42.8 percent of the CHHH3 steers would grade U.S. Good, and would be discounted appropriately from the quoted price for Choice steers.

Crude protein requirements in the model were calculated by a formula derived from experimental data and used in one of the later versions of the original Agriculture Canada feedlot model. Its format is:

Crude Protein Requirement per Feeding Stage (kg) =
(326.9 + (0.915 x Average Weight (kg) in the Stage) +
(124.4 x Rate of Gain (kg/day) in the Stage)) •
(Number of Days on Feed in the Stage) • .001

A more recent factorial method for calculating protein requirements was available; however, it was unable to be used in the models as it determined the crude protein requirement partly on the basis of the digestible energy concentration of the diet (Hironaka, 1986). Also because the least-cost diet selected by the models is a function of the crude protein requirement and the crude protein requirement is a function of the diet selected, a circular reference problem exists that creates complications for mathematical programming models. Also because the additional precision of the newer method was not that crucial for the majority of feedstuffs routinely fed by commercial feedlots, the simpler formula was employed in this study.

Table 9 Comparison of Canadian and U.S. Beef Grading Systems

	---- Current Canadian Grading System -----		
		------- Specifications -------	
Current U.S. Grades	Grades	Warm Carcass Wt. (lbs)	Fat Cover (inches)
Good	A1	300-499	.2-.3
Standard		500-699	.2-.4
		700+	.3-.5
Choice	A2	300-499	.31-.5
Prime		500-699	.41-.6
		700+	.51-.7
Prime	A3	300-499	.51-.7
Choice		500-699	.61-.8
		700+	.71-.9
Commercial	A4	300-499	.71+
		500-699	.81+
		700+	.91+

Source: Considine, Kerr, Smith and Ulmer, 1986.

The DE requirements for the British breed alternatives (LLH, LMH, etc.) are determined by using an equation derived from the data (Hironaka et al., 1986):

$$DE = 105\ W^{0.75}\ (3.684 - 0.003231\ W)^{ADG} \qquad (28)$$

R-SQR = .817

where

DE = total digestible energy intake requirement (kcal/day) for cattle fed on diets containing > 3300 kcal kg^{-1}

W = weight (kg) of an animal

ADG = average daily gain (kg).

In comparing DE values estimated for crossbred steers fed to higher target weights with actual experimental values, it was found that equation 28 underestimates digestible energy requirements, thus, actual experimental values were employed to determine the DE requirements for the crossbred feeder production alternatives (e.g., CLLH, CHML, CHHH3, etc.) (table 10).

Table 10 Digestible Energy Requirements (Mcal) per Stage of Feeding for the crossbred feeder Production Alternatives

Production Alternative	Stage 1	Stage 2	Stage 3	Total
CLLH	1126	1533	4141	6800
CLMH	1153	1801	3817	6771
CMMM	1275	1851	3318	6444
CHML	1463	1905	3103	6471
CHHH1	1596	2352	2499	6447
CHHH2	1581	2493	3785	7859
CHHH3	1619	2393	5286	9298

Since the experimental data was generated through individual steer feeding trials, the applicability of the determined DE requirements and formula to the commercial group feeding situation was investigated by comparing weight gains and digestible energy requirements experienced in commercial feedlots with those generated from the experiments. Lakeside research reported a feeding trial on 1762 steers fed from weights of approximately 363 kg to 592 kg (Lakeside Research, 1987a, p. 48). Results from the trial are compared in table 11 with values determined for a similar weight period using the Lethbridge Research Station experimental data (Hironaka, 1985) and with predicted values based on National Research Council (NRC) recommendations (NRC, 1987). Digestible energy required per kilogram of gain was similar between the Lakeside data and the Research Station data for both the early and late feeding periods. This tends to validate the DE equation (equation 28) and data employed in the models to estimate DE requirements. NRC predicted values were relatively low (34.68 versus about 40) for the late feeding period, indicating that NRC equations underpredict energy requirements for late feeding period when the steers are building fat rather than muscle tissue.

Historical Financial Data

To estimate the historical (1976-86) net revenue per head for each of the production-marketing alternatives, data were required on: feed barley prices, feeder prices, interest rates, the Consumer Price Index (CPI), Canadian livestock carcass grade prices and discounts, U.S. live cattle grade prices and discounts, transportation costs, Chicago Mercantile Exchange live cattle futures prices, Canadian dollar futures prices, seasonal slaughter cattle price indices and estimated Tripartite Stabilization Plan payouts and levies. For each production-marketing alternative, input costs were matched with the starting date, which was November 4 for all years.[37/] Output prices and

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37/This date corresponds to the peak of the traditional Fall calf sales run experienced in Alberta and Saskatchewan (Lakeside Research, 1986, p. 13-21.

Table 11 Comparison of Actual DE versus Predicted DE Values

	Early Feeding Period			Late Feeding Period		
Parameter	Lakeside Data	NRC Data	Research Station Data	Lakeside Data	NRC Data	Research Station Data
No. of Steers	1762		14	1762		14
Beg weight (kg)	362.27	362.27	360.74	550.91	550.91	550.71
Final weight (kg)	546.36	546.36	550.71	592.27	592.27	600.49
Avg weight (kg)	454.32	454.32	455.73	571.59	571.59	575.60
Weight Gain (kg)	184.09	184.09	189.97	41.36	41.36	49.78
Days on feed	116	116	190	42	42	62
Avg Daily Gain kg/d	1.59	1.59	1.00	1.00	1	0.803
DM conversion-(kg of diet/kg of gain)	3.05		7.64	5.05	5.05	12.25
DE (Mcal/kg gain)	24.42	24.24	25.23	40.47	34.68	39.18
Total DE (Mcal)	4510	4462	4793	1674	1435	1950

values were matched with the last date of the feeding period, which varied depending on the production alternative (table 4).

Input Prices and Costs

Feed barley prices, feeder steer prices, the Canadian bank prime interest rate and the Consumer Price Index for the period 1975-86 are displayed in table 12. The conditional relationship between feed barley price and feeder steer price is evident from table values: as barley price decreases, feeder steer price increases, and vice-versa. This reflects the bidding up of feeder calf prices when relatively inexpensive feed supplies are available. The estimated net revenues per head for each year 1976-86 were calculated using the feed barley price, feeder price and interest rate reported on November 4 of the

Table 12 Input Prices and Cost Factors for the period 1975-86

	November 4 values			
Year	Feed[a] Barley Price ($ per tonne)	Feeder[b] Steer Price ($ per 100 kg)	Interest[c] Rate (percent)	Consumer[d] Price Index (1981=100)
1975	95.99	50.60	10.75	61.0
1976	91.50	65.45	10.75	62.9
1977	80.38	105.60	9.25	67.9
1978	62.00	189.20	12.50	73.9
1979	98.75	231.00	16.00	80.7
1980	133.20	207.90	14.75	88.9
1981	107.00	159.50	18.25	100.0
1982	96.45	182.60	14.00	110.8
1983	119.00	185.35	12.00	117.2
1984	144.70	186.12	13.00	122.3
1985	130.90	195.80	11.00	127.2
1986	84.00	234.30	10.75	126.0

Sources: a/ Alberta Agriculture, IP Sharp Database, 1987, Weekly Cash Feed Barley Prices for Lethbridge, Alberta.
b/ Alberta Agriculture, IP Sharp Database, 1987, Weekly Cash Feeder Steer Prices for Calgary and Southern Alberta.
c/ Statistics Canada, CANSIM University Base 1986, Chartered Bank Prime Business Loan Rate.
d/ Agriculture Canada, Policy Branch, Handbook of Selected Agricultural Statistics, 1974-1986 editions.

previous year. For example, the net revenue per head calculated for 1976 reflects costs and returns arising from the 1975-76 feeding period that began on November 4, 1975. The Consumer Price Index was used to deflate estimated net revenue per head values to 1981 constant dollars. Historical values (in 1981 constant dollars) for various end of the feeding period costing parameters, such as, cattleliner transportation rates and Canadian and U.S. discounts on overweight cattle were determined from their 1987 values deflated by the Consumer Price Index to 1981 dollars and subtracted from calculated yearly net revenue per head amounts.[38/]

Output Prices and Values

Data requirements encompassing the returns side of the historical net revenue per head calculation varied according to marketing alternative. The cash marketing alternative required data on Canadian carcass grade prices and discounts, and on U.S. grade prices, discounts and transportation costs from Alberta to U.S. markets. The futures marketing alternatives required additional data on U.S. live cattle futures prices, Canadian dollar futures prices and exchange rate values. The Tripartite Stabilization Plan marketing alternative required data on historical payouts and levies per head. Output price data and values employed in the study are discussed below under the appropriate marketing alternative headings.

[38/]Since a time series was not available on overweight discounts it was assumed that their constant dollar value would remain the same from year-to-year. In fact they vary weekly with packing plant capacity utilization and local carcasses supply and demand conditions. Average discounts for 1987 were employed in this study.

Cash Market Data

Among the factors that affect beef carcass pricing in Canada, the Montreal wholesale price for dressed carcasses is paramount, and is quoted weekly in various farm publications for A1, A2 steers and heifers and D1, D2 cows. It also represents the only published series of carcass prices for the A3 and A4 grades.[39/] A 1976 report on the Canadian Beef System notes (Agriculture Canada, 1976):

> "The most important channel for the sale of dressed beef, in terms of price determination, is the weekly shipment of carload lots of Alberta beef to the Montreal wholesale trade. The weekly settlement of this price sets the pattern for beef trading throughout the country."

Although the beef trade has shifted somewhat to a north-south movement, (Western Canada to the U.S.) the Montreal wholesale price still determines the levels and differentials on carcass grade prices paid on direct-to-packer sales in Alberta and Saskatchewan. In addition, it has a determining influence on live slaughter cattle prices. For these reasons, the Montreal wholesale price, less an estimated transportation and processing cost differential between Calgary, Alberta and Montreal, Quebec, was selected as the basis for determining gross revenue per head. The transportation and processing

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[39/]In 1987 83.2 percent of cattle marketed in Alberta graded into the A grades (Agriculture Canada, 1987). Of those only 9.6 percent graded A3, A4. For this reason only A1, A2 railgrade and wholesale prices are reported in Alberta. Thus, the Montreal wholesale price series was the only published series for A3, A4 carcasses. The preferred price series would have been Alberta direct-to-the packer or railgrade prices for all A grades.

Table 13 Montreal Wholesale Carcass Grade Prices and Montreal-Calgary Price Differentials for the LLH Production Alternative ($/100 kg) on August 30 of each year[40/]

Year	Carcass Grade Category A1	A2	A3	A4	Montreal-Calgary Price Differential
1976	162.80	162.80	151.80	140.80	10.65
1977	171.60	171.60	160.60	149.60	16.50
1978	239.80	239.80	228.80	217.80	12.10
1979	301.40	301.40	279.40	268.40	9.35
1980	316.80	316.80	305.80	292.60	22.66
1981	310.20	310.20	288.20	277.20	27.50
1982	305.80	305.80	283.80	272.80	24.20
1983	288.20	288.20	266.20	255.20	32.67
1984	319.00	319.00	297.00	286.00	36.23
1985	288.20	288.20	255.20	244.20	23.65
1986	312.40	312.40	290.40	279.40	34.87

Source: Alberta Agriculture, IP Sharp Database, 1987.

cost differential was calculated yearly (1976-86) as the difference between the Montreal A1, A2 wholesale carcass price and the Calgary A1, A2 direct-to-the-packer carcass based price (railgrade price). Table 13 details the Montreal wholesale carcass grade prices and estimated transportation and processing cost differentials for the LLH production alternative.[41/] For the period 1976-86 no price differential existed between A1 and A2 carcasses; however, since May of 1987 a premium of

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[40/]For each production alternative, the selling or finishing date varies as documented in table 5.

[41/]A complete listing of the Montreal prices for all the production alternatives is given in Appendix A under Table LPR (F,YR,GD,) ACTUAL LIVESTOCK CARCASS PRICES. The Montreal-Calgary price differential in $ per 100 lb is given in Appendix A under table MARK (F,YR,*) HISTORICAL MARKETING CHARGES under column DIFF.

approximately $ 6.60 per 100 kg has been offered by packers for A1 carcasses over A2 carcasses. This reflects a continuing preference by consumers for leaner beef (Cattlemen, Oct. 1987).

In addition to price differentials between grades, Canadian packers also impose overweight discounts depending on market conditions. The discounts vary weekly, but for 1987 averaged $ 4.40 per 100 kg for carcasses between 330 kg and 375 kg, and $ 8.80 per 100 kg for carcasses over 375 kg (Canfax, 1987). The CPI was used to deflate the 1987 discount of $ 4.40 per 100 kg to determine a 1981 constant dollar discount for the period 1976-86. For the CHHH3 production alternative (where carcasses weigh 371 kg) the determined overweight discount was applied in calculating historical net revenue per head.

For CHHH3 cattle marketed into the U.S. (USCHHH3) determination of net revenue per head was based on the Washington-Oregon U.S. Choice grade live steer price (U.S. $ per cwt) minus discounts for yield grade (% Y4's) and carcass grade (% grading Good versus Choice), and minus customs duty ($ 1 per cwt) and transportation costs from Southern Alberta to Pasco, Washington. The Washington-Oregon price series is displayed in table 14. The CPI was used to deflate 1987 U.S. yield and grade discounts to 1981 constant dollars. The assumption was made that 5 percent of the USCHHH3 cattle would obtain yield 4 grade, and that approximately 42.8 percent would grade Good rather than Choice. The estimated U.S. carcass yield was set at 3 percent higher than the Canadian yield (Grainews). The 1987 discount for yield grade 4 was U.S. $ 20 per cwt., while the 1987 discount for grading Good rather the U.S. market were based on a 1987 cost of $ 2.85 per loaded mile for a 50,000 pound capacity cattle liner. A 1981 constant dollar transport charge for the historical period (1976-86) was determined using the CPI to deflate the 1987 transport cost.

Table 14 Washington-Oregon Live Slaughter Steer Prices and Carcass Calculated Prices for Choice 2-3 USCHHH3 Steers Marketed into the U.S. with 63.4 percent carcass yield for the period 1976-86 for the USCHHH3 finishing date of October 15

Year	Wash-Oregon[a/] Slaughter Steer Price (U.S. $ per cwt)	Exchange[b/] Rate ($ Cdn/ $ U.S.)	Canadian Dollar Price ($ per 100 kg Carcass)
1976	37.00	.9730	124.92
1977	43.62	1.1033	167.00
1978	54.25	1.1835	222.79
1979	64.50	1.1747	262.92
1980	68.94	1.1650	278.70
1981	64.00	1.1988	266.23
1982	60.88	1.2276	259.34
1983	59.50	1.2319	254.35
1984	60.69	1.3286	279.80
1985	60.06	1.3660	284.69
1986	60.50	1.3893	291.67

Sources: [a/]Oregon State University, AREC Dept., 1988.
[b/]Wall Street Journal (October 15 issues 1976-86).

Futures Market Data

To calculate net revenue per head for the production alternatives employing hedging, several items of data were required in addition to that detailed under the cash alternative. Data collected (for November 4 and the relevant finishing dates of each production alternative) included: the Chicago Mercantile Exchange live cattle futures closing prices, the Chicago Mercantile Exchange closing prices for the Canadian dollar, and the exchange rate ($ Cdn/$ U.S.). Table 15 details these items for the LLH production alternative.[42/]

Table 15 Futures Market Information for the LLH Production Alternative on November 4th and August 30th of the following year[43/]

Feeding Year	Closing CME Live Cattle Futures Price (US $ per cwt)		Exchange Rate ($ Cdn/$ US)		Closing NYSE Can. Dollar Futures Price ($ US/$ Cdn)	
	Nov 4	Aug 30	Nov 4	Aug 30	Nov 4	Aug 30
1975-76	39.50	41.18	1.0216	0.9818	1.0065	1.0136
1976-77	44.50	38.90	0.9720	1.0751	1.0060	0.9292
1977-78	40.00	53.18	1.1059	1.1459	0.8995	0.8691
1978-79	60.05	68.45	1.1727	1.1682	0.8640	0.8561
1979-80	71.50	68.72	1.1818	1.1593	0.8575	0.8651
1980-81	73.70	66.93	1.1718	1.2107	0.8578	0.8312
1981-82	63.65	61.65	1.2068	1.2377	0.8205	0.8053
1982-83	57.92	55.98	1.2227	1.2314	0.8104	0.8116
1983-84	61.65	63.66	1.2331	1.2990	0.8130	0.7701
1984-85	62.52	56.11	1.3115	1.3619	0.7568	0.7333
1985-86	58.85	60.97	1.3666	1.3924	0.7271	0.7176

Source: Wall Street Journal editions (1975-1986)

[42/]A complete listing for all the production alternatives is given in Appendix A Table MARK (F, YR,*) HISTORICAL MARKETING CHARGES.

[43/]For each production alternative, the finishing day varies as documented in table 5.

Tripartite Stabilization Plan Market Data

National Tripartite Stabilization Plan quarterly price supports, payout levels and levies for the period 1972-87 were estimated and provided by Agriculture Canada (Agriculture Canada, Policy Branch, 1987).[44/] For each production alternative, the appropriate last-quarter-of-the-year levy ($/cwt) was selected to match the starting date of cattle placed on feed. Payouts ($/cwt) were selected

Table 16 Estimated Tripartite Slaughter Cattle Stabilization Plan Payouts and Levies for the LLH Production Alternative[45/]

Feeding Year	4th Quarter Unit Levy ($/cwt)	Following Year 3rd Quarter TSP Payout ($/cwt)
1975-76	1.05	5.36
1976-77	.89	0
1977-78	1.06	0
1978-79	1.52	0
1979-80	1.82	1.91
1980-81	1.93	3.15
1981-82	1.72	0
1982-83	1.70	1.48
1983-84	1.77	0
1984-85	1.92	6.81
1985-86	1.90	0

Source: Agriculture Canada, Policy Branch, 1987.

[44/]See Appendix C for details.

[45/]A complete listing of all the production alternatives is given in Appendix A under TAble MARK (F, YR, *) HISTORICAL MARKETING CHARGES.

according to the upcoming quarter in which the cattle would finish. Table 16 details the estimated TSP payouts and levies for the LLH production alternative.

Current Financial Data

Using the above historical information to forecast net revenue per head for the current (1986-87) feeding period and to assess the risk impact associated with the various production-marketing alternatives, the models were employed to examine decision strategies for the 1986-87 feeding year. Three possible input price scenarios were considered:

1. Low grain-low forage-high feeder prices,
2. High grain-high forage-low feeder prices,
3. Actual November 4, 1986 grain-forage-feeder prices.

The first two scenarios represent the extremes of the feed-feeder price relationship. When feed prices are relatively low, feeder prices tend to be bid up to relative highs, and vice-versa. The low and high price levels represent the range extremes for the period 1975-1987. For example, feed barley prices reached a high of $ 120 per tonne, and a low of $ 55 per tonne during that period. Table 17 details the feedstuff and other price levels for the three pricing scenarios. Relative price rankings of the feedstuffs for 1986-87 reflect traditional price relationships existing in Southern Alberta.

For example, feedmill prices for oats in Southern Alberta have generally equalled or exceeded prices paid for barley (Lakeside Research, 1987a).

Summary

This chapter outlined the linear risk programming models used in this study. Both the MOTAD and Target MOTAD formulations were detailed. Data development and data employed in the models was described. The next chapter details the results of the study.

Table 17 Input Price Scenarios Employed for the 1986-87 Feeding Period (1986-87 Dollars)

	Nov. 1986 Price Levels	High Grain High Forage Low Feeder Price Levels	Low Grain Low Forage High Feeder Price Levels
Feed Barley, tonne[a/]	84.00	120.00	55.00
Feed Wheat, tonne	99.00	150.00	80.00
Feed Oats, tonne	85.20	130.00	85.00
Grain Corn, tonne	131.00	170.00	130.00
Beet Pulp, tonne	113.00	120.00	110.00
Soybean Meal, 100 kg	30.00	32.00	25.00
Canola Meal, 100 kg	170.00	175.00	170.00
Dehy Alfalfa, tonne	161.00	145.00	135.00
Alfalfa Hay, tonne[b/]	73.70	115.00	90.00
Brome Hay, tonne	68.70	110.00	85.00
Grass Legume Hay, tonne	68.70	110.00	85.00
Cereal Hay, tonne	68.70	110.00	85.00
Barley Straw, tonne	34.30	55.00	42.50
Oat Straw, tonne	34.30	55.00	42.50
Wheat Straw, tonne	34.30	55.00	42.50
Cereal Silage, tonne	50.03	65.00	60.00
Supplement, 25 kg	40.00	45.00	40.00
Corn Silage, tonne	55.00	68.00	63.00
Urea, 100 kg[c/]	30.00	30.00	30.00
Dicalcium Phosphate, 100 kg	57.80	57.80	57.80
Rock Phosphate, 100 kg	55.00	55.00	55.00
Limestone, 100 kg	8.00	8.00	8.00
Salt, 100 kg	19.80	19.80	19.80
Vitamin A, 100 kg	82.00	82.00	82.00
Buying Charges, per head	7.00	7.00	7.00
Selling Charges, per head	1.00	1.00	1.00
Interest, percent[d/]	10.75	10.75	10.75
Feeder Price, 100 kg[e/]	234.30	150.00	250.00

Sources: [a/] Grain Prices--Alberta Agriculture, IP Sharp Database.
[b/] Hay Prices--Alberta Agriculture, Economic Services Division, Statistics Branch, 1987.
[c/] Mineral Prices--Alberta Agriculture, Agricultural Prices and Indexes Newsletter, Statistics Branch, 1986.
[d/] Statistics Canada, CANSIM University Base 1986.
[e/] Feeder Prices--Alberta Agriculture, IP Sharp Database.

VI RESULTS

Introduction

This chapter presents results from the MOTAD and Target-MOTAD models. General results for the period simulated (1976-86) are presented first, followed by results for the forecast year (1986-87) and results pertaining to each of the study objectives.

General Historical Results

For each year of the historical period (1976-86) estimated net revenue per head was determined for each production-marketing alternative and expressed in 1981 constant dollars. To determine if the net revenue levels calculated by the feedlot models were consistent with actual values for the period, net margin levels determined by Canfax for a steer calf were compared to those determined by the models for the comparable LLH-CASH production-marketing alternative.[46/] Figure 17 displays the Canfax versus modelled net margins in real dollars for the historical period. The closeness and correlated

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[46/]Net margin values for the Canfax steer calf assumed a 450 lb steer calf on feed for 250 days from November to July of the following year to achieve a final weight at cash sale of 1050 lb. The comparable production-marketing alternative in the models is LHH-CASH representing a 450 lb British breed steer calf on feed for 258 days from November 4 to July 19 to achieve a final weight at cash sale of 1050 lb.

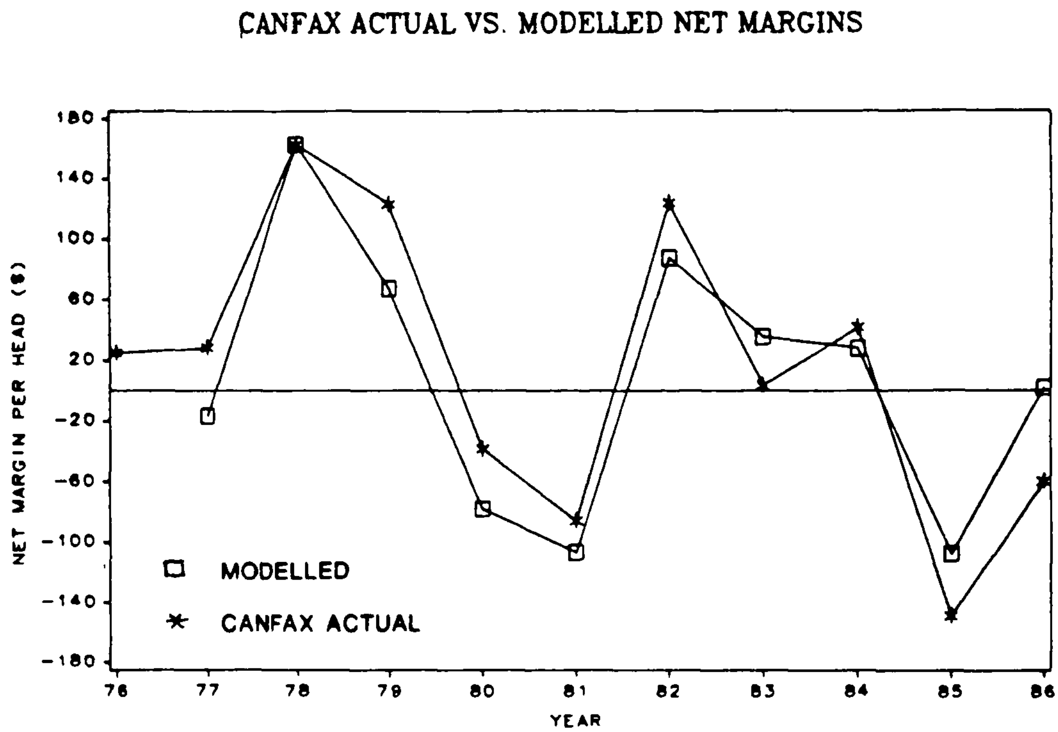

Figure 17 Canfax versus modelled net margins to cattle feeding in Southern Alberta, 1977-1986

movement of the values indicate that the model estimated the levels of net margins experienced by the feedlot industry in Southern Alberta over this time period with acceptable accuracy.

Table 18 details the values of average net revenue per head for the various production-marketing combinations for the period simulated (1976-86). The Tripartite Stabilization Program marketing strategy (TSP) had the highest average net income per head for every production alternative during this period. Regardless of the feeding alternative, the TSP generated a higher average net income per head than any other marketing plan. For example, for the CHHH1 feeding alternative, the TSP generated $16 more than received on the cash market. The highest net income per head feeding strategy varied depending on the associated marketing strategy. For example, for the hedging alternatives it was "CHHH2", that is, the feeding of a crossbred steer calf (250 kg) to a slaughter weight of 568 kg on a high rate of gain diet in each stage of the feeding period. The "CHHH2-CHEDG" alternative had a mean net income per head of $58. The highest feeding-marketing combination for the period was "HHH2-TSP", which had a mean net income per head of $81. Increasing the weights of crossbred steers from 568 kg to 614 kg resulted in reductions in average net income per head due to shifts in the grade distribution toward the A3 and A4 grades, and discounts for overweight carcasses. Marketing overweight (614 kg) steers into the U.S. market was on average not as profitable as marketing the same cattle into Canada (USCHHH3 versus CHHH3). Hedging of the Canadian dollar resulted in an improvement in the performance of hedging.

Table 18 Average Net Revenue Per Head for the period 1976-86 (Constant 1981 Dollars)

Production Alternatives	Marketing Alternatives			
	CASH	SHEDG	CHEDG	TSP
LLH	23	1	15	36
LMH	29	16	34	43
LHH	28	17	26	42
MMM	63	41	56	77
MMH	51	29	43	65
MHH	61	36	51	75
HML	19	2	17	33
HHH1	42	(7)	5	55
HHH2	67	19	29	81
HHH3	58	36	52	74
CLLH	38	17	35	54
CLMH	40	27	45	55
CMMM	46	29	48	61
CHML	43	30	46	58
CHHH1	64	26	40	80
CHHH2	62	40	58	79
CHHH3	62	21	41	72
USCHHH3	36	(5)	13	

For example, mean net income per head, for the CHHH1 production alternative, increased from $26 for simple hedging (SHEDG) to $40 for a routine hedge combined with a Canadian dollar hedge (CHEDG).

The risk reducing capabilities of the various production and marketing strategies are revealed in tables 19, 20 and 21. Table 19 displays the historical standard deviation in net revenue per head for the various production-marketing alternatives. Table 20 displays the one-step-ahead forecast error standard deviation for the historical period, while table 21 displays the average negative deviations from a target income of $50.

Both hedging and stabilization, reduced risk (as defined by historical standard deviation) over the cash alternative (table 19). For example, for the CHHH1 production alternative hedging reduced the standard deviation from $119 for the cash alternative to $87 for SHEDG and $88 for CHEDG. Stabilization reduced the standard deviation to $115.

A similar result held for forecast error risk. With the exception of CHHH3-TSP, one-step-ahead forecast error standard deviation was reduced by hedging or stabilization over the cash marketing

Table 19 Historical Standard Deviations for the period 1976-86 (Constant 1981 Dollars)

Production Alternatives	Marketing Alternatives			
	CASH	SHEDG	CHEDG	TSP
LLH	93	49	51	89
LMH	82	50	60	73
LHH	102	46	54	94
MMM	93	57	58	90
MMH	102	56	61	94
MHH	108	73	80	103
HML	91	37	44	89
HHH1	91	61	64	66
HHH2	110	67	69	85
HHH3	102	57	62	81
CLLH	104	49	56	104
CLMH	95	67	74	91
CMMM	104	58	66	100
CHML	104	49	57	104
CHHH1	119	87	88	115
CHHH2	113	44	53	109
CHHH3	130	62	63	130
USCHHH3	117	54	68	

alternative. Production-marketing alternatives with relatively low historical forecast error standard deviation included: CHHH2-SHEDG ($18), CHHH2-CHEDG ($39), HML-SHEDG ($20) and HML-CHEDG ($33).

However, in examining table 21, which defines risk in terms of the average negative deviation below a target income of $50 per head, certain production-marketing alternatives, such as HHH1-SHEDG, HHH2-SHEDG, CHHH1-SHEDG, CHHH3-SHEDG, USCHHH3-SHEDG, HHH2-CHEDG, HHH3-CHEDG and CHHH1-CHEDG, actually increased risk. This occurred because of the drop in mean net income per head associated with these alternatives. For example, for the HHH1 alternative, simple hedging (SHEDG) increased the average negative deviation below $50 to $61 per head from $39 for the cash alternative. Stabilization was the only marketing alternative that not only decreased risk (as defined by standard deviation or average deviation below $50), but also increased mean net income per head over the cash alternative. For example, for the CHHH1 alternative, stabilization (TSP) increased average net revenue from $64 for the cash alternative to $80 and reduced average negative deviation risk from $40 per head for the cash alternative to $30 per head.

For the hedging alternatives, the lowest average negative deviation risk feeding alternative for the period was the feeding of a crossbred steer to 568 kg (CHHH2). For the cash marketing alternative it was the feeding of a British breed steer to 477 kg on a medium rate of gain diet in each feeding stage (MMM). Under Stabilization it was HHH3, the feeding of a British breed steer to 477 kg on a high rate of gain diet in each feeding stage (table 21).

Production-marketing alternatives with relatively low average negative deviation risk included: CHHH2-SHEDG ($25), CHHH2-CHEDG ($16), HHH2-TSP ($19), HHH3-TSP ($17) and MMM-CHEDG ($21).

Table 20 One-Step-Ahead Forecast Error Standard Deviation for the period 1976-86 (Constant 1981 Dollars)

Production Alternatives	Marketing Alternatives			
	CASH	SHEDG	CHEDG	TSP
LLH	94	48	48	87
LMH	85	49	62	75
LHH	104	47	65	96
MMM	94	57	56	89
MMH	104	50	60	96
MHH	113	110	83	10
HML	92	20	33	87
HHH1	104	68	71	74
HHH2	122	76	80	92
HHH3	106	58	64	83
CLLH	104	28	40	101
CLMH	99	58	70	92
CMMM	107	45	60	101
CHML	104	34	45	101
CHHH1	123	95	95	117
CHHH2	115	18	39	107
CHHH3	130	59	58	135
USCHHH3	128	63	83	

Table 21 Average Negative Deviation Below a Target Income of $50 for the period 1976-86 (Constant 1981 Dollars)

Production Alternatives	Marketing Alternatives			
	CASH	SHEDG	CHEDG	TSP
LLH	53	52	43	45
LMH	43	41	35	31
LHH	52	42	39	43
MMM	30	30	21	22
MMH	39	34	27	30
MHH	36	37	33	27
HML	55	49	39	48
HHH1	39	61	50	24
HHH2	36	48	40	19
CHHH3	35	30	24	17
CLLH	46	42	33	38
CLMH	42	41	33	33
CMMM	41	38	29	32
CHML	44	33	26	35
CHHH1	40	48	41	30
CHHH2	33	25	16	23
CHHH3	36	42	29	35
USCHHH3	53	63	52	

General Results for the 1986-87 Forecast Year

Although the general historical results give some estimate of the best overall marketing and production strategies for the long term, the ranking of such strategies may change for any specific year. Forecasted net revenues per head for the 1987 feeding period were developed using simple exponential smoothing techniques, as referenced in chapter 5. Table 22 displays the 1987 forecasted net revenues per head for each of the production-marketing alternatives. For all but two of the production alternatives, namely CLMH and CMMM, the

Table 22 Forecasted Expected Values of Net Revenue Per Head and Differences between Marketing Alternatives for the 1986-87 Feeding Year (1987 Dollars)

	Marketing Alternatives				Differences between Marketing Options					
Prodn Options	CASH	SHEDG	CHEDG	TSP	shedg-cash	chedg-cash	tsp-cash	chedg-shedg	tsp-shedg	tsp-chedg
LLH	(41)	(67)	(54)	(38)	-26	-13	3	13	28	15
LMH	(8)	(45)	(29)	(5)	-37	-22	3	15	40	24
LHH	(59)	(27)	(19)	(44)	32	40	15	8	-17	-24
MMM	5	(18)	(5)	10	-23	-10	5	13	28	15
MMH	(33)	(52)	(49)	(15)	-19	-15	18	4	37	33
MHH	(35)	(96)	(49)	(12)	-61	-14	23	47	84	37
HML	(40)	(46)	(31)	(36)	-6	9	4	15	10	-5
HHH1	(14)	18	45	14	32	59	28	27	-4	-31
HHH2	(42)	17	32	(3)	59	84	40	15	-19	-35
HHH3	(110)	(51)	(82)	(51)	59	28	59	-31	0	31
CLLH	(27)	(31)	(15)	(19)	-4	12	8	15	12	-4
CLMH	(6)	(59)	(45)	(9)	-52	-38	-3	14	50	36
CMMM	(6)	(69)	(19)	(9)	-63	-13	-3	50	60	10
CHML	(22)	(14)	0	(13)	8	22	9	14	1	-13
CHHH1	(38)	(15)	(6)	(28)	23	32	10	9	-13	-22
CHHH2	(3)	(20)	0	4	-18	3	6	21	24	4
CHHH3	(6)	(59)	(35)	(1)	-52	-28	5	24	58	33
USCHHH3	(32)	(31)	(18)		1	14	32	13	31	18

Tripartite Stabilization Plan was forecast to outperform the cash marketing alternative. Forecast value differences between TSP and SHEDG or CHEDG were mixed, with TSP expected to perform better than SHEDG or CHEDG for only some of the production alternatives. With the exception of the HHH3 alternative, hedging of the Canadian dollar combined with a routine live cattle hedge (CHEDG) was forecast to perform better than a routine live cattle hedge alone (SHEDG). The best single production-marketing combination was forecast to be HHH1-CHEDG, the feeding of a British breed steer calf from 210 kg to 386 kg to achieve a net revenue per head of $45. This was $40 above the best cash marketing production alternative of MMM.

For each production-marketing alternative, the associated value in table 22 represents the estimated level of net revenue per head expected in the current (1986-87) feeding period as based upon current feed costs and the weighted average of past net revenue values[46/].
Adjustments for actual feed and feeder costs are made in the models' objective functions depending upon the feeder price specified and the quantities and prices of the feeds formulated in the solution diets.
Given the expected level of net revenue, three alternate input price

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[46/]The "smoothed" forecast value of expected net revenue per head represents a geometric weighted average of past net revenue values. The weights decline for values further in the past and the rate at which the rates decline depends on the value selected for the single exponential smoothing constant. High values for the smoothing constant (e.g., 0.90 to 0.99) cause the weights to decline rapidly and essentially consider only the recent observation (table 5).

scenarios were employed to determine the sensitivity of the results to input price extremes. The input price scenarios were:[47/]

1. High forage-high grain-low feeder prices,
2. Low forage-low grain-high feeder prices,
3. Actual Fall 1987 forage-grain-feeder prices.

For each of the input scenarios and complete models (Target MOTAD and MOTAD models with all defined production-marketing alternatives) risk efficiency frontiers were generated to display the highest expected value-minimum risk production-marketing plans at various levels of risk aversion. By parameterizing the risk aversion coefficient (α)[48/] in the MOTAD model from 0.0 to 1.8, basis change solution points were used to draw out an expected value-standard deviation (Es) frontier. Similarly, by parameterizing the Target MOTAD omega (Ω)[49/] value of acceptable mean absolute negative deviations below the target income of $ 50, basis change solution points were used to draw out an expected value-absolute negative deviation (EA) frontier. In this manner Es and EA frontiers were developed for each of the input price scenarios. Results of model runs under these input price scenarios are presented in the sections that follow.

[47/]See table 17 for a description of input price values.

[48/]See the detailed MOTAD objective function as detailed in chapter 5 under the section "The MOTAD Objective Function and Deviation Rows".

[49/]See the deviation row constraints for the target MOTAD model as detailed in chapter 5 under section "Target MOTAD Model Adjustments".

Results Pertaining to the Study Objectives

This next section details the results that address the specific objectives of the study. Testable hypotheses in the study objectives include:

1. The risk reducing strategies of hedging and Stabilization will increase firm level slaughter cattle output in terms of slaughter weight per head,
2. Portfolio effects will exist between the specified production and marketing alternatives,
3. Participation in Stabilization will decrease the level of conventional hedging,
4. Publicly supplied Stabilization will be more effective than privately supplied hedging at reducing risk, and
5. Hedging performance will be increased by hedging Canadian dollar.

Output Effects of Risk Reducing Strategies

To determine whether output increased under hedging or stabilization, separate model runs were conducted for each risk-reducing marketing alternative employed in combination with the cash marketing alternative. Results were compared with model runs employing only the cash marketing alternative. Orientation of the expected value-standard deviation (Es) and expected value-average negative deviation (EA) frontiers for the risk-reducing alternatives were checked against those for the cash alternative. Target weights associated with the efficient feeding plans were examined.

Hedging

Hedging was postulated to result in an increase in slaughter cattle output since the production decision depends not on the expected cash price, but on the certain futures price. With the addition of basis risk the postulated increase in output was shown to depend on the basis variance being less than the cash price variance. Partial hedging was predicted to occur when the discounted expected spot price is greater than the futures market price, or if diversification of the cash and futures positions permits a reduction in risk.

Figure 18 details the Es (Expected Value-Standard Deviation) frontiers for the CASH, CASH-SHEDG, and CASH-CHEDG combinations of marketing alternatives. The addition of the hedging alternatives (SHEDG and CHEDG) to the cash marketing alternative (CASH) resulted in an upwards-and-to-the-left movement of the Es frontiers. It was expected that the reduction in risk associated with the SHEDG and CHEDG strategies would permit finishing of cattle to higher weights since the risk costs are decreased. On a per head basis, kilograms of live cattle produced increased at the higher risk parameter levels for the strategies of CASH-SHEDG (α>1.0) and CASH-CHEDG (α>1.4) versus CASH (figure 19). At these risk parameter levels standard deviation forecast error risk dropped substantially enough ($43 down to $18 for CASH-CHEDG, and $31 down to $17 for CASH-SHEDG) to cause the model to

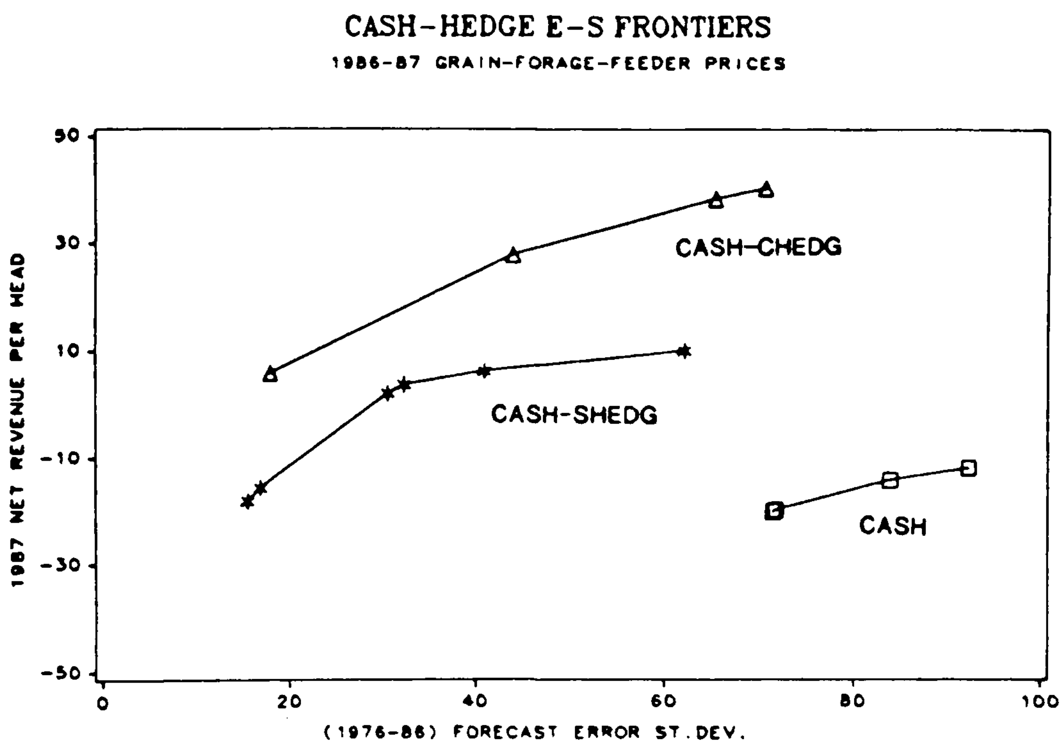

Figure 18 Es Frontiers for CASH, CASH-SHEDG, and CASH-CHEDG Risk-Reducing Alternatives for 1986-87 Grain-Forage-Feeder Prices

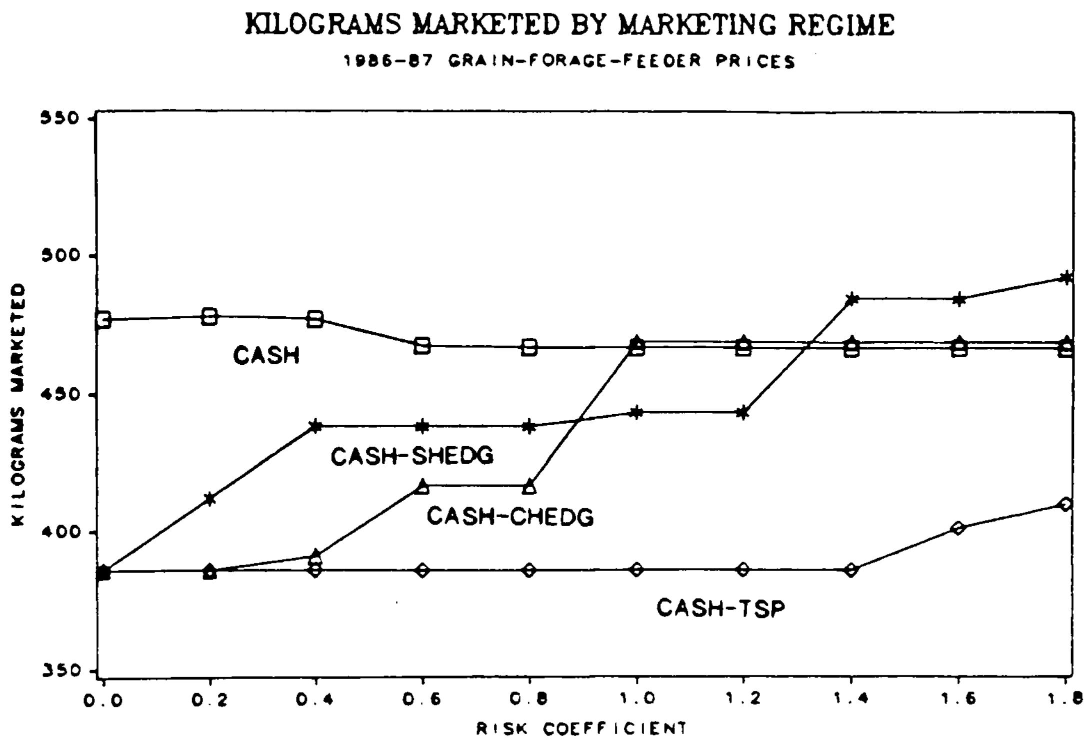

Figure 19 Market Weight (kilograms) by Marketing Regime for 1986-87 Grain-Forage-Feeder Prices

diversify away from lower weight production alternatives (HHH1, MMM), to higher weight production alternatives (HHH2, CHHH2, USCHHH3, CHML).[50/]

Stabilization

Participation in the Tripartite Stabilization program was hypothesized to result in an increase in slaughter cattle output (higher slaughter weights or heavier feeder types) due to truncation of the output price probability distribution at the support price. Since the producer only pays one-third of the levy, the negative income effect of the levy cost on output should be less than would be the case under alternative insurance schemes, e.g., purchase of a put option on the live cattle futures market, where the producer pays the full cost of the insurance premium. However, figure 19 details a lower output, at all risk coefficient levels, for the CASH-TSP alternative versus the CASH, CASH-SHEDG or CASH-CHEDG alternatives. This result is opposite to that hypothesized and points out the complications arising from the inclusion of time and grade effects in the models. In other words, despite a reduction in risk and associated costs, time and grade effects make a lower weight alternative more profitable than a higher weight alternative might be. In addition it is worthwhile noting that

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[50/]Similar results were obtained for the alternative risk definitions (standard deviation forecast error or average negative deviation below a target income) and input price scenarios. (see figures D-1 to D-7 in Appendix D).

the results show inclusion of the TSP alternative alone with the CASH alternative raises net income but has little effect on forecast error standard deviation risk.[51/]

Portfolio Effects

Chapter three hypothesized that diversification of the production and marketing alternatives would be risk-reducing. To test this hypothesis, complete (includes all production and marketing alternatives) model runs were made for each of the three input price scenarios and for each of the Target MOTAD and MOTAD models.

Figures 20 and 21 display the efficient Es and EA frontiers for the 1986-87 grain-forage-feeder price input scenario. For the MOTAD model, diversification proceeds from the highest expected value net revenue per head production-marketing alternative of 100 percent HHH1-CHEDG toward a mix of alternatives that involve less hedging with some involvement in the TSP and the cash market (figure 20). Some of the alternatives selected at high risk aversion levels have relatively high expected value and low forecast risk standard deviation (e.g., CHML-CHEDG with $0 expected value and $34 standard deviation), but most (e.g., LMH-CASH, USCHHH3-CHEDG and HHH1-TSP) have relatively moderate expected values ($-8 to $14) with high forecast standard deviations (about $80). They are selected by the model because of their diversification potential, i.e., their ability to reduce risk in

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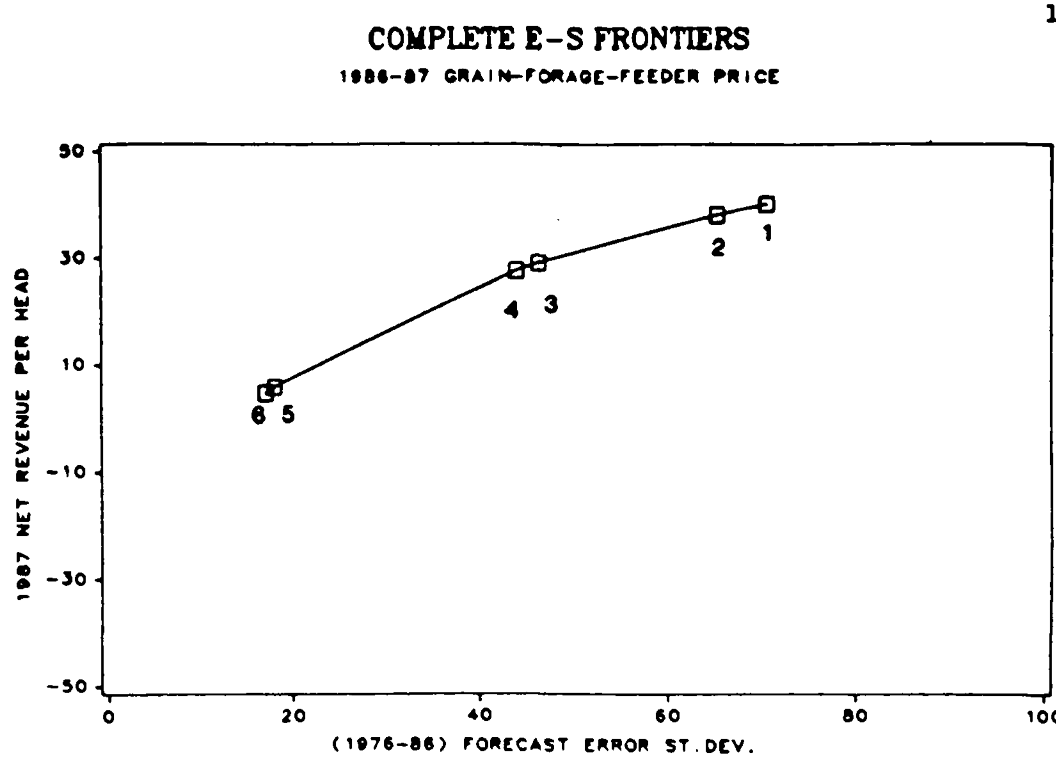
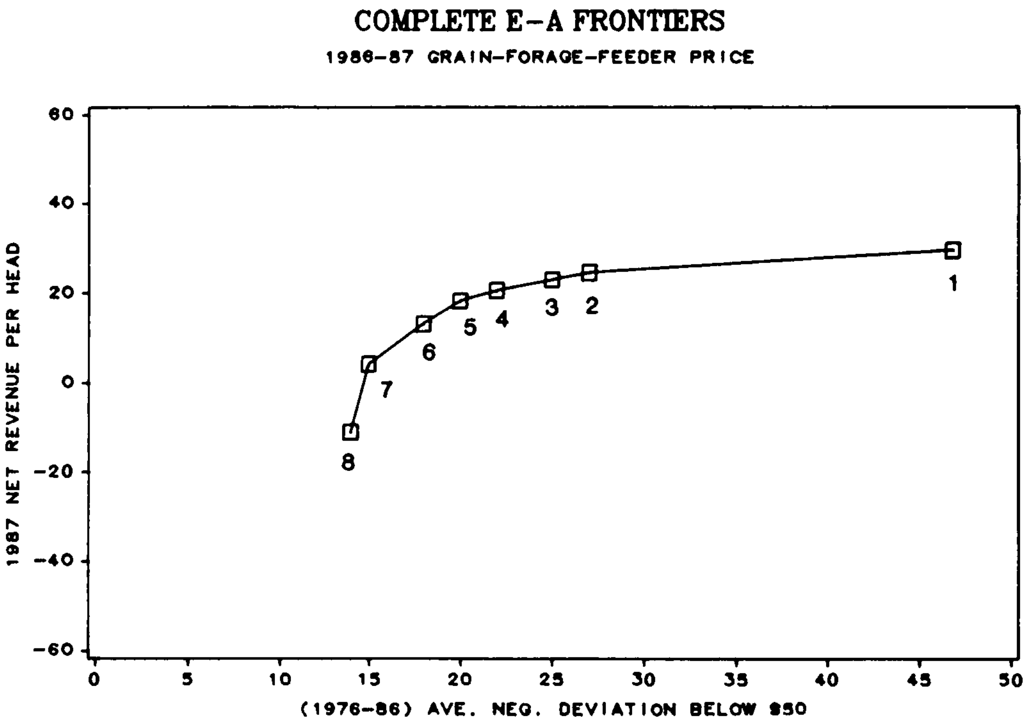
51/See figure 25.



PERCENTAGE OF CATTLE IN EACH FEEDING-MARKETING PLAN

		CASH	CHEDG	TSP	WEIGHT
1/	HHH1		100.000		386.0
2/	MMM	2.104			390.9
	HHH1		96.218		
	CHHH2	1.678			
3/	MMM	2.206			391.2
	HHH1		69.469	26.565	.
	CHHH2	1.760			
4/	MMM	12.615			416.5
	HHH1		68.965		
	HHH2		10.628		
	CHHH2	7.793			
5/	LMH	11.982			468.9
	MMM	11.590			
	HHH1		33.155		
	HHH2		14.836		
	CHML		11.168		
	USHHH3		17.269		
6/	LMH	12.062			463.5
	HHH1		31.987	16.515	
	HHH2		12.201		
	CHML		1.242		
	USHHH3		25.992		

Figure 20 Es Frontier for all Risk-Reducing Alternatives for 1986-87 Forage-Grain-Feeder Prices



PERCENTAGE OF CATTLE IN EACH FEEDING-MARKETING PLAN

		CHEDG	TSP
1/	HHH1	100.00	
2/	MMM		21.319
	HHH1	8.307	
	HHH2	67.843	
	CHHH2		2.531
3/	MMM		23.315
	HHH1	2.934	
	HHH2	70.112	
	CHHH2		3.638
4/	MMM		25.695
	HHH1	7.094	
	HHH2	59.388	
	CHHH2		7.823
5/	MMM		33.551
	HHH1	13.125	
	HHH2	46.659	
	CHHH2	6.665	
6/	MMM		9.070
	HHH1	12.238	
	HHH2	40.011	25.230
	CHHH2	13.450	
7/	HHH1	30.830	
	HHH2		47.862
	CHHH2	21.307	
8/	HHH1	18.275	
	HHH3		10.615
	CHHH2	71.111	

Figure 21 EA Frontier for all Risk-Reducing Alternatives for 1986-87 Forage-Grain-Feeder Prices

combination with the other alternatives. Regardless of the mix of production alternatives, hedging of live cattle and the Canadian dollar (CHEDG) falls only to 71 percent as the level of risk aversion increases. At the higher risk aversion levels (α = 1.0 to 1.8) from 17 to 26 percent of the cattle are suggested to be held to the higher weight of 634 kg and be marketed into the U.S. This compares closely with the 15 to 20 percent of Alberta fed cattle which were exported to the U.S. in the summer of 1987 (Agriculture Canada, 1987). Two of the risk-efficient plans (3 and 6) on the Es frontier indicate 27 and 17 percent, respectively, of the cattle production should be enrolled in the Stabilization Plan. As diversification of the production and marketing plans reduce forecast error risk, slaughter weight per head averages also increase from 386 kg to 469 kg, indicating the move to higher output as risk costs decline. Results for the high forage-high grain-low feeder price and low forage-low grain-high feeder price scenarios were similar to those for the 1986-87 price scenario (figures D-8 and D-9).

Target MOTAD results for the 1986-87 grain-forage-feeder price scenario involve very similar production alternatives (e.g., MMM, HHH1, HHH2, CHHH2) in the risk efficient plans as those selected in the MOTAD model (figures 20 and 21). Diversification again proceeds from the risk neutral solution of HHH1-CHEDG and from the risk averse but high expected value alternatives (e.g., HHH1-CHEDG, HHH2-CHEDG, CHHH2-TSP, MMM-TSP) to those with moderate expected values and low average negative deviation risk (e.g., HHH3-TSP and CHHH2-CHEDG).[52/] Involvement in the TSP ranges from an initial risk-averse solution (plan 2, figure 21) value of 21 percent of cattle fed up to a value of 48 percent at higher risk averse levels. As average negative deviation risk falls, diversification proceeds from 3 percent of the fed cattle in the higher weight production alternative CHHH2 to 21 percent in plan 7 and 71 percent in plan 8 (figure 21). Similar results were obtained for the other price scenarios (figures D-10 and D-11) except that for the high grain-high forage-low feeder price scenario the initial level of TSP participation was higher (31 percent) and the diversification into the CHHH2 alternative occurred only at the higher risk aversion levels. Higher feed costs of this scenario are likely the reason for these differences.

Effects of Stabilization on Hedging Levels

Participation in the Tripartite Stabilization Plan was hypothesized to decrease the level of conventional hedging. To test this hypothesis model run results for the cash-hedging strategies only, were compared with run results where the TSP strategy was added. For the 1986-87 input price scenario, the Es frontier for the CASH-Hedge-TSP run, was

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[52/] See tables 21 and 22. The alternatives mentioned are noted below with their expected values and average negative deviation values, respectively, cited in brackets. They are HHH1-CHEDG(45,50). HHH2-CHEDG (32-,40), CHHH2-TSP (4,23), MMM-TSP(10,22), HHH3-TSP (-51,17) and CHHH2(0,16).

plans at risk aversion levels of α=0.6 and $\alpha \geq 1.2$. At these levels addition of the TSP marketing alternative decreased the level of hedging involvement by approximately 6 to 10 percent (figure 23). For example, at the risk coefficient level α=0.6, addition of the TSP alternative reduced the level of hedging from 79 percent to 69 percent. Nearly identical results were obtained for the other input price scenarios.

Results from the Target MOTAD model showed a drop in the level of hedging involvement at all average negative deviation risk constraint levels (figure 24). The drop varied from 4 percent at the lower risk aversion levels to 50 percent in the mid-range levels and down to 10 percent at the high risk aversion levels. Nearly identical results were obtained for the other input price scenarios.

Public (TSP) Versus Private (Hedging) Mechanisms for Reducing Risk

To test the effectiveness of public versus private marketing mechanisms for reducing risk, model runs featuring cash and hedging alternatives were compared with those featuring cash and Stabilization alternatives. Figures 25 and 26 display the Es and EA frontiers for the various marketing alternatives for the 1986-87 input price scenario. The Tripartite Stabilization Plan (in concert with feeding regime diversification) was not as effective as hedging at reducing forecast error standard deviation risk (figure 24). The TSP reduced forecast error standard deviation risk from about $70 at zero risk aversion levels down to $65 at high risk aversion levels. Hedging

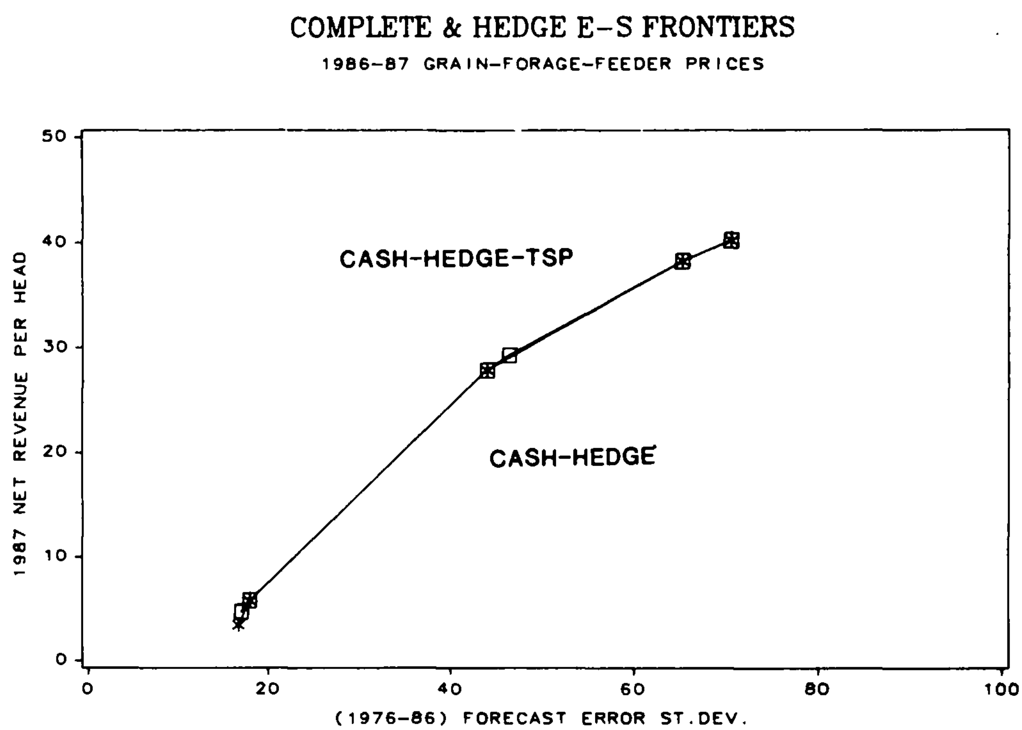

Figure 22 Es Frontiers for the Cash-Hedge and Cash-Hedge-Stabilization Scenarios for 1986-87 Forage-Grain-Feeder Prices

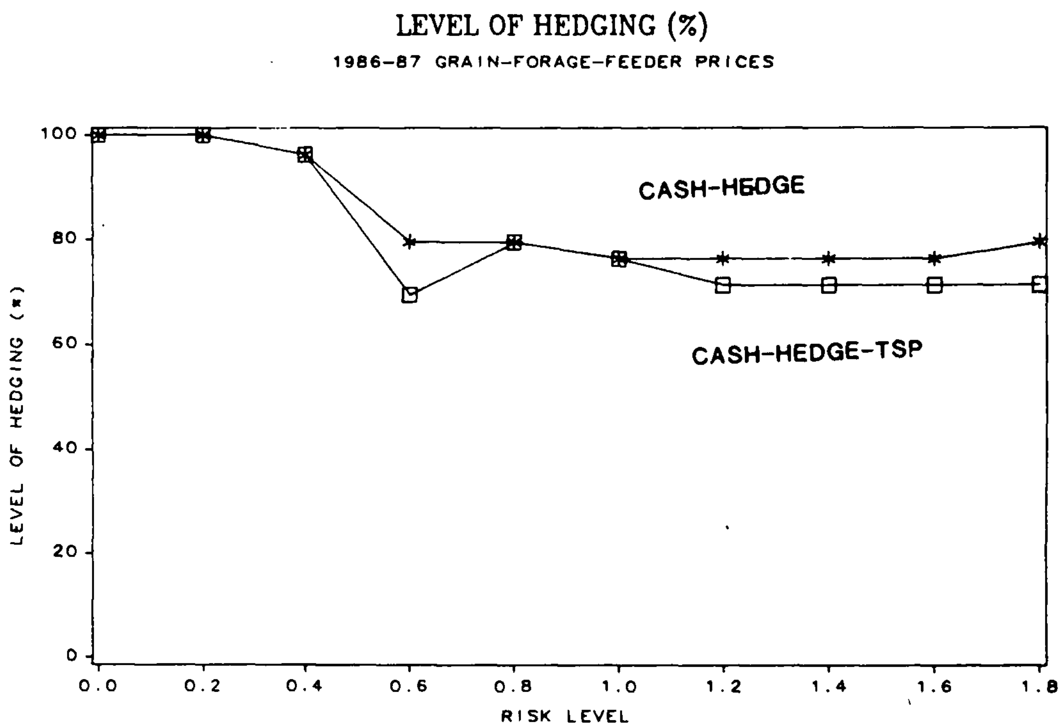

Figure 23 Level of Hedging Reduction (Percent) with Addition of Stabilization - MOTAD Results for 1986-87 Forage-Grain-Feeder Prices

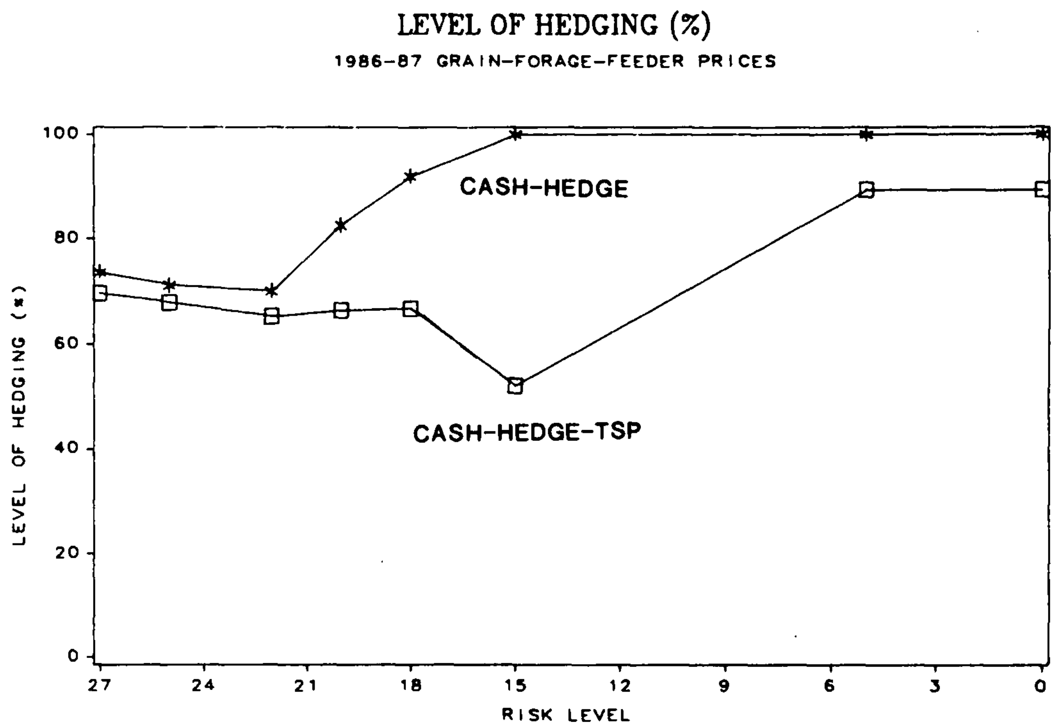

Figure 24 Level of Hedging Reduction (Percent) with Addition of Stabilization - Target MOTAD Results for 1986-87 Forage-Grain-Feeder Prices

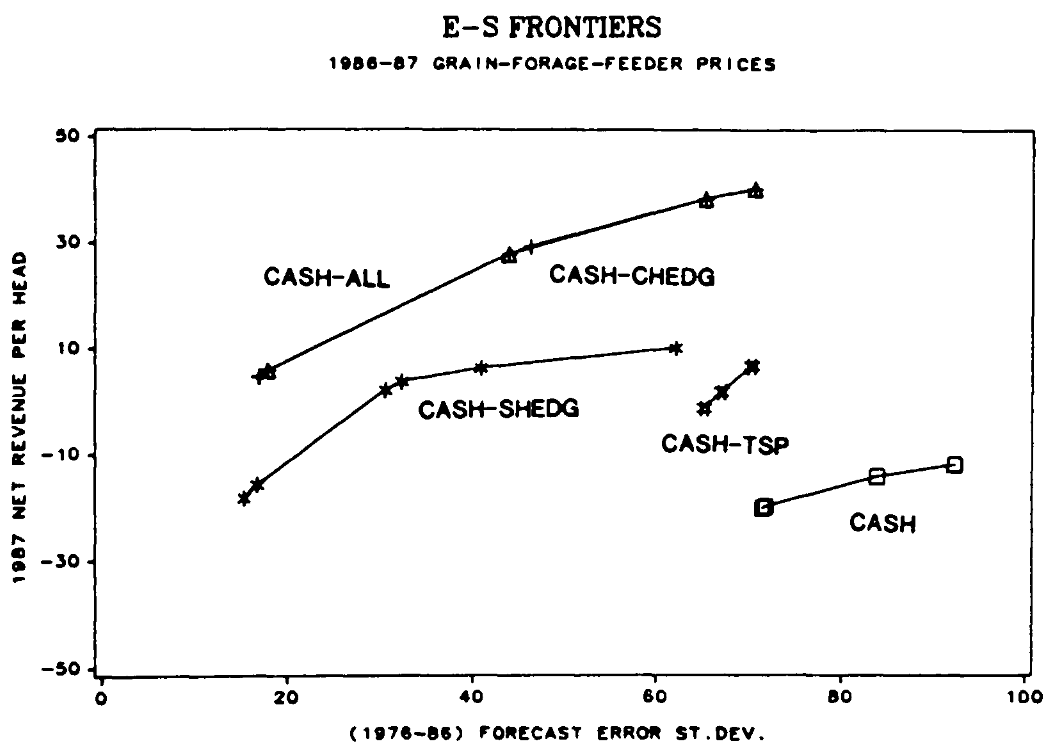

Figure 25 Es Frontiers for Various Combinations of Risk-Reducing Alternatives for 1986-87 Forage-Grain-Feeder Prices

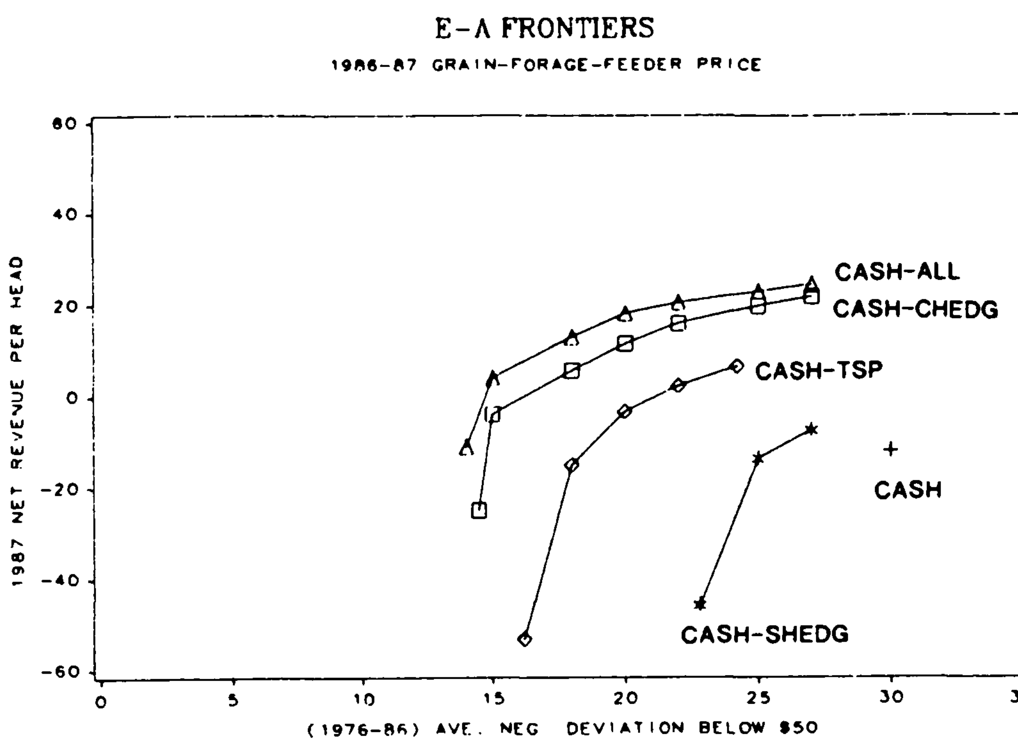

Figure 26 EA Frontiers for Various Combinations of Risk-Reducing Alternatives for 1986-87 Forage-Grain-Feeder Prices

alternatives reduced forecast error standard deviation risk from about $70 down to $15 for SHEDG and $18 for CHEDG (table 23). The TSP increased net revenue per head, at all risk aversion levels, over the cash alternative. For the 1986-87 grain-forage-feeder price scenario the increase ranged from $19 to $21 (table 23), but was less than that attained by hedging (SHEDG or CHEDG). Concomitant hedging of live cattle and the Canadian dollar (CHEDG), in particular, was expected to generate $20 to$ 30 more net income per head with less forecast error risk than participation in TSP alone (table 23).

Target MOTAD results reveal a similar benefit from hedging of the Canadian dollar as evident from the position of the CASH-CHEDG EA frontier above those of CASH-TSP, CASH-SHEDG and CASH (figure 26). This benefit enhances the performance of hedging live cattle on the U.S. futures markets. Without it, the Target MOTAD results indicate the Stabilization program to be superior to routine hedging (SHEDG) in decreasing average negative deviation risk and increasing net income (figure 26). An interesting result is the upward rotation of the EA frontiers as simple routine hedging (SHEDG) is replaced by Stabilization, and as Stabilization is replaced by the complex hedging (CHEDG), each in combination with the cash marketing alternative (figure 26). The flatter the EA frontier the more effective feeding regime diversification becomes in reducing average negative deviation risk.

Effect of the Canadian Dollar Hedge on Live Cattle Hedging Performance

To determine whether hedging of the Canadian dollar would increase the performance of live cattle hedging by reducing basis risk, model run results featuring the simple hedging alternative were compared with run results featuring hedging in combination with a Canadian dollar hedge. Over all price scenarios, hedging of the Canadian dollar led to an upward rotation of the Es and EA hedging frontiers (figures 25 and 26)[53./] The increased net revenue per head resulting from the Canadian dollar hedge permitted an increased acceptance of forecast error standard deviation risk at equivalent risk coefficient levels ($\alpha \geq 0.0$ but ≤ 0.8) between the CHEDG versus SHEDG alternatives (table 23).

[53/]Also see figures D-12 to D-15 in Appendix E.

Table 23 Expected Value Net Revenue Per Head (E) and Forecast Error Standard Deviation Risk (S) (1987 Dollars)

	1986-87 Grain-Forage-Feeder Prices				
Risk Level	CASH E	SHEDG E	CHEDG E	TSP E	COMPLETE E
0.0	(12)	10	40	7	40
0.2	(12)	6	40	7	40
0.4	(14)	4	38	7	38
0.6	(19)	4	28	7	29
0.8	(20)	4	28	7	28
1.0	(20)	2	6	7	6
1.2	(20)	(16)	6	7	5
1.4	(20)	(16)	6	7	5
1.6	(20)	(16)	6	2	5
1.8	(20)	(18)	6	(1)	5
	S	S	S	S	S
0.0	92	62	71	70	17
0.2	92	41	71	70	71
0.4	84	32	65	70	65
0.6	72	32	44	70	46
0.8	72	32	44	70	44
1.0	72	31	18	70	18
1.2	72	31	18	70	17
1.4	72	17	18	70	17
1.6	72	17	18	67	17
1.8	72	16	18	65	17

Summary

This chapter presented the results of a risk analysis of beef feedlot production and marketing alternatives. Historical (1976-86) net income averages indicated the Tripartite Stabilization Plan was the highest net income per head marketing plan for feedlot cattle regardless of the production alternative considered. However, it was shown that the optimum mix of production and marketing alternatives for the current feeding year depends both on the expected level of net income forecast for the period and the level of historical forecast error standard deviation or average negative deviation risk associated with each of the production-marketing alternatives in the models. For the 1986-87 feeding year, risk efficient plans generated for the Es and EA frontiers involved very similar production and marketing alternatives. At lower risk aversion levels the high income alternatives of HHH1-CHEDG and HHH2-CHEDG dominated. At higher risk aversion levels, risk efficient plans included production-marketing combinations that either had moderately high expected net income values and low risk, or had ability to reduce risk in combination with other production-marketing alternatives in the risk efficient plan, i.e., they exhibited portfolio effects.

The specific objectives of the study were addressed by analyzing the results of the models given alternate assumptions. Slaughter weight output was shown to increase with hedging, but not with Stabilization. Availability of the Stabilization alternative in the models reduced hedging levels approximately 10 percent in the MOTAD model results, to up to 50 percent in the Target MOTAD model results. Stabilization was more effective than routine hedging in reducing average negative deviation risk, but not as effective as routine hedging in reducing historical forecast error risk. Hedging of the Canadian dollar improved the performance of conventional live cattle hedging. Target MOTAD results showed that diversification of feeding regime is more effective in reducing risk, with less relative loss in net income per head, as SHEDG is replaced as a marketing alternative in the model by TSP and as TSP is in turn replaced by CHEDG.

Comparing the MOTAD (Es) and target MOTAD (EA) results shows that in some cases the conclusion that can be drawn regarding the hypotheses depends upon which formulation is believed to be appropriate for representing producers risk preferences.

The next chapter summarizes and draws conclusions from the study. Aspects of model validation, study limitations and future research are discussed.

VII SUMMARY AND CONCLUSIONS

Introduction

Feeding of cattle involves risk. Feed, feeder and slaughter cattle prices are highly variable. Rate of gain and feed conversion are also variable. This study concentrated on price risk, in particular the variability of slaughter cattle prices and their effect on net income. In Canada, private and public mechanisms for alleviating cattle feeding income risk are available. In addition to the traditional strategies of hedging and feeding diversification, strategies have emerged such as the National Tripartite Stabilization Plan. Despite the importance of feedlot income risk, little research has been undertaken to evaluate the relative efficacy and interaction effects of strategies to reduce risk.

This study was unique in two ways: first, it employed economic theory of the firm under uncertainty in a expected value-risk context to examine alternatives for reducing feedlot risk in Alberta. Second, it combined both the production and marketing aspects of the feedlot management problem in a linear risk model and considered alternative definitions of risk. The two risk definitions considered were forecast error standard deviation and average negative deviation below a target income. The results focused on the relative efficacy and interactions of production and marketing alternatives for reducing risk and specifically apply to the 1986-87 feeding period.

This chapter summarizes the approach and conclusions of the study. It discusses the study limitations and offers suggestions for future research.

Study Approach

This study was undertaken to provide a more complete model of the beef feedlot management process in the presence of risk and time effects. Risk was examined in light of two definitions. The first, determined feedlot risk as the difference between the observed value of net revenue per head minus its expected value. Expected value was calculated for each production-marketing alternative for each year of the historical period (1976-86) by simple exponential smoothing techniques. Alternatively, risk was determined in a safety-first context as being the probability of differences between a target net revenue per head value of $50 and observed values falling below the target.

Interacting with risk is the time effect, defined as the effect of feeder type, length of the feeding period and diet specification on quality, grading and pricing of the carcass. Thus, the risk associated with a particular production-marketing alternative in the feedlot finishing process is conditioned on its associated time effect. The time effect is accommodated in the feedlot models by detailing a range of production alternatives, each of which characterize a particular feeder type-feeding regime-target weight combination.

Determining how to best accommodate the risk aspect of the feedlot finishing process involved reviewing the theory of decision making under uncertainty. Maximization of expected utility was advanced as the most theoretically consistent and powerful approach to the ordering of risky prospects by individual decision-makers. The results of the Expected Utility Theorem can be extended to classes of decision-makers by developing the average risk aversion measure (α) which acts as a general index for ranking individuals according to their risk aversion for a particular gamble or distribution of outcomes. Also, Expected Value-Variance (EV) analysis can be used to approximate utility rankings. Several criteria were presented to establish that the EV efficient set would be a good approximation of the EUT efficient set in regard to the feedlot management problem.

The possibility of transforming an expected utility problem into an expected value-variance analysis has important empirical implications. First of all, EV provides a theoretical framework for examining the effect on optimal choice solutions from changes in some or all of the relevant probability distributions for choice variables. For the feedlot management problem, the EV framework provided the means to develop testable hypothesis regarding the effects of adoption of the various feedlot risk-reducing alternatives, i.e., hedging and Stabilization. Secondly, the EV framework facilitated formulation of the feedlot management problem in a mathematical programming context. Quadratic programming best fits the EV structure, but the linear MOTAD formulation was selected because of its ease of solution, and its adaptability in considering the alternative "safety-first" risk definition via a Target MOTAD formulation.

The actual models approached the feedlot management problem on a per head basis. Options available to the decision-maker included a set of production alternatives defined by various feeder type-feeding regime-slaughter weight combinations and an associated set of marketing alternatives. The marketing alternatives reflected either selling on the cash market, or selling on the cash market in combination with some method of risk-reduction, such as hedging or participation in the Tripartite Stabilization Plan for slaughter cattle. Biological data and technical coefficients for the model were derived from a series of feeding experiments conducted on over 650 individually fed steers (Hironaka, 1979, 1984, 1985). Marketing data were derived from secondary sources, and the models assumed to sufficiently reflect reality that prescriptive, meaningful results could be obtained. The solutions generated suggested ways feedlot managers might have structured cattle feeding and marketing operations for the 1986-87 feeding period, depending on their risk attitudes.

Conclusions, Implications and Reflections

This section first develops general conclusions from the results of the study and makes recommendations for the production and marketing of feedlot cattle for the forecast feeding period (1986-87). Next, conclusions are made regarding the specific study objectives. Throughout the discussion implications and reflections are offered regarding the feedlot management problem.

General Conclusions Pertaining to the Overall Objective of the Study

The overall objective of this study was to identify the most effective feeding and marketing strategies for reducing net income variability in cattle feeding in Southern Alberta. To that end, the models prescribed a set of risk-efficient production-marketing plans for the 1986-87 feeding period that varied depending on the assumed risk attitude and risk perception of the feedlot manager. The plans were portrayed graphically as risk frontiers (Es and EA) in expected value-risk defined space and allow the manager to access the trade-offs involved between plans as to net income and associated risk.

For both the MOTAD and Target MOTAD results, plans detailed at low levels of risk aversion were dominated by high expected value, high risk production-marketing alternatives, such as HHH1-CHEDG and HHH2-CHEDG (figures 20 and 21). These alternatives had consistently higher net revenues per head over other alternatives for the recent years of 1984, 1985 and 1986. Net revenue values for their SHEDG counterparts of HHH1-SHEDG and HHH2-SHEDG averaged $20 lower in these same years, indicating a significant benefit in recent years from hedging the Canadian dollar. This benefit was present in all production alternatives in 1984 when the value of the Canadian dollar fell from $0.8130 U.S. on November 4, 1983 to approximately $0.73 U.S. in the April to August period of 1984 when the majority of November placed cattle were finished. The HHH1 and HHH2 production alternatives, which finish cattle in April and May respectively, experienced smaller gains from hedging the Canadian dollar in 1985 and 1986, but these gains tended to be larger than other production alternatives because the Canadian dollar strengthened from April into early August for these years.

At higher risk aversion levels, MOTAD plans diversified into production-marketing alternatives that were either characterized by moderate expected value net incomes and low forecast error standard deviation risk (e.g., CHML-CHEDG) or were able to reduce risk through their portfolio effects in combination with other alternatives (e.g., LMH-CASH, USCHHH3-CHEDG, and HHH1-TSP). Important among these plans was the prescription that 17 to 25 percent of crossbred cattle be fed to the higher slaughter weight of 614 kg and be marketed into the United States. This was essentially in agreement with what producers did in the 1986-87 year. Target MOTAD results did not prescribe the U.S. marketing option, but were similar to the MOTAD results in suggesting participation levels in the Stabilization plan of about 20 to 40 percent of cattle fed (figures 20 and 21). Also, at high risk aversion levels, MOTAD and Target MOTAD results suggested high percentages (e.g., 70 percent) of cattle be managed in a complex hedging (CHEDG) program and that production be diversified into higher slaughter weight alternatives (e.g., CHML, USCHHH3, CHHH2).

Target MOTAD results for the low forage-low grain-high feeder price scenario suggested proportionately more cattle be fed to higher slaughter weights than suggested by the 1986-87 price scenario results.[54/]

[54/]See figures D-9 and D-10 in comparison to figure 20 and 21.

Conclusions Regarding the Specific Objectives of the Study

Empirical evidence was found that the risk-reducing alternative of hedging would increase individual firms' output of slaughter cattle by increasing the slaughter weights to which cattle are fed. However, results for Stabilization were contrary to those expected, i.e., slaughter weights were lower than for the cash marketing alternative. The conflicting results indicate the confounding that is present due to time and carcass quality effects. Individual production-marketing alternatives, by the nature to their finishing dates and carcass quality performance, may effect a higher net revenue-lower risk result than the hypothesized heavier slaughter weight alternatives. For example, the MOTAD results for the CASH-TSP runs versus the CASH-only runs indicated HHH1-TSP was optimal at almost all risk aversion levels over combinations the heavier weight alternatives of MMM-CASH and HHH1-CASH. HHH1-TSP had an expected net revenue per head of $14 and on associated historical forecast error standard deviation of $74 (tables 20 and 22). This was better than the MMM-CASH alternative with its expected value of $5 and standard deviation of $94 and the HHH1-CASH alternative with its expected value of $-14 and standard deviation of $104 (tables 20 and 22). Even in various proportionate combinations MMM-CASH and HHH1-CASH failed to achieve net revenue-forecast error risk levels better than HHH1-TSP alone.[55/]

55/This result is visualized in figure 25 by noting the dominant position of the CASH-TSP Es frontier over the CASH Es frontier.

Despite these conflicting results, the ability of hedging and Stabilization to reduce risk and its associated costs, as evidenced by the upward rotation of their associated Es and EA frontiers, necessitates the hypothesis that their employment will increase slaughter cattle output (slaughter weights and numbers of cattle fed) in the aggregate. The implication is that the National Tripartite Stabilization plan, in particular, may violate its founding assumption of not providing incentive to over-produce. Of potential concern is the effect that increased profitability of finished cattle production (due to a reduction in risk costs) might have on feeder cattle prices. As the risk costs of feeding are decreased, additional demand is created for feeder cattle leading to higher prices which eventually figure into the TSP cost of production formulae and lead to higher support price levels and larger or more frequent payouts. Thus, the Stabilization plan has potential for large deficits resulting from a combination of low slaughter prices (produced from over-production) and high support prices.

Both MOTAD and Target MOTAD results demonstrated that live cattle hedging performance was improved with concomitant hedging of the Canadian dollar, so it is recommended that producers who are involved in hedging slaughter cattle also consider hedging the Canadian dollar, particularly if the Canadian dollar is expected to weaken relative to the U.S. dollar as it did during the period 1976-86.

On the basis of the MOTAD results, participation in the TSP was found to reduce the level of hedging demanded at the various risk aversion levels by about 10 percent (figure 23). For the Target MOTAD results, the level of hedging decline varied from 4 to 50 percent (figure 24). Generally it can be concluded that participation in the Stabilization plan leads to a reduction in hedging participation. The implication is hedging of Canadian slaughter cattle on U.S. commodity exchanges will decline with the continuing availability of the Tripartite Stabilization Plan.

Indeed, Target MOTAD results indicated the superiority of Stabilization over routine hedging (SHEDG) in reducing average negative deviation risk. Although live cattle hedging combined with a Canadian dollar hedge (CHEDG) performed better than Stabilization in reducing average negative deviation risk, this result was in part a reflection of the consistent weakening of the Canadian dollar relative to the U.S. dollar during the historical period (1976-86). MOTAD results, however, indicate both CHEDG and SHEDG to be superior to Stabilization in reducing forecast error risk (figure 25). This discrepancy between MOTAD and Target MOTAD results relates to the target MOTAD formulation which, by concentrating on minimizing risk below a target income, does not penalize the income increasing ability of the Stabilization plan. In determining whether to employ the private risk-reducing mechanism of hedging versus the public Stabilization programs in any year feedlot managers would be advised to consider trends in the Canadian dollar versus the U.S. dollar and the potential for Stabilization payouts in the upcoming year.[56/] Even if the feedlot manager decides to

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[56/]Generally, it is not possible for a cattle feeder to "jump" in and out of the TSP from year-to-year.

participate in the Stabilization plan for the long term, hedging should be considered in light of its diversification or portfolio benefits.

The study results confirmed that portfolio benefits do exist between the various production and marketing alternatives. For the 1986-87 input price scenario, diversification facilitated a reduction in historical forecast error standard deviation risk from $71 at low risk aversion levels to $17 at high levels (figure 20). The reduction in risk was accompanied by a fall in net income per head from $40 to $5. At the high risk aversion levels ($\alpha \geq 1.2$) the net income-risk levels of $5 net income and $17 forecast error standard deviation were better than could have been achieved by the closest ranked individual risk-reducing production-marketing plan of CHHH2-SHEDG (tables 20 and 22). Its expected value net income was $-20 with a forecast error standard deviation of $18.

Similarly, Target MOTAD results showed that diversification facilitated a reduction in average negative deviation risk below $50 from $47 down to $14 (figure 21). At high risk aversion levels, the diversified plan of point 7 on figure 21 was projected to produce a net income of $4 with an average deviation risk of $15, which was better than the best ranked individual risk-reducing production-marketing plan of CHHH2-CHEDG. Its expected value net income was $0 with an average negative deviation risk of $16.

These positive results regarding portfolio effects indicate the potential for feedlot managers to consider both production and marketing diversification. Risk-efficient plans detailed by the models are specific to the forecast year, that is, the upcoming feeding period. For 1986-87 the results suggested that regardless of the input price scenario and at moderate levels of risk aversion, feedlot managers should maintain high levels of hedging of both live cattle and the Canadian dollar, with moderate participation in the Tripartite Stabilization Plan. This advice may change from year-to-year. The specific plan adopted by the manager would depend on his or her level of risk aversion and conception of risk (forecast error risk or safety-first risk). The question of which approach, MOTAD or Target MOTAD, best models manager behavior is empirical and deserves study with future validation tests.

Reflections on Validation

The usefulness of the study results and conclusions depends largely on the validity of the models as portrayals of the cattle feedlot feeding and marketing system. In this regard, the developed MOTAD and Target MOTAD feedlot models are argued as being "validated" by assumption. A precaution here is McCarl's comment that "Models can never be validated, only invalidated." (McCarl, 1984b, p. 157). Thus, a "valid" model is one which has not failed any validation tests, i.e., has yet to be invalidated. Validation by assumption implies: 1/ the model problem was conceptualized properly in light of theory or experience, 2/ the data were specified properly as based on statistical or accounting procedures, and 3/ the results examined do not contradict the modeler's or other expert opinions of reality (McCarl, 1984a).

In the feedlot models, the feedlot management problem was conceptualized in the framework of EV analysis, which was shown to be a valid approximation of expected utility maximization. Biological data and equations calculating energy, protein and other nutrient requirements were the result of individual feeding experiments on over 650 steer calves (Hironaka, 1979, 1984, 1985), and were validated by results obtained by a commercial feedlot. Formulated diets resulting from the model appeared reasonable when compared to example diets typically formulated by industry (Lakeside Research, 1986b). Net margins to cattle feeding as determined by the models for the historical period (1976-87) were in agreement with those recorded by industry analysts (Canfax). Feeding and marketing solution results tended to approximate actual industry experience for the feeding year simulated (1986-87). In that year, relatively low grain and forage prices coupled with high slaughter prices led to finishing of cattle to higher than traditional weights (crossbred feeders to 620 kg). Many of these cattle were shipped into the U.S. market to avoid overweight discounts and downgrading in Canada.

Another approach to model validation is validation by results. This essentially involves the assembly of a parameter-output data set to which model results are compared and validity judged on the basis of statistical association tests. This type of test was not done to judge the validity of the feedlot models, but is an objective of future research.

Study Limitations

Results and conclusions of the study must be evaluated in light of the simplifying assumptions made in constructing the models. Some of these assumptions are not serious, while others may limit the applicability of the results. Among these are assumptions on hedging strategy, feeder type, feeding start date, environment interactions and grade standard stability.

The models employed routine hedging of live cattle as a first basis for comparison of Stabilization and cash marketing alone. Selective heding strategies, where a hedge position is taken only when there is a high probability that a profit can be taken on the futures market, may offer a better opportunity for hedging success.[57/] In a study by Folwell and Wilhelm, routine hedge and hold strategies were successful (had a higher gain or lower loss than cash marketing alone) only 43 percent of the time. Thus, the models could be expanded to include selective hedging strategies and the comparative results of hedging versus Stabilization be reexamined.

Producers suggest that there may be differences in calf condition and disease susceptibility between breed and crossbred feeder types. For example, the traditional British breeds appear more hardy and able to withstand drought conditions than the newer exotic breed cross feeders, and thus arrive in the feedlot in better condition. Over the

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57/For example, Gaston and Martin showed that selective hedging strategies both increased profit and reduced cash flow risk over other routine and profit margin breakeven strategies.

last five years, a study conducted in Western Canada on feedlot respiratory disease attempted to quantify some of these aspects, but the results have not been released (Wilson, 1988). The importance of these risk variables to this study would certainly impact the optimum feeder type and feeding regime, but may have little impact on marketing results.

The assumption of a single starting date for feeding may have an effect in overstating the income risk associated with feedlot production. In Southern Alberta calves are purchased throughout the Fall. Feedlots tend to empty throughout the late Spring and early Summer, and to some extent this gradual marketing of Fall fed calves reduces risk. However, the production and marketing results of this study should be uniformly affected by this assumption and, in relative terms, unaffected.

Environment is also assumed constant over the period simulated in the study. There is no provision in the models to handle the effect of colder than normal temperatures on energy requirements, which impact not only on production costs, but may interact with feeder type. The winter climate of Southern Alberta is generally mild compared to the rest of the Canadian prairies; however, there is some low probability of an extended colder-than-normal period. It is unlikely though that this would impact the results of this study very much.

A unique aspect in the feedlot models is the link between the specified feeding regimes and carcass grade distributions. To the extent that the Canadian grading system remains stable, the results of the study should remain valid. Although grading system changes have occurred periodically, they have not been significant enough yet to require the reconstruction of the original feeding data. Should major changes occur, the feeding data set is comprehensive enough in its measurements of carcass characteristics that it should be possible to reconstruct the grade distributions according to new grade specifications. If not, new feeding experiments would be required to provide data to update the models.

Suggestions for Future Research

Several possibilities for future research on feedlot modeling arise from the present study and can be classified in terms of model testing and refinement, additions to the model and additional analyses.

In regard to model testing, a parameter-output data set would be developed by collecting Southern Alberta feedlot data on input and output prices, diets fed, types of cattle finished, finishing weights and marketing practices, degree of hedging use, participation levels in the Tripartite Stabilization Plan, and subjective probability distributions on futures prices, cash prices, interest rates, feeder and feed prices, the exchange rate, and TSP payouts. A possibility test[58/] would be conducted to determine the capability of the models to duplicate the "reality" situation corresponding to the collected data.

[58/]See McCarl (1984b, p. 163).

Future refinements to the model could include the incorporation of more sophisticated equations on protein and energy requirements. For protein, this would involve developing a method to overcome the circular problem in matching protein requirements to concentrations of particular feedstuffs in the diet(e.g., long hay). Future feeding experiments are required to define energy requirements for steers fed to alternative target weights for production alternatives other than "HHH" and "CHHH".

Additions to the model could include: 1/ alternatives relating to the National Tripartite Stabilization Plan for feeder cattle, 2/ alternatives relating to live cattle options use and strategies on U.S. futures markets, 3/ a statistical forecasting model for slaughter cattle prices based on variables such as feed grain prices, cattle on feed, feeder prices, etc., and 4/ hedging alternatives for feed supplies. Other useful additions would be the ability to examine alternative starting dates, the feeding of yearling feeders to finish, and the interaction of feeder type and calf condition. An eventual tie-in with a Western Canadian based beef-forage-grain simulation model is also planned, to allow the examination of the economics of vertically integrated feeding operations.

Additional useful analyses with the present model might be the examination of new information on protein or energy requirements versus current information to determine the value of such information, either ex ante or ex post.

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APPENDICES

APPENDIX A

MOTAD MODEL LISTING

```
OPTIONS SOLPRINT = OFF, SYSOUT = OFF, LIMROW = 0, LIMCOL = 0;

* LETHBRIDGE FEEDLOT QP AND MOTAD MODEL

SET MTH NUMBERS OF THE MONTHS
   / 1 JANUARY
     2 FEBRUARY
     3 MARCH
     4 APRIL
     5 MAY
     6 JUNE
     7 JULY
     8 AUGUST
     9 SEPTEMBER
    10 OCTOBER
    11 NOVEMBER
    12 DECEMBER /


SET IV  VITAMINS
   / VTA /

SET I  NUTRIENTS
   / DE  DIGESTIBLE ENERGY (MCAL PER KG)
     CP  CRUDE PROTEIN (G PER KG)
     CA  CALCIUM (G PER KG)
     PH  PHOSPHORUS (G PER KG)
     DM  DRY MATTER (KG OF DM PER KG OF FEEDSTUFF)
     DMM DM EXCEPT SILAGES WHERE IS KM DM PER KG DM
     WT  WETNESS CONTENT  /

SET J  INGREDIENTS
   / BLY BARLEY
     WHT WHEAT
     OAT OATS
     CRN CORN
     BTP BEET PULP
     MOL MOLASSES (BEET)
     SOM SOYBEAN MEAL
     RPM RAPESEED MEAL
     DHY DEHY ALFALFA
```

```
      ALF ALFALFA HAY
      BRH BARLEY HAY
      GLH GRASS LEGUME HAY
      CER CEREAL HAY
      BST BARLEY STRAW
      OST OAT STRAW
      WST WHEAT STRAW
      CRS CEREAL SILAGE
      SUP SUPPLEMENT
      COS CORN SILAGE
      URA UREA
      DIC DICAL PHOSPHATE
      RKP ROCK PHOSPHATE
      LIM LIMESTONE
      SLT SALT /

SET JM  MOLASSES ONLY
      / MOL /;

SET N  FEEDSTUFFS PLUS VITAMINS;
      N(IV) = YES;
      N(J) = YES;

SET JC  CONCENTRATES
      / BLY, WHT, CRN, BTP, MOL, SOM, RPM /
     JU  UREA ONLY
      / URA /
     JS  SALT ONLY
      / SLT /
     JB  BEET PULP ONLY
      / BTP /
     JR  RAPESEED MEAL ONLY
      / RPM /
     JL  LIMESTONE ONLY
      / LIM /
     NJU FEEDSTUFFS MINUS UREA;
        NJU(J) = YES;
        NJU(JU) = NO;
SET  NJM FEEDSTUFFS MINUS MOLASSES;
        NJM(J) = YES;
        NJM(JM) = NO;
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SET  NJB FEEDSTUFFS MINUS BEETPULP;
        NJB(J) = YES;
        NJB(JB) = NO;
SET  NJS FEEDSTUFFS MINUS SALT;
        NJS(J) = YES;
        NJS(JS) = NO;
SET  NJR FEEDSTUFFS MINUS RAPESEED MEAL;
        NJR(J) = YES;
        NJR(JR) = NO;
SET  NJL FEEDSTUFFS MINUS LIMESTONE;
        NJL(J) = YES;
        NJL(JL) = NO;

SET K  PRICE SERIES ALTERNATIVES
   / OBA, OBB, OBC, OBD /

SET GD
  /  A1     A1 GRADE OF FINISHED STEER
     A2     A2 GRADE OF FINISHED STEER
     A3     A3 GRADE OF FINISHED STEER
     A4     A4 GRADE OF FINISHED STEER /

SET LR  LIVESTOCK COEFFCIENTS
  /  LDIS
     HDIS
     YARD  YARDAGE CHARGE
     BUY   BUYING CHARGES
     SELL  SELLING CHARGES
     INT   INTEREST RATE  /


SET F  FEEDING PROGRAM ALTERNATIVES
   / LLH, LMH, LHH, MMM, MMH, MHH, HML, HHH1, HHH2, HHH3,
     CLLH,CLMH,CMMM,CHML,CHHH1,CHHH2,CHHH3,USCHHH3 /

SET MK  MARKETING ALTERNATIVES
   / CASH, SHEDG, CHEDG, TSP /

ALIAS(F,FC);
ALIAS(MK,MKC);
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```
SET C  CARCASS WEIGHT CATEGORIES
  /L, M, H/

SET M   MINIMUM AND MAXIMUM COEFFICIENTS
  / MOLC  MOLASSES MAX CONCENTRATION IN CONCENTRATE (% IN DECIMAL)
    MOLF  MOLASSES MAX CONCENTRATION IN FORAGE (% IN DECIMAL)
    CAL   MIN CA REQT (GRAMS PER MCAL OF DE)
    PHO   MIN PH REQT (GRAMS PER MCAL OF DE)
    URE   MAX UREA CONCENTATION (% OF DIET IN DECIMAL)
    NCL   SALT REQT (% OF DIET IN DECIMAL)
    BEP   MAX BEET PULP CONCENTRATION (% OF DIET IN DECIMAL)
    VIT   VIT A REQT ('000 IU'S)
    RMM   MAX RAPESEED MEAL LIMIT (% OF DIET IN DECIMAL)
    MIXF  MIXING CHARGE PER 1000 KG OF DIET
    LIME  MAX LIMESTONE CONCENTRATION (% OF DIET IN DECIMAL)  /;

SET Z
  /1, 2, 3/

SET YR  SAMPLE YEARS
  /1976*1986 /

SCALARS CALP    MINIMUM CALCIUM TO PHOSPHORUS RATIO /1.3/
        CALPX   MAXIMUM CALCIUM TO PHOSPHORUS RATIO /7.0/
        PHI     RISK FACTOR / 0.0 /
        TARG    TARGET INCOME / 100 /
        FCPI    FORECASTED CONSUMER PRICE INDEX /128/
        TRAT    CURRENT TRANSPORTATION RATE PER LOADED MILE /2.85/
        S       SCALING FACTOR / .002 /
        LAMBDA  TARGET MOTAD RISK FACTOR / 0.0/
        NUMBER  NUMBER OF HEAD TO BE FED / 1.0 /;

SCALAR  TRSP  CURRENT TRANSPORT COST FOR 400 MILES TO US MARKET ($ PER 100 KG);
        TRSP = ((TRAT*400)/(50000))*2.2*100;
DISPLAY TRSP;
SCALAR  KL      NORMALIZING CONSTANT;
        KL = SQRT(3.1415926 * CARD(YR)/(CARD(YR)-1)/2);
SCALAR  CT      NUMBER OF CATTLE FUTURES CONTRACTS;
        CT = NUMBER/40;

TABLE A(*,I) FEED COMPOSITION
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```

          DE    CP    CA    PH    DM    DMM   WT
     BLY  3.42  10.6  0.4   3.4   0.88  0.88  1.0
     WHT  3.44  13.7  0.4   3.5   0.88  0.88  1.0
     OAT  3.13  9.9   0.6   3.1   0.88  0.88  1.0
     CRN  3.47  9.0   0.3   3.0   0.88  0.88  1.0
     BTP  3.22  9.0   6.7   1.0   0.90  0.88  1.0
     MOL  2.65  6.7   1.6   0.3   0.77  0.77  1.0
     SOM  3.44  47.0  3.0   6.5   0.90  0.90  1.0
     RPM  3.26  38.0  4.0   9.4   0.90  0.90  1.0
     DHY  2.40  17.0  13.0  2.3   0.90  0.90  1.0
     ALF  2.25  15.2  14.9  1.9   0.92  0.92  1.0
     BRH  2.20  7.98  3.9   1.3   0.90  0.90  1.0
     GLM  2.42  11.8  10.0  1.7   0.90  0.90  1.0
     CER  2.74  8.0   2.5   1.9   0.90  0.90  1.0
     BST  1.75  4.1   2.8   0.9   0.90  0.90  1.0
     OST  1.87  3.9   2.2   0.9   0.90  0.90  1.0
     WST  1.70  3.6   1.9   0.7   0.90  0.90  1.0
     CRS  2.78  14.3  4.6   3.5   0.313 1.00  3.12
     SUP  2.86  32.0  30.0  10.0  0.90  0.90  1.0
     COS  2.89  9.3   9.7   2.2   0.303 1.00  3.3
     URA  0.0   262.0 0.0   0.0   1.0   1.0   1.0
     DIC  0.0   0.0   230.0 185.0 0.95  1.0   1.0
     RKP  0.0   0.0   300.0 181.0 0.95  1.0   1.0
     LIM  0.0   0.0   380.0 0.0   0.95  1.0   1.0
     SLT  0.0   0.0   0.0   0.0   0.95  1.0   1.0
     VTA  0.0   0.0   0.0   0.0   1.0   1.0   1.0

TABLE GN(F,Z) RATE OF GAIN BY FEEDING REGIME AND STAGE (KG PER DAY)

           1      2      3
LLH        0.50   0.50   1.39
LMH        0.50   0.80   1.45
LHH        0.50   1.50   1.10
MMM        0.80   0.80   1.04
MMH        0.80   0.80   1.51
MHH        0.80   1.40   1.07
HML        1.65   0.80   0.50
HHH1       1.0    1.11   0.0
HHH2       1.0    1.3    1.31
HHH3       1.0    1.3    1.10
```

```
CLLH      0.53    0.82   1.28
CLMH      0.53    0.97   1.40
CMMM      0.63    1.02   1.12
CHML      0.87    0.95   0.91
CHHH1     0.87    1.32   0.94
CHHH2     0.83    1.29   1.02
CHHH3     0.89    1.33   0.98
USCHHH3   0.89    1.33   0.98;


TABLE MNMX(M,Z) MINIMUM AND MAXIMUM PARAMETERS BY STAGE

              1       2       3
    MOLC     .025    .025    .025
    MOLF     .05     .05     .05
    CAL      1.25    1.25    1.25
    PHO      .96     .96     .96
    URE      .005    .005    .005
    NCL      .0025   .0025   .0025
    BEP      .05     .05     .05
    VIT      30.0    35.0    40.0
    RMM      .10     .10     .10
    MIXF     6.25    6.25    6.25
    LIME     .015    .015    .015

PARAMETER BARPR(YR) BARLEY PRICE PER YEAR FOR NOV 4 ($ PER 100 KG)
/ 1976 9.599, 1977 9.15, 1978 8.038, 1979 6.2, 1980 9.875, 1981 13.32,
  1982 10.70, 1983 9.645, 1984 11.9, 1985 14.47, 1986 13.09 /;

TABLE P(*,K)  FEED INGREDIENT COST COEFFICIENTS ($ PER 100 KG)

            OBA     OBB     OBC     OBD
     BLY   8.4     12.0    5.5     12.0
     WHT   9.9     15.0    8.0     15.0
     OAT   8.52    13.0    8.5     13.0
     CRN   13.1    17.0    13.0    17.0
     BTP   11.3    12.0    11.0    12.0
     MOL   100     100     100     100
     SOM   30.0    32.0    25.0    32.0
     RPM   17.0    17.5    17.0    17.5
     DHY   16.1    14.5    13.5    14.5
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```
        ALF  7.37   11.5   9.0    9.0
        BRH  6.87   11.0   8.5    8.5
        GLM  6.87   11.0   8.5    8.5
        CER  6.87   11.0   8.5    8.5
        BST  3.43   5.5    4.25   4.25
        OST  3.43   5.5    4.25   4.25
        WST  3.43   5.5    4.25   4.25
        CRS  5.03   6.5    6.0    6.0
        SUP  40.0   45.0   40.0   45.0
        COS  5.5    6.8    6.3    6.3
        URA  30.0   30.0   30.0   30.0
        DIC  57.8   57.8   57.8   57.8
        RKP  55.0   55.0   55.0   55.0
        LIM  8.0    8.0    8.0    8.0
        SLT  19.8   19.8   19.8   19.8
        VTA  82.0   82.0   82.0   82.0

TABLE L(*,K)  COST COEFFICIENTS

             OBA    OBB    OBC    OBD
        FEDR 234.3  150    250    150
        VET  .02    .02    .02    .02
        DEATH .015  .015   .015   .015
        YARD .14    .14    .14    .14
        BUY  7.0    7.0    7.0    7.0
        SELL 1.0    1.0    1.0    1.0
        INT  .1075  .1075  .1075  .1075

PARAMETER CPI(YR) CONSUMER PRICE INDEX
   / 1976 62.9, 1977 67.9, 1978 73.9, 1979 80.7, 1980 88.9,
     1981 100.0, 1982 110.8, 1983 117.2, 1984 122.3, 1985 127.2, 1986 126 /;


TRSP = (TRSP*100)/FCPI;

PARAMETER TRANS(YR) TRANSPORTATION COST ($ PER 100 KG) TO US MARKET BY YEAR;
          TRANS(YR) = (TRSP/100)*CPI(YR);

PARAMETER INTR(YR) PRIME PLUS ONE INTEREST RATE PER YEAR FOR 4TH QUARTER
/ 1976 .1075, 1977 .1075, 1978 .0925, 1979 .125, 1980 .16, 1981 .1475,
  1982 .1825, 1983 .14, 1984 .12, 1985 .13, 1986 .11 /;
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PARAMETER FDR(YR)  FEEDER COST BY YEAR FOR NOV 4 ($ PER 100 KG)
/ 1976 50.6, 1977 65.45, 1978 105.6, 1979 189.2, 1980 231.0, 1981 207.9,
  1982 159.5, 1983 182.6, 1984 185.35, 1985 186.12, 1986 195.8 /;
DISPLAY FDR;

SCALAR  DGY4  CURRENT US RAIL DISCOUNT FOR CHC4 TO CHC3 CARCASSES (US $ PER CWT)
              /20/
        DUTY  CURRENT CUSTOMS DUTY CHARGE IN CDN $ PER CWT /1.0/
        DGD   CURRENT US RAIL DISCOUNT FOR GD STRS TO CHC3 (US $ PER CWT) /5.0/;
SCALAR  DCT   CURRENT CDN RAIL DISCOUNT FOR 725 TO 821 LB CARCASSES ($ PER 100 KG);
        DCT = 2*2.2;

        DGY4 = (DGY4*100)/FCPI;
        DGD  = (DGD*100)/FCPI;
        DCT  = (DCT*100)/FCPI;

PARAMETER D4(YR) HISTORICAL CPI ADJUSTED US YIELD DISCOUNT (US $ PER CWT)
          DG(YR) HISTORICAL CPI ADJUSTED US GRADE DISCOUNT (US $ PER CWT)
          DST(YR) HISTORICAL CPI ADJUSTED CDN WEIGHT DISCOUNT ($ PER 100 KG)
          DUT(YR) HISTORICAL CPI ADJUSTED CDN CUSTOMS DUTY ($ PER 100 KG);
          D4(YR) = (DGY4/100)*CPI(YR);
          DG(YR) = (DGD/100)*CPI(YR);
          DST(YR) = (DCT/100)*CPI(YR);
          DUT(YR) = (DUTY*2.2/100)*CPI(YR);

TABLE LK(F,*)  LIVESTOCK PRODUCTION COEFFICIENTS

           DRS    A1     A2     A3      A4     END  BEG
LLH        0.569  0.065  0.297  0.361   0.277  477  210
LMH        0.574  0.158  0.319  0.326   0.197  477  210
LHH        0.586  0.0    0.0    0.638   0.362  477  210
MMM        0.568  0.201  0.532  0.267   0.0    477  210
MMH        0.584  0.064  0.258  0.335   0.342  477  210
MHH        0.593  0.0    0.07   0.567   0.363  477  210
HML        0.568  0.211  0.425  0.363   0.0    477  210
HHH1       0.560  0.25   0.563  0.0     0.1875 386  210
HHH2       0.558  0.25   0.375  0.3125  0.0625 432  210
HHH3       0.590  0.031  0.062  0.349   0.558  477  210
CLLH       0.573  0.625  0.375  0.0     0.0    523  250
CLMH       0.580  0.625  0.375  0.0     0.0    523  250
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  CMMM      0.567  0.885  0.125  0.0     0.0    523  250
  CHML      0.568  0.812  0.188  0.0     0.0    523  250
  CHHH1     0.576  0.188  0.562  0.250   0.0    523  250
  CHHH2     0.596  0.267  0.40   0.333   0.0    568  250
  CHHH3     0.604  0.214  0.286  0.286   0.214  614  250
 USCHHH3    0.604  1.0    0.0    0.0     0.0    614  250;

  TABLE MARK(F,YR,*) HISTORICAL MARKETING CHARGES

                  RI     RO     SI    PREM   EI      EO      TEI     TEO     PAY   LEV  DIFF
       LLH.1976  39.50  41.18   40   11.99  1.0216  0.9818  1.0065  1.0136  5.36  1.05  4.84
       LLH.1977  44.50  38.90   45    9.09  0.9720  1.0751  1.0060  0.9292  0.00  0.89  7.50
       LLH.1978  40.00  53.18   40   12.16  1.1059  1.1459  0.8995  0.8691  0.00  1.06  5.50
       LLH.1979  60.05  68.45   60    7.79  1.1727  1.1682  0.8640  0.8561  0.00  1.52  4.25
       LLH.1980  71.50  68.72   72    5.34  1.1818  1.1593  0.8575  0.8651  1.91  1.82 10.30
       LLH.1981  73.70  66.93   74    6.12  1.1718  1.2107  0.8578  0.8312  3.15  1.93 12.50
       LLH.1982  63.65  61.65   64    6.44  1.2068  1.2377  0.8205  0.8053  0.00  1.72 11.00
       LLH.1983  57.92  55.98   58    6.46  1.2227  1.2314  0.8104  0.8116  1.48  1.70 14.85
       LLH.1984  61.65  63.66   62    6.42  1.2331  1.2990  0.8130  0.7701  0.00  1.77 16.47
       LLH.1985  62.52  56.11   64    2.70  1.3115  1.3619  0.7568  0.7333  6.81  1.92 10.75
       LLH.1986  58.85  60.97   60    7.80  1.3666  1.3924  0.7271  0.7176  0.00  1.90 15.85
       LMH.1976  39.50  41.87   40   10.28  1.0216  0.9876  1.0065  1.0066  5.36  1.05  5.88
       LMH.1977  44.50  38.37   45    7.79  0.9720  1.0745  1.0060  0.9295  0.00 0.89   8.10
       LMH.1978  40.00  50.47   40   10.42  1.1059  1.1377  0.8995  0.8764  0.00  1.06  9.50
       LMH.1979  60.05  57.98   60    6.68  1.1727  1.1739  0.8640  0.8545  0.00  1.52  4.90
       LMH.1980  71.50  69.71   72    4.58  1.1818  1.1583  0.8575  0.8626  1.91  1.82 10.00
       LMH.1981  73.70  63.90   74    5.24  1.1718  1.2372  0.8578  0.8014  3.15  1.93 12.50
       LMH.1982  63.65  64.35   64    5.52  1.2068  1.2559  0.8205  0.7954  0.00  1.72 14.35
       LMH.1983  57.92  60.93   58    5.54  1.2227  1.2355  0.8104  0.8099  1.48  1.70 10.00
       LMH.1984  61.65  62.93   62    5.50  1.2331  1.3096  0.8130  0.7650  0.00  1.77 20.25
       LMH.1985  62.52  57.50   64    2.70  1.3115  1.3608  0.7568  0.7549  6.81  1.92 12.92
       LMH.1986  58.85  59.82   60    7.80  1.3666  1.3811  0.7271  0.7196  0.00  1.90 16.90
       LHH.1976  39.50  41.77   40    9.04  1.0216  0.9743  1.0065  1.0910  5.36  1.05  3.66
       LHH.1977  44.05  39.37   44    6.29  0.9720  1.0595  1.0060  0.9378  0.00  0.89  7.53
       LHH.1978  39.95  52.80   40    9.28  1.1059  1.1243  0.8995  0.8905  0.00  1.06  7.75
       LHH.1979  60.11  65.15   60    5.80  1.1727  1.1610  0.8640  0.8585  0.00  1.52  1.00
       LHH.1980  72.61  70.68   73    3.80  1.1818  1.1502  0.8575  0.8645  1.91  1.82 12.00
       LHH.1981  74.45  65.75   74    3.92  1.1718  1.2042  0.8578  0.8245  3.15  1.93 17.15
       LHH.1982  64.98  64.11   65    4.37  1.2068  1.2574  0.8205  0.7940  0.00  1.72 14.00
       LHH.1983  59.23  61.02   59    4.41  1.2227  1.2329  0.8104  0.8124  1.48  1.70 13.90
       LHH.1984  63.30  64.38   63    4.06  1.2331  1.3287  0.8130  0.7515  0.00  1.77 15.00
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372	LHH.1985	64.58	54.77	66	3.24	1.3115	1.3481	0.7568	0.7402	6.81	1.92	20.42
373	LHH.1986	60.00	57.97	62	8.67	1.3666	1.3746	0.7271	0.7235	0.00	1.90	20.51
374	MMM.1976	39.50	40.74	40	11.67	1.0216	0.9818	1.0065	1.0136	5.36	1.05	4.84
375	MMM.1977	44.50	39.15	45	8.85	0.9720	1.0751	1.0060	0.9293	0.00	0.89	7.50
376	MMM.1978	40.00	53.98	40	11.84	1.1059	1.1459	0.8995	0.8723	0.00	1.06	5.50
377	MMM.1979	60.05	65.47	60	7.58	1.1727	1.1682	0.8640	0.8559	0.00	1.52	4.25
378	MMM.1980	71.50	68.72	72	5.20	1.1818	1.1593	0.8575	0.8627	1.91	1.82	10.30
379	MMM.1981	73.70	67.45	74	5.96	1.1718	1.2107	0.8578	0.8276	3.15	1.93	12.50
380	MMM.1982	63.65	62.55	64	6.27	1.2068	1.2377	0.8205	0.8048	0.00	1.72	11.00
381	MMM.1983	57.92	57.69	58	6.29	1.2227	1.2314	0.8104	0.8137	1.48	1.70	14.85
382	MMM.1984	61.65	63.24	62	6.25	1.2331	1.2990	0.8130	0.7695	0.00	1.77	16.47
383	MMM.1985	62.52	56.55	64	2.70	1.3115	1.3619	0.7568	0.7352	6.81	1.92	10.75
384	MMM.1986	58.85	60.45	60	7.80	1.3666	1.3924	0.7271	0.7145	0.00	1.90	15.85
385	MMH.1976	39.50	41.83	40	8.92	1.0216	0.9743	1.0065	1.0192	5.36	1.05	3.66
386	MMH.1977	44.05	39.98	44	6.20	0.9720	1.0595	1.0060	0.9420	0.00	0.89	7.53
387	MMH.1978	39.95	50.92	40	9.15	1.1059	1.1243	0.8995	0.8893	0.00	1.06	7.75
388	MMH.1979	60.11	67.13	60	5.72	1.1727	1.1610	0.8640	0.8563	0.00	1.52	1.00
389	MMH.1980	72.61	69.83	73	3.75	1.1818	1.1502	0.8575	0.8665	1.91	1.82	12.00
390	MMH.1981	74.45	66.04	74	3.86	1.1718	1.2042	0.8578	0.8283	3.15	1.93	17.15
391	MMH.1982	64.98	64.80	65	4.31	1.2068	1.2574	0.8205	0.7908	0.00	1.72	14.00
392	MMH.1983	59.23	62.02	59	4.35	1.2227	1.2329	0.8104	0.8120	1.48	1.70	13.90
393	MMH.1984	63.30	65.25	63	4.00	1.2331	1.3287	0.8130	0.7509	0.00	1.77	15.00
394	MMH.1985	64.58	55.52	66	3.24	1.3115	1.3481	0.7568	0.7402	6.81	1.92	20.42
395	MMH.1986	60.00	65.02	62	8.67	1.3666	1.3746	0.7271	0.7251	0.00	1.90	20.51
396	MHH.1976	39.50	39.80	40	8.29	1.0216	0.9696	1.0065	1.0256	5.36	1.05	1.06
397	MHH.1977	44.05	40.27	44	5.76	0.9720	1.0587	1.0060	0.9397	0.00	0.89	6.13
398	MHH.1978	39.95	53.15	40	8.50	1.1059	1.1233	0.8995	0.8890	0.00	1.06	4.75
399	MHH.1979	60.11	68.25	60	5.31	1.1727	1.1656	0.8640	0.8628	0.00	1.52	0.60
400	MHH.1980	72.61	71.33	73	3.48	1.1818	1.1498	0.8575	0.8703	1.91	1.82	8.45
401	MHH.1981	74.45	66.02	74	3.59	1.1718	1.2009	0.8578	0.8294	3.15	1.93	12.55
402	MHH.1982	64.98	62.27	65	4.01	1.2068	1.2281	0.8205	0.7714	0.00	1.72	11.00
403	MHH.1983	59.23	62.32	59	4.04	1.2227	1.2298	0.8104	0.8131	1.48	1.70	17.25
404	MHH.1984	63.30	64.45	63	3.72	1.2331	1.3269	0.8130	0.7540	0.00	1.77	14.22
405	MHH.1985	64.58	60.09	66	3.24	1.3115	1.3568	0.7568	0.7346	6.81	1.92	17.80
406	MHH.1986	60.00	63.92	62	8.67	1.3666	1.3782	0.7271	0.7217	0.00	1.90	19.55
407	HML.1976	39.50	42.46	40	11.21	1.0216	0.9862	1.0065	1.0012	5.36	1.05	2.89
408	HML.1977	44.50	38.73	45	8.50	0.9720	1.0746	1.0060	0.9281	0.00	0.89	7.50
409	HML.1978	40.00	51.36	40	11.37	1.1059	1.1388	0.8995	0.8766	0.00	1.06	5.88
410	HML.1979	60.05	65.08	60	7.29	1.1727	1.1683	0.8640	0.8563	0.00	1.52	1.78
411	HML.1980	71.50	69.60	72	5.00	1.1818	1.1615	0.8575	0.8609	1.91	1.82	9.38
412	HML.1981	73.70	65.11	74	5.72	1.1718	1.2214	0.8578	0.8298	3.15	1.93	10.35

413	HML.1982	63.65	64.15	64	6.02	1.2068	1.2392	0.8205	0.8081	0.00	1.72	10.97
414	HML.1983	57.92	58.68	58	6.04	1.2227	1.2319	0.8104	0.8110	1.48	1.70	13.88
415	HML.1984	61.65	61.93	62	6.01	1.2331	1.2990	0.8130	0.7679	0.00	1.77	20.82
416	HML.1985	62.52	55.62	64	2.70	1.3115	1.3545	0.7568	0.7374	6.81	1.92	12.05
417	HML.1986	58.85	59.10	60	7.80	1.3666	1.3901	0.7271	0.7183	0.00	1.90	17.69
418	HHH1.1976	41.25	49.04	41	4.02	1.0216	0.9853	1.0065	0.9962	0.00	1.05	4.12
419	HHH1.1977	43.87	44.33	44	3.55	0.9720	1.0497	1.0060	0.9465	0.00	0.89	6.80
420	HHH1.1978	39.67	52.60	40	5.35	1.1059	1.1480	0.8995	0.8724	0.00	1.06	7.33
421	HHH1.1979	59.95	78.55	60	3.26	1.1727	1.1443	0.8655	0.8761	0.00	1.52	2.40
422	HHH1.1980	73.52	62.83	74	2.03	1.1818	1.1835	0.8460	0.8482	11.91	1.82	9.45
423	HHH1.1981	74.82	70.18	75	2.36	1.1718	1.1907	0.8569	0.8354	2.97	1.93	8.00
424	HHH1.1982	65.23	68.68	65	2.25	1.2068	1.2240	0.8250	0.8176	0.00	1.72	11.38
425	HHH1.1983	60.43	67.05	60	2.21	1.2227	1.2350	0.8104	0.8113	0.00	1.70	16.88
426	HHH1.1984	64.50	66.85	65	2.45	1.2331	1.2813	0.8121	0.7395	0.00	1.77	13.47
427	HHH1.1985	66.63	63.60	66	2.44	1.3115	1.3517	0.7576	0.7181	2.42	1.92	12.92
428	HHH1.1986	61.72	55.55	62	10.32	1.3666	1.3905	0.7317	0.7192	5.61	1.90	14.91
429	HHH2.1976	41.25	43.55	41	4.70	1.0216	0.9798	1.0065	1.0012	0.00	1.05	2.79
430	HHH2.1977	43.87	43.65	44	4.14	0.9720	1.0478	1.0060	0.9508	0.00	0.89	8.40
431	HHH2.1978	39.67	56.88	40	6.25	1.1059	1.1244	0.8995	0.8974	0.00	1.06	7.50
432	HHH2.1979	59.95	73.62	60	3.81	1.1727	1.1525	0.8655	0.8611	0.00	1.52	0.53
433	HHH2.1980	73.52	67.36	74	2.37	1.1818	1.1886	0.8460	0.8468	11.91	1.82	13.07
434	HHH2.1981	74.82	67.62	75	2.75	1.1718	1.1988	0.8569	0.8324	2.97	1.93	9.10
435	HHH2.1982	65.23	71.68	65	2.62	1.2068	1.2403	0.8250	0.8063	0.00	1.72	7.45
436	HHH2.1983	60.43	66.26	60	2.58	1.2227	1.2259	0.8104	0.8145	0.00	1.70	15.72
437	HHH2.1984	64.50	65.86	65	2.86	1.2331	1.2971	0.8121	0.7715	0.00	1.77	18.07
438	HHH2.1985	66.63	62.61	66	2.44	1.3115	1.3789	0.7576	0.7254	2.42	1.92	13.55
439	HHH2.1986	61.72	58.65	62	10.32	1.3666	1.3778	0.7271	0.7239	5.61	1.90	20.58
440	HHH3.1976	39.50	43.87	40	7.75	1.0216	0.9679	1.0065	1.0280	0.00	1.05	2.79
441	HHH3.1977	44.05	42.23	44	5.39	0.9720	1.0613	1.0060	0.9380	0.00	0.89	5.47
442	HHH3.1978	39.95	47.80	40	7.95	1.1059	1.1248	0.8995	0.8885	0.00	1.06	9.25
443	HHH3.1979	60.11	67.75	60	4.97	1.1727	1.1701	0.8640	0.8574	0.00	1.52	0.40
444	HHH3.1980	72.61	68.75	73	3.26	1.1818	1.1501	0.8575	0.8658	11.91	1.82	9.40
445	HHH3.1981	74.45	67.35	74	3.35	1.1718	1.2024	0.8578	0.8207	2.97	1.93	10.47
446	HHH3.1982	64.98	64.35	65	3.75	1.2068	1.2906	0.8205	0.7722	0.00	1.72	22.35
447	HHH3.1983	59.23	63.43	59	3.78	1.2227	1.2305	0.8104	0.8138	0.00	1.70	14.67
448	HHH3.1984	63.30	63.80	63	3.48	1.2331	1.3159	0.8130	0.7616	0.00	1.77	17.77
449	HHH3.1985	64.58	57.93	66	3.24	1.3115	1.3638	0.7568	0.7303	2.42	1.92	15.38
450	HHH3.1986	60.00	57.55	62	8.67	1.3666	1.3938	0.7271	0.7140	5.61	1.90	20.58
451	CLLH.1976	39.50	43.20	40	11.06	1.0216	0.9872	1.0065	1.0010	5.36	1.05	2.89
452	CLLH.1977	44.50	38.73	45	8.39	0.9720	1.0765	1.0060	0.9281	0.00	0.89	7.50
453	CLLH.1978	40.00	51.85	40	11.22	1.1059	1.1371	0.8995	0.8722	0.00	1.06	5.88

454	CLLH.1979	60.05	64.68	60	7.19	1.1727	1.1725	0.8640	0.8559	0.00	1.52	1.78
455	CLLH.1980	71.50	68.71	72	4.93	1.1818	1.1589	0.8575	0.8579	1.91	1.82	9.38
456	CLLH.1981	73.70	65.60	74	5.65	1.1718	1.2363	0.8578	0.8238	3.15	1.93	10.35
457	CLLH.1982	63.65	65.27	64	5.94	1.2068	1.2447	0.8205	0.8048	0.00	1.72	10.97
458	CLLH.1983	57.92	58.68	58	5.96	1.2227	1.2353	0.8104	0.8110	1.48	1.70	13.88
459	CLLH.1984	61.65	62.35	62	5.93	1.2331	1.3038	0.8130	0.7668	0.00	1.77	20.82
460	CLLH.1985	62.52	56.22	64	2.70	1.3115	1.3543	0.7568	0.7372	6.81	1.92	12.05
461	CLLH.1986	58.85	59.42	60	7.80	1.3666	1.3853	0.7271	0.7165	0.00	1.90	17.69
462	CLMH.1976	39.50	41.87	40	10.21	1.0216	0.9876	1.0065	1.0066	5.36	1.05	2.89
463	CLMH.1977	44.50	37.89	45	7.74	0.9720	1.0745	1.0060	0.9313	0.00	0.89	8.10
464	CLMH.1978	40.00	50.45	40	10.35	1.1059	1.1377	0.8995	0.8969	0.00	1.06	9.50
465	CLMH.1979	60.05	56.52	60	6.63	1.1727	1.1739	0.8640	0.8521	0.00	1.52	4.90
466	CLMH.1980	71.50	69.58	72	4.55	1.1818	1.1583	0.8575	0.8642	1.91	1.82	10.00
467	CLMH.1981	73.70	63.90	74	5.21	1.1718	1.2372	0.8578	0.8014	3.15	1.93	12.50
468	CLMH.1982	63.65	64.35	64	5.48	1.2068	1.2559	0.8205	0.7954	0.00	1.72	14.35
469	CLMH.1983	57.92	61.32	58	5.50	1.2227	1.2355	0.8104	0.8103	1.48	1.70	10.00
470	CLMH.1984	61.65	62.65	62	5.47	1.2331	1.3096	0.8130	0.7634	0.00	1.77	20.25
471	CLMH.1985	62.52	57.12	64	2.70	1.3115	1.3608	0.7568	0.7333	6.81	1.92	12.92
472	CLMH.1986	58.85	63.22	60	7.80	1.3666	1.3811	0.7271	0.7223	0.00	1.90	17.69
473	CMMH.1976	39.50	42.62	40	10.63	1.0216	0.9872	1.0065	1.0101	5.36	1.05	4.67
474	CMMH.1977	44.50	38.48	45	8.05	0.9720	1.0765	1.0060	0.9265	0.00	0.89	7.75
475	CMMH.1978	40.00	49.50	40	10.78	1.1059	1.1371	0.8995	0.8799	0.00	1.06	6.50
476	CMMH.1979	60.05	61.95	60	6.90	1.1727	1.1725	0.8640	0.8529	0.00	1.52	4.90
477	CMMH.1980	71.50	69.88	72	4.73	1.1818	1.1589	0.8575	0.8625	1.91	1.82	9.95
478	CMMH.1981	73.70	64.88	74	5.42	1.1718	1.2363	0.8578	0.8080	3.15	1.93	12.13
479	CMMH.1982	63.65	65.13	64	5.71	1.2068	1.2447	0.8205	0.7969	0.00	1.72	12.88
480	CMMH.1983	57.92	60.55	58	5.73	1.2227	1.2353	0.8104	0.8090	1.48	1.70	11.47
481	CMMH.1984	61.65	63.75	62	5.69	1.2331	1.3038	0.8130	0.7632	0.00	1.77	20.25
482	CMMH.1985	62.52	56.57	64	2.70	1.3115	1.3543	0.7568	0.7369	6.81	1.92	12.92
483	CMMH.1986	58.85	59.42	60	7.80	1.3666	1.3853	0.7271	0.7190	0.00	1.90	17.47
484	CHML.1976	39.50	42.46	40	11.29	1.0216	0.9862	1.0065	1.0012	5.36	1.05	2.89
485	CHML.1977	44.50	38.39	45	8.56	0.9720	1.0746	1.0060	0.9293	0.00	0.89	7.50
486	CHML.1978	40.00	51.36	40	11.45	1.1059	1.1388	0.8995	0.8766	0.00	1.06	5.88
487	CHML.1979	60.05	64.77	60	7.33	1.1727	1.1683	0.8640	0.8563	0.00	1.52	1.78
488	CHML.1980	71.50	68.83	72	5.03	1.1818	1.1615	0.8575	0.8606	1.91	1.82	9.38
489	CHML.1981	73.70	65.11	74	5.76	1.1718	1.2214	0.8578	0.8298	3.15	1.93	10.35
490	CHML.1982	63.65	64.15	64	6.06	1.2068	1.2392	0.8205	0.8081	0.00	1.72	10.97
491	CHML.1983	57.92	57.62	58	6.08	1.2227	1.2319	0.8104	0.8123	1.48	1.70	13.88
492	CHML.1984	61.65	62.18	62	6.05	1.2331	1.2990	0.8130	0.7679	0.00	1.77	20.82
493	CHML.1985	62.52	55.25	64	2.70	1.3115	1.3545	0.7568	0.7376	6.81	1.92	12.05
494	CHML.1986	58.85	58.65	60	7.80	1.3666	1.3901	0.7271	0.7178	0.00	1.90	17.69

495	CHHH1.1976	39.50	40.57	40	8.46	1.0216	0.9688	1.0065	1.0260	5.36	1.05	3.66
496	CHHH1.1977	44.05	40.02	44	5.88	0.9720	1.0594	1.0060	0.9415	0.00	0.89	6.13
497	CHHH1.1978	39.95	52.91	40	8.67	1.1059	1.1231	0.8995	0.8907	0.00	1.06	4.75
498	CHHH1.1979	60.11	68.97	60	5.42	1.1727	1.1599	0.8640	0.8613	0.00	1.52	0.60
499	CHHH1.1980	72.61	71.43	73	3.55	1.1818	1.1435	0.8575	0.8706	1.91	1.82	8.45
500	CHHH1.1981	74.45	66.13	74	3.66	1.1718	1.5060	0.8578	0.8301	3.15	1.93	12.55
501	CHHH1.1982	64.98	63.85	65	4.09	1.2068	1.2685	0.8205	0.7827	0.00	1.72	11.00
502	CHHH1.1983	59.23	61.83	59	4.12	1.2227	1.2317	0.8104	0.8133	1.48	1.70	17.25
503	CHHH1.1984	63.30	65.38	63	3.80	1.2331	1.3347	0.8130	0.7530	0.00	1.77	14.22
504	CHHH1.1985	64.58	57.70	66	3.24	1.3115	1.3527	0.7568	0.7383	6.81	1.92	17.80
505	CHHH1.1986	60.00	56.42	62	8.67	1.3666	1.3776	0.7271	0.7235	0.00	1.90	20.51
506	CHHH2.1976	39.50	42.04	40	11.52	1.0216	0.9862	1.0065	1.0120	5.36	1.0	4.84
507	CHHH2.1977	44.50	39.05	45	8.73	0.9720	1.0746	1.0060	0.9295	0.00	0.89	7.50
508	CHHH2.1978	40.00	53.98	40	11.68	1.1059	1.1388	0.8995	0.8723	0.00	1.06	5.50
509	CHHH2.1979	60.05	66.97	60	7.48	1.1727	1.1683	0.8640	0.8578	0.00	1.52	4.25
510	CHHH2.1980	71.50	68.45	72	5.13	1.1818	1.1615	0.8575	0.8630	1.91	1.82	10.30
511	CHHH2.1981	73.70	64.98	74	5.88	1.1718	1.2214	0.8578	0.8215	3.15	1.93	12.50
512	CHHH2.1982	63.65	64.32	64	6.19	1.2068	1.2392	0.8205	0.8081	0.00	1.72	11.00
513	CHHH2.1983	57.92	57.77	58	6.21	1.2227	1.2319	0.8104	0.8133	1.48	1.70	14.85
514	CHHH2.1984	61.65	63.24	62	6.17	1.2331	1.2990	0.8130	0.7698	0.00	1.77	16.47
515	CHHH2.1985	62.52	56.29	64	2.70	1.3115	1.3545	0.7568	0.7372	6.81	1.92	10.75
516	CHHH2.1986	58.85	59.05	60	7.80	1.3666	1.3901	0.7271	0.7160	0.00	1.90	15.85
517	CHHH3.1976	41.30	41.68	41	13.24	1.0216	0.9730	1.0065	1.0195	3.62	1.05	4.56
518	CHHH3.1977	44.50	40.35	45	12.38	0.9720	1.1033	1.0060	0.9096	0.00	0.89	7.50
519	CHHH3.1978	40.40	55.43	40	15.17	1.1059	1.1835	0.8680	0.8427	0.00	1.06	1.50
520	CHHH3.1979	60.90	67.77	61	10.60	1.1727	1.1747	0.8500	0.8536	2.44	1.52	4.45
521	CHHH3.1980	72.00	71.65	72	6.52	1.1818	1.1650	0.8523	0.8612	0.00	1.82	8.15
522	CHHH3.1981	74.50	66.40	75	8.42	1.1718	1.1988	0.8575	0.8273	4.30	1.93	13.50
523	CHHH3.1982	64.00	62.75	64	8.12	1.2068	1.2276	0.8165	0.8099	1.31	1.72	9.22
524	CHHH3.1983	57.92	59.94	58	8.80	1.2227	1.2319	0.8104	0.8116	0.00	1.70	10.33
525	CHHH3.1984	61.65	64.82	62	8.75	1.2331	1.3286	0.8130	0.7523	0.00	1.77	10.50
526	CHHH3.1985	64.02	63.80	66	3.24	1.3115	1.3660	0.7568	0.7292	0.00	1.92	8.38
527	CHHH3.1986	60.20	62.77	62	10.35	1.3666	1.3893	0.7271	0.7166	0.00	1.90	11.78
528	USCHHH3.1976	41.30	41.68	41	13.24	1.0216	0.9730	1.0065	1.0195	0	0	0
529	USCHHH3.1977	44.50	40.35	45	12.38	0.9720	1.1033	1.0060	0.9096	0	0	0
530	USCHHH3.1978	40.40	55.43	40	15.17	1.1059	1.1835	0.8680	0.8427	0	0	0
531	USCHHH3.1979	60.90	67.77	61	10.60	1.1727	1.1747	0.8500	0.8536	0	0	0
532	USCHHH3.1980	72.00	71.65	72	6.52	1.1818	1.1650	0.8523	0.8612	0	0	0
533	USCHHH3.1981	74.50	66.40	75	8.42	1.1718	1.1988	0.8575	0.8273	0	0	0
534	USCHHH3.1982	64.00	62.75	64	8.12	1.2068	1.2276	0.8165	0.8099	0	0	0
535	USCHHH3.1983	57.92	59.94	58	8.80	1.2227	1.2319	0.8104	0.8116	0	0	0

```
USCHHH3.1984  61.65  64.82  62    8.75  1.2331  1.3286  0.8130  0.7523  0    0    0
USCHHH3.1985  64.02  63.80  66    3.24  1.3115  1.3660  0.7568  0.7292  0    0    0
USCHHH3.1986  60.20  62.77  62   10.35  1.3666  1.3893  0.7271  0.7166  0    0    0;

TABLE LPR(F,YR,GD)  ACTUAL LIVESTOCK CARCASS PRICES ($ PER 100 KG)
                    A1       A2       A3       A4
     LLH.1976   162.80   162.80   151.80   140.80
     LLH.1977   171.60   171.60   160.60   149.60
     LLH.1978   239.80   239.80   228.80   217.80
     LLH.1979   301.40   301.40   279.40   268.40
     LLH.1980   316.80   316.80   305.80   292.60
     LLH.1981   310.20   310.20   288.20   277.20
     LLH.1982   305.80   305.80   283.80   272.80
     LLH.1983   288.20   288.20   266.20   255.20
     LLH.1984   319.00   319.00   297.00   286.00
     LLH.1985   288.20   288.20   255.20   244.20
     LLH.1986   312.40   312.40   290.40   279.40
     LMH.1976   149.60   149.60   134.20   118.80
     LMH.1977   171.60   171.60   160.60   149.60
     LMH.1978   247.50   247.50   236.50   225.50
     LMH.1979   268.40   268.40   246.40   235.40
     LMH.1980   310.20   310.20   299.20   288.20
     LMH.1981   310.20   310.20   288.20   277.20
     LMH.1982   314.60   314.60   292.60   281.60
     LMH.1983   290.40   290.40   268.40   257.40
     LMH.1984   316.80   316.80   294.80   283.80
     LMH.1985   283.80   283.80   250.80   239.80
     LMH.1986   319.00   319.00   297.00   286.00
     LHH.1976   158.40   158.40   143.00   127.60
     LHH.1977   171.60   171.60   160.60   149.60
     LHH.1978   245.30   245.30   234.30   223.30
     LHH.1979   288.20   288.20   266.20   255.20
     LHH.1980   308.00   308.00   297.00   286.00
     LHH.1981   314.60   314.60   292.60   281.60
     LHH.1982   327.80   327.80   305.80   294.80
     LHH.1983   292.60   292.60   270.60   259.60
     LHH.1984   323.40   323.40   301.40   290.40
     LHH.1985   297.00   297.00   264.00   253.00
     LHH.1986   314.60   314.60   292.60   281.60
     MMM.1976   162.80   162.80   151.80   140.80
     MMM.1977   171.60   171.60   160.60   149.60
```

577	MMM.1978	239.80	239.80	228.80	217.80
578	MMM.1979	301.40	301.40	279.40	268.40
579	MMM.1980	316.80	316.80	305.80	292.60
580	MMM.1981	310.20	310.20	288.20	277.20
581	MMM.1982	305.80	305.80	283.80	272.80
582	MMM.1983	288.20	288.20	266.20	255.20
583	MMM.1984	319.00	319.00	297.00	286.00
584	MMM.1985	288.20	288.20	255.20	244.20
585	MMM.1986	312.40	312.40	290.40	279.40
586	MMH.1976	158.40	158.40	143.00	127.60
587	MMH.1977	171.60	171.60	160.60	149.60
588	MMH.1978	245.30	245.30	234.30	223.30
589	MMH.1979	288.20	288.20	266.20	255.20
590	MMH.1980	308.00	308.00	297.00	286.00
591	MMH.1981	314.60	314.60	292.60	281.60
592	MMH.1982	327.80	327.80	305.80	294.80
593	MMH.1983	292.60	292.60	270.60	259.60
594	MMH.1984	323.40	323.40	301.40	290.40
595	MMH.1985	297.00	297.00	264.00	253.00
596	MMH.1986	314.60	314.60	292.60	281.60
597	MHH.1976	158.40	158.40	143.00	127.60
598	MHH.1977	167.20	167.20	156.20	145.20
599	MHH.1978	246.40	246.40	235.40	224.40
600	MHH.1979	290.40	290.40	272.80	257.40
601	MHH.1980	290.40	290.40	272.80	261.80
602	MHH.1981	321.20	321.20	299.20	288.20
603	MHH.1982	323.40	323.40	301.40	290.40
604	MHH.1983	305.80	305.80	283.80	272.80
605	MHH.1984	316.80	316.80	294.80	283.80
606	MHH.1985	305.80	305.80	272.80	261.80
607	MHH.1986	308.00	308.00	286.00	286.00
608	HML.1976	160.60	160.60	149.60	138.60
609	HML.1977	171.60	171.60	160.60	149.60
610	HML.1978	248.60	248.60	237.60	226.60
611	HML.1979	277.20	277.20	255.20	244.20
612	HML.1980	310.20	310.20	299.20	288.20
613	HML.1981	310.20	310.20	288.20	277.20
614	HML.1982	303.60	270.60	259.60	299.20
615	HML.1983	292.60	292.60	270.60	259.60
616	HML.1984	323.40	323.40	301.40	290.40
617	HML.1985	290.40	290.40	257.40	246.40

618	HML.1986	319.00	319.00	297.00	286.00
619	HHH1.1976	180.40	180.40	169.40	158.40
620	HHH1.1977	158.40	158.40	147.40	136.40
621	HHH1.1978	233.20	233.20	222.20	211.20
622	HHH1.1979	294.80	294.80	283.80	266.20
623	HHH1.1980	286.00	286.00	253.00	242.00
624	HHH1.1981	312.40	312.40	290.40	279.40
625	HHH1.1982	327.80	327.80	305.80	294.80
626	HHH1.1983	338.80	338.80	316.80	305.80
627	HHH1.1984	330.00	330.00	308.00	297.00
628	HHH1.1985	323.40	323.40	290.40	279.40
629	HHH1.1986	301.40	301.40	268.40	257.40
630	HHH2.1976	173.80	173.80	162.80	151.80
631	HHH2.1977	165.00	165.00	154.00	143.00
632	HHH2.1978	246.40	246.40	235.40	224.40
633	HHH2.1979	299.20	299.20	277.20	266.20
634	HHH2.1980	294.80	294.80	272.80	261.80
635	HHH2.1981	319.00	319.00	297.00	286.00
636	HHH2.1982	348.15	348.15	337.15	326.15
637	HHH2.1983	325.60	325.60	303.60	292.60
638	HHH2.1984	334.40	334.40	312.40	301.40
639	HHH2.1985	323.40	323.40	290.40	279.40
640	HHH2.1986	294.80	294.80	272.80	261.80
641	HHH3.1976	162.80	162.80	147.40	132.00
642	HHH3.1977	163.90	163.90	152.90	141.90
643	HHH3.1978	246.40	246.40	235.40	224.40
644	HHH3.1979	294.80	294.80	272.80	261.80
645	HHH3.1980	290.40	290.40	272.80	261.80
646	HHH3.1981	321.20	321.20	310.20	299.20
647	HHH3.1982	338.80	338.80	325.60	316.80
648	HHH3.1983	312.40	312.40	290.40	279.40
649	HHH3.1984	316.80	316.80	294.80	283.80
650	HHH3.1985	308.00	308.00	297.00	275.00
651	HHH3.1986	288.20	288.20	266.20	255.20
652	CLLH.1976	160.60	160.60	149.60	138.60
653	CLLH.1977	171.60	171.60	160.60	149.60
654	CLLH.1978	248.60	248.60	237.60	226.60
655	CLLH.1979	277.20	277.20	255.20	244.20
656	CLLH.1980	310.20	310.20	299.20	288.20
657	CLLH.1981	310.20	310.20	288.20	277.20
658	CLLH.1982	303.60	270.60	259.60	299.20

659	CLLH.1983	292.60	292.60	270.60	259.60
660	CLLH.1984	323.40	323.40	301.40	290.40
661	CLLH.1985	290.40	290.40	257.40	246.40
662	CLLH.1986	319.00	319.00	297.00	286.00
663	CLMH.1976	149.60	149.60	134.20	118.80
664	CLMH.1977	171.60	171.60	160.60	149.60
665	CLMH.1978	247.50	247.50	236.50	225.50
666	CLMH.1979	268.40	268.40	246.40	235.40
667	CLMH.1980	310.20	310.20	299.20	288.20
668	CLMH.1981	310.20	310.20	288.20	277.20
669	CLMH.1982	314.60	314.60	292.60	281.60
670	CLMH.1983	290.40	290.40	268.40	257.40
671	CLMH.1984	316.80	316.80	294.80	283.80
672	CLMH.1985	283.80	283.80	250.80	239.80
673	CLMH.1986	319.00	319.00	297.00	286.00
674	CMMM.1976	158.40	158.40	147.40	136.40
675	CMMM.1977	171.60	171.60	160.60	149.60
676	CMMM.1978	247.50	247.50	236.50	225.50
677	CMMM.1979	272.80	272.80	250.80	239.80
678	CMMM.1980	310.20	310.20	299.20	288.20
679	CMMM.1981	310.20	310.20	288.20	277.20
680	CMMM.1982	310.20	310.20	288.20	277.20
681	CMMM.1983	292.60	292.60	270.60	259.60
682	CMMM.1984	327.80	327.80	305.80	272.80
683	CMMM.1985	275.00	275.00	242.00	231.00
684	CMMM.1986	319.00	319.00	297.00	286.00
685	CHML.1976	160.60	160.60	149.60	138.60
686	CHML.1977	171.60	171.60	160.60	149.60
687	CHML.1978	248.60	248.60	237.60	226.60
688	CHML.1979	277.20	277.20	255.20	244.20
689	CHML.1980	310.20	310.20	299.20	288.20
690	CHML.1981	310.20	310.20	288.20	277.20
691	CHML.1982	303.60	270.60	259.60	299.20
692	CHML.1983	292.60	292.60	270.60	259.60
693	CHML.1984	323.40	323.40	301.40	290.40
694	CHML.1985	290.40	290.40	257.40	246.40
695	CHML.1986	319.00	319.00	297.00	264.00
696	CHHH1.1976	158.40	158.40	143.00	127.60
697	CHHH1.1977	167.20	167.20	156.20	145.20
698	CHHH1.1978	248.60	248.60	237.60	226.60
699	CHHH1.1979	290.40	290.40	272.80	257.40

CHHH1.1980	301.40	301.40	290.40	279.40
CHHH1.1981	316.80	316.80	297.00	286.00
CHHH1.1982	323.40	323.40	301.40	290.40
CHHH1.1983	305.80	305.80	283.80	272.80
CHHH1.1984	323.40	323.40	301.40	290.40
CHHH1.1985	301.40	301.40	268.40	257.40
CHHH1.1986	308.00	308.00	286.00	275.00
CHHH2.1976	160.60	160.60	149.60	138.60
CHHH2.1977	171.60	171.60	160.60	149.60
CHHH2.1978	248.60	248.60	237.60	226.60
CHHH2.1979	277.20	277.20	255.20	244.20
CHHH2.1980	310.20	310.20	299.20	288.20
CHHH2.1981	310.20	310.20	288.20	277.20
CHHH2.1982	303.60	270.60	259.60	299.20
CHHH2.1983	292.60	292.60	270.60	259.60
CHHH2.1984	323.40	323.40	301.40	290.40
CHHH2.1985	290.40	290.40	257.40	246.40
CHHH2.1986	312.40	312.40	290.40	279.40
CHHH3.1976	160.60	160.60	149.60	138.60
CHHH3.1977	182.60	182.60	171.60	160.60
CHHH3.1978	242.00	242.00	231.00	220.00
CHHH3.1979	286.00	286.00	257.40	246.40
CHHH3.1980	314.60	314.60	292.60	281.60
CHHH3.1981	303.60	303.60	270.60	259.60
CHHH3.1982	290.40	290.40	268.40	257.40
CHHH3.1983	294.80	294.80	272.80	261.80
CHHH3.1984	308.00	308.00	286.00	264.00
CHHH3.1985	308.00	308.00	281.60	270.60
CHHH3.1986	334.40	334.40	312.40	301.40
USCHHH3.1976	124.92			
USCHHH3.1977	167.00			
USCHHH3.1978	222.79			
USCHHH3.1979	262.92			
USCHHH3.1980	278.70			
USCHHH3.1981	266.23			
USCHHH3.1982	259.34			
USCHHH3.1983	254.35			
USCHHH3.1984	279.80			
USCHHH3.1985	284.69			
USCHHH3.1986	291.67			

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```
LPR('CHHH2',YR,GD) = LPR('CHHH2',YR,GD) - DST(YR);
LPR('CHHH3',YR,GD) = LPR('CHHH2',YR,GD) - DST(YR);
LPR('USCHHH3',YR,'A1') = LPR('USCHHH3',YR,'A1') - (TRANS(YR)/LK('USCHHH3','DRS'))
  -(DG(YR)*2.2*MARK('USCHHH3',YR,'E0')*(LK('CHHH3','A1')+LK('CHHH3','A4')))
  -(D4(YR)*2.2*MARK('USCHHH3',YR,'E0')*.05)
  -DUT(YR);

DISPLAY LPR;

TABLE DAY(F,Z) DAYS ON FEED BY FEEDING REGIME AND STAGE

           1       2       3
LLH        84      84      132
LMH        84      84      109
LHH        84      84      90
MMM        84      84      128
MMH        84      84      88
MHH        84      84      77
HML        84      84      122
HHH1       84      83      0
HHH2       84      84      22
HHH3       84      84      67
CLLH       84      84      120
CLMH       84      84      108
CMMM       84      84      114
CHML       84      84      123
CHHH1      84      84      80
CHHH2      84      84      126
CHHH3      84      84      178
USCHHH3    84      84      178 ;

TABLE DEM(F,Z) MINIMUM DE CONCENTRATION (MCAL PER KG OF DIET PER STAGE)

           1       2       3
LLH        2.31    2.31    3.41
LMH        2.31    2.86    3.41
LHH        2.31    3.41    3.41
MMM        2.86    2.86    2.86
MMH        2.86    2.86    3.41
MHH        2.86    3.41    3.41
HML        3.41    2.86    2.31
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HHH1      3.41     3.41     3.41
HHH2      3.41     3.41     3.41
HHH3      3.41     3.41     3.41
CLLH      2.31     2.31     3.41
CLMH      2.31     2.86     3.41
CMMM      2.86     2.86     2.86
CHML      3.41     2.86     2.31
CHHH1     3.41     3.41     3.41
CHHH2     3.41     3.41     3.41
CHHH3     3.41     3.41     3.41
USCHHH3   3.41     3.41     3.41;

PARAMETER DME(J) MCAL OF ENERGY PER KG DM OF FEEDSTUFF;
          DME(J) = A(J,'DE')/ A(J,'DMM');
PARAMETER MC(J) CONCENTRATE TEST PARAMETER
          NM(J) TEST PARAMETER
          KM(J) TEST PARAMETER
          FM(J) FORAGE TEST PARAMETER;

          MC(J) = MAX(0,(DME(J)-3.0));
          NM(J) = MC(J);
          KM(J) = 10;
          NM(J) = 5 $ MC(J);
          KM(J) $ NM(J) = NM(J);
          FM(J) = MAX(0,(KM(J) - 5.0));

PARAMETER AWT(F,Z)  AVERAGE WEIGHT BY STAGE BY FEEDING REGIME;
          AWT(F,'1') = LK(F,'BEG') + (DAY(F,'1') * GN(F,'1')* 0.5);
          AWT(F,'2') = (LK(F,'BEG') + (DAY(F,'1') * GN(F,'1'))) +
                       (DAY(F,'2') * GN(F,'2') * 0.5);
          AWT(F,'3') = LK(F,'END') - (DAY(F,'3') * GN(F,'3') * 0.5);

PARAMETER DEE(F,Z)  DIGESTIBLE ENERGY RQT BY FEEDING REGIME (MCAL PER KG);
          DEE(F,Z) = (105* (AWT(F,Z)**.75)*((3.684-.003231*AWT(F,Z))**GN(F,Z)))
                     * .001 * DAY(F,Z);

          DEE('CLLH','1') = 1126;
          DEE('CLLH','2') = 1533;
          DEE('CLLH','3') = 4141;
          DEE('CLMH','1') = 1153;
          DEE('CLMH','2') = 1801;
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            DEE('CLMH','3') = 3817;
            DEE('CMMM','1') = 1275;
            DEE('CMMM','2') = 1851;
            DEE('CMMM','3') = 3318;
            DEE('CHML','1') = 1463;
            DEE('CHML','2') = 1905;
            DEE('CHML','3') = 3103;
            DEE('CHHH1','1') = 1596;
            DEE('CHHH1','2') = 2352;
            DEE('CHHH1','3') = 2499;
            DEE('CHHH2','1') = 1581;
            DEE('CHHH2','2') = 2493;
            DEE('CHHH2','3') = 3785;
            DEE('CHHH3','1') = 1619;
            DEE('CHHH3','2') = 2393;
            DEE('CHHH3','3') = 5286;
            DEE('USCHHH3','1') = 1619;
            DEE('USCHHH3','2') = 2393;
            DEE('USCHHH3','3') = 5286;

PARAMETER CPP(F,Z)  CRUDE PROTEIN REQT (KG) PER STAGE PER FEEDING REGIME;
            CPP(F,Z) = (326.9 + (.915 * AWT(F,Z)) + (124.4 * GN(F,Z)))
                         * DAY(F,Z) * .001;

PARAMETER   DT(F,YR)  APPROXIMATE VALUE OF CATTLE TO BE SOLD BY YEAR;
              DT(F,YR) = NUMBER * LK(F,'END') * LK(F,'DRS') *
                      (LPR(F,YR,'A1')/100);

PARAMETER VAR(F,YR) HISTORICAL INTEREST,YARDAGE AND MARKETING CHARGES BY FEEDING REGIME
                                                                              BY YEAR;
            VAR(F,YR) = (((LK(F,'BEG') * .01 * FDR(YR)) +
                    (((SUM(Z,DEE(F,Z))/A('BLY','DE')) * BARPR(YR) * .01 )/2))
                    * INTR(YR) * (SUM(Z,DAY(F,Z))/365))
                    + SUM(Z,DAY(F,Z) * L('YARD','OBA'))
                    + L('BUY','OBA') + L('SELL','OBA')
                    + ((LK(F,'BEG') * .01 * FDR(YR))*
                      (L('DEATH','OBA') + L('VET','OBA')));

DISPLAY VAR;
PARAMETER FVAR(F) FORECAST INTEREST,YARDAGE AND MARKETING CHARGES BY FEEDING REGIME;
            FVAR(F) = (((LK(F,'BEG') * .01 * L('FEDR','OBA')) +
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                    (((SUM(Z,DEE(F,Z))/A('BLY','DE')) * P('BLY','OBA') * .01 )/2))
                    * L('INT','OBA') * (SUM(Z,DAY(F,Z))/365))
                    + SUM(Z,DAY(F,Z) * L('YARD','OBA'))
                    + L('BUY','OBA') + L('SELL','OBA')
                    + ((LK(F,'BEG') * .01 * L('FEDR','OBA'))*
                      (L('DEATH','OBA') + L('VET','OBA')));

PARAMETER GR(F,YR)  GROSS REVENUE BY FEEDING REGIME BY YEAR;
          GR(F,YR) = SUM(GD, LK(F,'DRS') * LK(F,'END') * LK(F,GD)
                     * LPR(F,YR,GD) * .01)-(MARK(F,YR,'DIFF')
                     * 2.2 * LK(F,'DRS') * LK(F,'END') * .01);

PARAMETER FDRCST(F)  FEEDER COST BY FEED REGIME FOR UPCOMING YEAR;
          FDRCST(F) = (LK(F,'BEG') * .01 * L('FEDR','OBA'));

PARAMETER  AFEED(F,YR) APPROXIMATED FEED COST BY FEEDING REGIME BY YEAR;
           AFEED(F,YR) = ((SUM(Z,DEE(F,Z))/A('BLY','DE')) * BARPR(YR) * .01 );

PARAMETER  FFEED(F) FORECASTED APPROX FEED COST BY FEEDING REGIME FOR CURRENT YEAR;
           FFEED(F) = ((SUM(Z,DEE(F,Z))/A('BLY','DE')) * P('BLY','OBA') * .01 );

PARAMETER NR(F,MK,YR) NET REVENUE BY FEEDING AND MARKETING ALTERNATIVES;
          NR(F,'CASH',YR) = (((GR(F,YR) - VAR(F,YR) - AFEED(F,YR) - (FDR(YR)*
                            .01 * LK(F,'BEG')))*100)/CPI(YR)) * NUMBER;
          NR(F,'SHEDG',YR) = NR(F,'CASH',YR) +
                             ((((MARK(F,YR,'RI') * 2.2)/CPI(YR) * MARK(F,YR,'EI'))-
                               ((MARK(F,YR,'RO') * 2.2)/CPI(YR) * MARK(F,YR,'EO')))*
                               (18182 * CT));
          NR(F,'CHEDG',YR) = NR(F,'SHEDG',YR) +
                             (((MARK(F,YR,'TEI') - MARK(F,YR,'TEO')) * DT(F,YR))*100)
                                                                          /CPI(YR);
          NR(F,'TSP',YR) = NR(F,'CASH',YR) +
                           ((((MARK(F,YR,'PAY') - (MARK(F,YR,'LEV')/3)) *
                           (LK(F,'END')/100) * 2.2)*100)/CPI(YR));

          NR('USCHHH3','TSP',YR) = -500;

DISPLAY NR;

TABLE BETA(F,MK) SIMPLE EXPONENTIAL SMOOTHING CONSTANTS
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                 CASH       SHEDG      CHEDG      TSP

       LLH       0.31       0.49       0.44       0.46
       LMH       0.01       0.62       0.55       0.32
       LHH       0.01       0.29       0.30       0.37
       MMM       0.34       0.43       0.39       0.36
       MMH       0.01       0.54       0.43       0.38
       MHH       0.01       0.01       0.34       0.36
       HML       0.36       0.83       0.68       0.50
       HHH1      0.45       0.96       0.93       0.50
       HHH2      0.29       0.99       0.99       0.32
       HHH3      0.01       0.32       0.01       0.05
       CLLH      0.39       0.99       0.87       0.53
       CLMH      0.23       0.53       0.43       0.45
       CMMM      0.29       0.99       0.55       0.47
       CHML      0.39       0.94       0.79       0.53
       CHHH1     0.25       0.36       0.29       0.40
       CHHH2     0.31       0.99       0.95       0.47
       CHHH3     0.01       0.50       0.49       0.25
     USCHHH3     0.99       0.17       0.21       0;

  SCALAR LOSS  PROFIT LOSS ADJUSTER /500.0/;



  PARAMETER FNR(F,MK,YR) NET REVENUE BY FEEDING AND MARKETING ALTERNATIVES;
            FNR(F,MK,'1976')=NR(F,MK,'1976');
         FNR(F,MK,'1977')=(BETA(F,MK)*NR(F,MK,'1976'))+((1-BETA(F,MK))*FNR(F,MK,'1976'));

         FNR(F,MK,'1978')=(BETA(F,MK)*NR(F,MK,'1977'))+((1-BETA(F,MK))*FNR(F,MK,'1977'));

         FNR(F,MK,'1979')=(BETA(F,MK)*NR(F,MK,'1978'))+((1-BETA(F,MK))*FNR(F,MK,'1978'));

         FNR(F,MK,'1980')=(BETA(F,MK)*NR(F,MK,'1979'))+((1-BETA(F,MK))*FNR(F,MK,'1979'));

         FNR(F,MK,'1981')=(BETA(F,MK)*NR(F,MK,'1980'))+((1-BETA(F,MK))*FNR(F,MK,'1980'));

         FNR(F,MK,'1982')=(BETA(F,MK)*NR(F,MK,'1981'))+((1-BETA(F,MK))*FNR(F,MK,'1981'));

         FNR(F,MK,'1983')=(BETA(F,MK)*NR(F,MK,'1982'))+((1-BETA(F,MK))*FNR(F,MK,'1982'));
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        FNR(F,MK,'1984')=(BETA(F,MK)*NR(F,MK,'1983'))+((1-BETA(F,MK))*FNR(F,MK,'1983'));

        FNR(F,MK,'1985')=(BETA(F,MK)*NR(F,MK,'1984'))+((1-BETA(F,MK))*FNR(F,MK,'1984'));

        FNR(F,MK,'1986')=(BETA(F,MK)*NR(F,MK,'1985'))+((1-BETA(F,MK))*FNR(F,MK,'1985'));
DISPLAY FNR;

PARAMETERS  MVAR(F)  AVERAGE HISTORICAL INTEREST CHARGES (1981 CONSTANT DOLLARS)
            MAFEED(F) AVERAGE APPROX FEED COST (1981 CONSTANT DOLLARS)
            MFDR(F) MEAN FEEDER COST (1981 CONSTANT DOLLARS)
            NRAVG(F,MK) REALIZED AVERAGE NET REVENUE (1981 CONSTANT DOLLARS)
            NRDEV(F,MK,YR) REALIZED NET REVENUE DEVIATIONS
            NRVC(F,MK,FC,MKC) REALIZED VARIANCE-COVARIANCE MATRIX
            VRC(F,MK) REALIZED VARIANCE MATRIX
            STDEV(F,MK) REALIZED STANDARD DEVIATION MATRIX (1981 CONSTANT DOLLARS)
            ERR(F,MK,YR)  FORECAST ERROR PER YEAR
            ERVC(F,MK,FC,MKC) ONE STEP AHEAD FORECAST VARIANCE-COVARIANCE
            EVRC(F,MK) ONE STEP AHEAD VARIANCE
            ESTDEV(F,MK) ONE STEP AHEAD STANDARD DEVIATION
            ERRAVG(F,MK)  AVERAGE FORECAST ERROR
            ERRDEV(F,MK,YR) FORECAST ERROR DEVIATIONS
            ERRVC(F,MK,FC,MKC) FORECAST ERROR VARIANCE-COVARIANCE
            ERRVRC(F,MK) FORECAST ERROR VARIANCE MATRIX
            ERRSTDEV(F,MK) ERROR STANDARD DEVIATION MATRIX (1981 CONSTANT DOLLARS)
            FNRAVG(F,MK) FORECAST AVERAGE NET REVENUE
            FNRDEV(F,MK,YR) FORECAST NET REVENUE DEVIATIONS
            FNRVC(F,MK,FC,MKC) FORECAST VARIANCE-COVARIANCE MATRIX
            FVRC(F,MK) FORECAST VARIANCE MATRIX
            FSTDEV(F,MK) FORECASTSTANDARD DEVIATION MATRIX (1981 CONSTANT DOLLARS)
            NDEVTG(F,MK,YR) NEGATIVE DEVIATIONS FROM TARGET INCOME
            AVND(F,MK) AVERAGE NEGATIVE DEVIATIONS FROM TARGET INCOME

            NRVC(F,MK,FC,MKC) REALIZED VARIANCE-COVARIANCE MATRIX;

            MVAR(F) = SUM(YR, ((VAR(F,YR)*100)/CPI(YR)))/CARD(YR);
            MAFEED(F) = SUM(YR, ((AFEED(F,YR)*100)/CPI(YR)))/CARD(YR);
            MFDR(F) = SUM(YR, ((LK(F,'BEG')*.01*FDR(YR)*100)/CPI(YR)))/CARD(YR);
            NRAVG(F,MK) = SUM(YR,NR(F,MK,YR))/CARD(YR);
            NRDEV(F,MK,YR) = NR(F,MK,YR) - NRAVG(F,MK);
            NRVC(F,MK,FC,MKC) = SUM(YR,NRDEV(F,MK,YR) * NRDEV(FC,MKC,YR))/(CARD(YR)-1);
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           VRC(F,MK) = SUM(YR,NRDEV(F,MK,YR) * NRDEV(F,MK,YR))/(CARD(YR)-1);
           STDEV(F,MK) = SQRT(VRC(F,MK));
           ERR(F,MK,YR) = NR(F,MK,YR) - FNR(F,MK,YR);
           ERVC(F,MK,FC,MKC) = SUM(YR,ERR(F,MK,YR) * ERR(FC,MKC,YR))/(CARD(YR)-1);
           EVRC(F,MK) = SUM(YR,ERR(F,MK,YR) * ERR(F,MK,YR))/(CARD(YR)-1);
           ESTDEV(F,MK) = SQRT(EVRC(F,MK));
           ERRAVG(F,MK) = SUM(YR,ERR(F,MK,YR))/CARD(YR);
           ERRDEV(F,MK,YR) = ERR(F,MK,YR) - ERRAVG(F,MK);
           ERRVC(F,MK,FC,MKC) = SUM(YR,ERRDEV(F,MK,YR) * ERRDEV(FC,MKC,YR))/(CARD(YR)-1);

           ERRVRC(F,MK) = SUM(YR,ERRDEV(F,MK,YR) * ERRDEV(F,MK,YR))/(CARD(YR)-1);
           ERRSTDEV(F,MK) = SQRT(ERRVRC(F,MK));
           FNRAVG(F,MK) = SUM(YR,FNR(F,MK,YR))/CARD(YR);
           FNRDEV(F,MK,YR) = FNR(F,MK,YR) - FNRAVG(F,MK);
           FNRVC(F,MK,FC,MKC) = SUM(YR,FNRDEV(F,MK,YR) * FNRDEV(FC,MKC,YR))/(CARD(YR)-1);

           FVRC(F,MK) = SUM(YR,FNRDEV(F,MK,YR) * FNRDEV(F,MK,YR))/(CARD(YR)-1);
           FSTDEV(F,MK) = SQRT(FVRC(F,MK));
           NDEVTG(F,MK,YR) = -MIN(NR(F,MK,YR)-TARG,0);
           AVND(F,MK) = SUM(YR, NDEVTG(F,MK,YR)/CARD(YR));
           AVND('USCHHH3','TSP')=0;


DISPLAY NRAVG, STDEV, FNRAVG, FSTDEV, ERRAVG, ERRSTDEV, ESTDEV, AVND,MVAR,MAFEED,MFDR;
PARAMETER FFNR(F,MK) CURRENT YEAR FORECASTED NET REVENUE BY FEEDING AND MARKETING
                                                                          REGIMES;
          FFNR(F,MK)=(BETA(F,MK)*FNR(F,MK,'1986'))+((1-BETA(F,MK))*NR(F,MK,'1986'));
DISPLAY FFNR;


VARIABLES
 FEED(J,Z)    FEEDSTUFFS (KG PER HD PER STAGE)
 VTMA(Z)      VITAMIN A (GRAMS PER STAGE)
 OBJ          MAXIMUM PROFIT OBJECTIVE FUNCTION
 DIET(F,MK)      FEEDING AND MARKETING REGIMES (# OF .01 HD PER STAGE)
 FDRR         KG OF FEEDER STEER PURCHASED
 MIX(Z)       100 KG FEED MIXED BY STAGE
 FEEDCST(Z)   FEEDCOST PER STAGE
 PDEV(YR)     POSITIVE NET REVENUE DEVIATIONS (DOLLARS)
 NNDEV(YR)    PRECISE NET REVENUE DEVIATIONS (DOLLARS)
 NDEV(YR)     NEGATIVE NET REVENUE DEVIATIONS (DOLLARS);
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POSITIVE VARIABLES FEED, VTMA, DIET, FDRR, MIX, FEEDCST, PDEV, NDEV, NNDEV;

EQUATIONS

 OJ1            NET REVENUE USING OBA PRICE SERIES (QP)
 OJ2            NET REVENUE USING OBA PRICE SERIES AND FORECAST (QP)
 OJ3            NET REVENUE USING OBA PRICE SERIES (MOTAD)
 OJ4            NET REVENUE USING OBA PRICE SERIES AND FORECAST (MOTAD)
 OJ5            NET REVENUE USING OBA PRICE SERIES AND FORECAST (TMOTAD)
 ENRGYBAL(Z)    DIGESTIBLE ENERGY BALANCE BY STAGE (MCAL)
 DMWTMAX(Z)     MAXIMUM DRY MATTER WT (KG DM) OF DIET TO SATISFY ENERGY
 CPBAL(Z)       CRUDE PROTEIN BALANCE (KG CP) BY STAGE
 CABAL(Z)       CALCIUM BALANCE (G CA) BY STAGE
 PBAL(Z)        PHOSPHORUS BALANCE (G P) BY STAGE
 CAPBAL(Z)      MINIMUM CALCIUM PHOSPHORUS RATIO BALANCE (G) BY STAGE
 CAPXBAL(Z)     MAXIMUM CALCIUM PHOSPHORUS RATIO BALANCE (G) BY STAGE
 UREABAL(Z)     MAXIMUM UREA CONCENTRATION BALANCE EQUATION (KG) BY STAGE
 BTPBAL(Z)      MAXIMUM BEET PULP CONCENTRATION BALANCE EQUATION (KG) BY STAGE
 SALTBAL(Z)     MAXIMUM SALT CONCENTRATION BALANCE EQUATION (KG) BY STAGE
 RAPEBAL(Z)     MAXIMUM RAPESEED MEAL CONCENTRATION BALANCE (KG) BY STAGE
 LIMBAL(Z)      MAXIMUM LIMESTONE CONCENTRATION BALANCE (KG) BY STAGE
 MOLSBAL(Z)     MAXIMUM MOLASSES CONCENTRATION BALANCE (KG) BY STAGE
 VITABAL(Z)     VITAMIN A BALANCE (CG) BY STAGE
 MIXBAL(Z)      FEED BATCH (KG DM) MIXING BALANCE BY STAGE
 FDRBAL         FEEDER WEIGHT (KG) PURCHASE BALANCE
 CAPACITY       CAPACITY BALANCE OR NUMBER OF .01 HEAD FED
 FEEDCOST(Z)    ACCOUNTING EQUATION OF FEEDCOST PER STAGE
 DDEV(YR)       DEFINITION OF NET REVENUE DEVIATIONS (DOLLARS)
 NEGDEV(YR)     TARGET MOTAD NEG NET REV DEV BELOW TARGET
 NNEGDEV(YR)    PRECISE TARGET MOTAD NEG NET REV DEV BELOW TARGET
 TDEV           TARGET DEVIATION CONSTRAINT;

 OJ1..                  -(SUM((J,Z), P(J.'OBA')* .01 * FEED(J,Z))) -
                        (SUM(Z, VTMA(Z) * P('VTA','OBA') * .01)) -
                        (L('FEDR','OBA')*(FDRR/100)) -
                        (SUM(Z, (MIX(Z)/10) * MNMX('MIXF',Z))) +
                        SUM((F,MK), ((((NRAVG(F,MK)+MAFEED(F)+MFDR(F))
                        *FCPI)/100)+LOSS)
                        * (DIET(F,MK)/100)) -(PHI * S *
                        SUM((F,MK,FC,MKC),(DIET(F,MK)/100)*NRVC(F,MK,FC,MKC)*
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                              (DIET(FC,MKC)/100))) =E= OBJ;
      OJ2..                  -(SUM((J,Z), P(J,'OBA')* .01 * FEED(J,Z))) -
                              (SUM(Z, VTMA(Z) * P('VTA','OBA') * .01)) -
                              (L('FEDR','OBA')*(FDRR/100)) -
                              (SUM(Z, (MIX(Z)/10) * MNMX('MIXF',Z))) +
                              SUM((F,MK), (FFNR(F,MK)+FFEED(F) + FDRCST(F) + LOSS)
                              * (DIET(F,MK)/100)) -(PHI * S *
                              SUM((F,MK,FC,MKC),(DIET(F,MK)/100)*NRVC(F,MK,FC,MKC)*
                              (DIET(FC,MKC)/100))) =E= OBJ;


      OJ3..                  -(SUM((J,Z), P(J,'OBA')* .01 * FEED(J,Z))) -
                              (SUM(Z, VTMA(Z) * P('VTA','OBA') * .01)) -
                              (L('FEDR','OBA')*(FDRR/100)) -
                              (SUM(Z, (MIX(Z)/10) * MNMX('MIXF',Z))) +
                              SUM((F,MK), ((((NRAVG(F,MK)+NAFEED(F)+NFDR(F))
                              *FCPI)/100)+LOSS) * (DIET(F,MK)/100))
                              -(PHI*KL*SUM(YR,PDEV(YR)+NDEV(YR))/CARD(YR))=E= OBJ;

      OJ4..                  -(SUM((J,Z), P(J,'OBA')* .01 * FEED(J,Z))) -
                              (SUM(Z, VTMA(Z) * P('VTA','OBA') * .01)) -
                              (L('FEDR','OBA')*(FDRR/100)) -
                              (SUM(Z, (MIX(Z)/10) * MNMX('MIXF',Z))) +
                              SUM((F,MK), ((FFNR(F,MK)*FCPI*.01)+FFEED(F) + FDRCST(F) + LOSS)
                                                                      * (DIET(F,MK)/100))
                              -(PHI*KL*SUM(YR,PDEV(YR)+NDEV(YR))/CARD(YR))=E= OBJ;

      OJ5..                  -(SUM((J,Z), P(J,'OBA')* .01 * FEED(J,Z))) -
                              (SUM(Z, VTMA(Z) * P('VTA','OBA') * .01)) -
                              (L('FEDR','OBA')*(FDRR/100)) -
                              (SUM(Z, (MIX(Z)/10) * MNMX('MIXF',Z))) +
                              SUM((F,MK), (FFNR(F,MK)+FFEED(F) + FDRCST(F)
                              + LOSS) * (DIET(F,MK)/100))=E=OBJ;


      ENRGYBAL(Z)..     SUM((F,MK), (DIET(F,MK)/100) * DEE(F,Z)) -
                        (SUM(J, (A(J,'DE')/A(J,'WT')) * FEED(J,Z))) =E= 0;
      DMWTMAX(Z)..     -(SUM((F,MK), (DIET(F,MK)/100) * (DEE(F,Z)/DEM(F,Z)))) +
                        (SUM(J, FEED(J,Z) * A(J,'DM'))) =L= 0;
      CPBAL(Z)..        SUM((F,MK), (DIET(F,MK)/100) * CPP(F,Z)) -
                        (SUM(J, (A(J,'CP')/A(J,'WT')) * FEED(J,Z) * .01)) =L= 0;
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CABAL(Z)..       SUM((F,MK), (DIET(F,MK)/100) * MNMX('CAL',Z) * DEE(F,Z)) -
                 (SUM(J, (A(J,'CA')/A(J,'WT')) * FEED(J,Z))) =L= 0;
PBAL(Z)..        SUM((F,MK), (DIET(F,MK)/100) * MNMX('PHO',Z) * DEE(F,Z)) -
                 (SUM(J, (A(J,'PH')/A(J,'WT')) * FEED(J,Z))) =L= 0;
CAPBAL(Z)..      SUM(J, (A(J,'CA')/A(J,'WT'))* FEED(J,Z))
                -(SUM(J, (A(J,'PH')/A(J,'WT')) * FEED(J,Z) * CALP)) =G= 0;
CAPXBAL(Z)..     SUM(J, (A(J,'CA')/A(J,'WT')) * FEED(J,Z))
                -(SUM(J, (A(J,'PH')/A(J,'WT')) * FEED(J,Z) * CALPX)) =L= 0;
UREABAL(Z)..    -(SUM(J $ NJU(J),FEED(J,Z) * (1/A(J,'WT')) * MNMX('URE',Z))) +
                 (FEED('URA',Z) * (1 - MNMX('URE',Z))) =L= 0;
BTPBAL(Z)..     -(SUM(J $ NJB(J),FEED(J,Z) * (1/A(J,'WT')) * MNMX('BEP',Z))) +
                 (FEED('BTP',Z) * (1 - MNMX('BEP',Z))) =L= 0;
SALTBAL(Z)..    -(SUM(J $ NJS(J),FEED(J,Z) * (1/A(J,'WT')) * MNMX('NCL',Z))) +
                 (FEED('SLT',Z) * (1 - MNMX('NCL',Z))) =L= 0;
RAPEBAL(Z)..    -(SUM(J $ NJR(J),FEED(J,Z) * (1/A(J,'WT')) * MNMX('RMM',Z))) +
                 (FEED('RPM',Z) * (1 - MNMX('RMM',Z))) =L= 0;
LIMBAL(Z)..     -(SUM(J $ NJL(J),FEED(J,Z) * (1/A(J,'WT')) * MNMX('LIME',Z))) +

                 (FEED('LIM',Z) * (1 - MNMX('LIME',Z))) =L= 0;
MOLSBAL(Z)..     FEED('MOL',Z) =L=
                 SUM(J $ MC(J), FEED(J,Z) * MNMX('MOLC',Z)) +
                 SUM(J $ FM(J), FEED(J,Z) * MNMX('MOLF',Z));
VITABAL(Z)..     SUM((F,MK), (DIET(F,MK)/100) * MNMX('VIT',Z) * DAY(F,Z) / 1000) -
                (10 * VTMA(Z)) =E= 0;
MIXBAL(Z)..      -(SUM(J, FEED(J,Z)*A(J,'WT'))) + (1000 * (MIX(Z)/10)) =E= 0;

FDRBAL..         SUM((F,MK), (DIET(F,MK)/100) * LK(F,'BEG'))
                 -(100 * (FDRR/100)) =E= 0;
CAPACITY..       SUM((F,MK), (DIET(F,MK)/100)) =L= NUMBER;
FEEDCOST(Z)..    SUM(J, FEED(J,Z) * P(J,'OBA')* .01) +
                 ((MIX(Z)/10)* MNMX('MIXF',Z)) + (VTMA(Z)*P('VTA','OBA')*.01)
                 - FEEDCST(Z) =L=0;
DDEV(YR)..       SUM((F,MK), (DIET(F,MK)/100)*ERR(F,MK,YR))=E= PDEV(YR) - NDEV(YR);
NEGDEV(YR)..     SUM((F,MK), (DIET(F,MK)/100)*NR(F,MK,YR))+NDEV(YR) =G= TARG;
NNEGDEV(YR)..     SUM((F,MK), (DIET(F,MK)/100)*NR(F,MK,YR))+NNDEV(YR) =G= TARG;

TDEV..           SUM(YR, (NDEV(YR)/CARD(YR)))=E=LAMBDA;

MODEL  QP1  / OJ1,ENRGYBAL,CPBAL,CABAL,PBAL,CAPBAL,CAPXBAL,
              UREABAL,BTPBAL,SALTBAL,RAPEBAL,MOLSBAL,LIMBAL,VITABAL,
              MIXBAL,FDRBAL,DMWTMAX,CAPACITY,FEEDCOST /;
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MODEL  QPF   / OJ2,ENRGYBAL,CPBAL,CABAL,PBAL,CAPBAL,CAPXBAL,
               UREABAL,BTPBAL,SALTBAL,RAPEBAL,MOLSBAL,LIMBAL,VITABAL,
               MIXBAL,FDRBAL,DMWTMAX,CAPACITY,FEEDCOST /;

MODEL  MOTAD1  / OJ3,ENRGYBAL,CPBAL,CABAL,PBAL,CAPBAL,CAPXBAL,
               UREABAL,BTPBAL,SALTBAL,RAPEBAL,MOLSBAL,LIMBAL,VITABAL,
               MIXBAL,FDRBAL,DMWTMAX,CAPACITY,FEEDCOST,DDEV /;

MODEL  MOTADF  / OJ4,ENRGYBAL,CPBAL,CABAL,PBAL,CAPBAL,CAPXBAL,
               UREABAL,BTPBAL,SALTBAL,RAPEBAL,MOLSBAL,LIMBAL,VITABAL,
               MIXBAL,FDRBAL,DMWTMAX,CAPACITY,FEEDCOST,DDEV /;

MODEL  TMOTAD  / OJ5,ENRGYBAL,CPBAL,CABAL,PBAL,CAPBAL,CAPXBAL,
               UREABAL,BTPBAL,SALTBAL,RAPEBAL,MOLSBAL,LIMBAL,VITABAL,
               MIXBAL,FDRBAL,DMWTMAX,CAPACITY,FEEDCOST,NEGDEV,NNEGDEV,TDEV /;

PHI =0.0;
SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
DISPLAY NRAVG, STDEV;
DISPLAY P;
DISPLAY L;
PARAMETERS TFEED(J)   TOTAL AMOUNT OF FEEDSTUFFS USED (KG PER HD)
           TVTMA      TOTAL AMOUNT OF VITAMIN A USED (GRAMS)
           TFDCST     TOTAL FEED, VIT A AND MIXING COSTS (DOLLARS)
           TFDRCST    TOTAL FEEDER STEER COST (DOLLARS)
           MAD        MEAN ABSOLUTE DEVIATION OF NET INCOME (DOLLARS)
           STD        STANDARD DEVIATION ON NET INCOME (DOLLARS)
           INC        MEAN NET INCOME (DOLLARS)
           FDIET(F)   PERCENT OF STEERS IN SELECTED FEEDING REGIMES
           MDIET(MK)  PERCENT OF STEERS IN SELECTED MARKETING REGIMES
           WEIGHT     WEIGHTED AVGERAGE WEIGHT (KG) OF LOT OF FEEDER STEERS;
           TFEED(J) = SUM(Z, FEED.L (J,Z));
           TVTMA = SUM(Z, VTMA.L (Z));
           TFDCST = SUM(Z, FEEDCST.L (Z));
           TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
           MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
           STD = MAD * KL;
           INC = OBJ.L + (PHI*STD)-LOSS;
           FDIET(F) = SUM(MK, DIET.L (F,MK));
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          MDIET(MK) = SUM(F, DIET.L (F,MK));
          WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
PARAMETER RREP  RISK SCENARIO REPORT FOR OBA AND MOTADF SPECIFICATIONS;
RREP(J,'RISK-0.0')              = TFEED(J);
RREP('VIT-A','RISK-0.0')        = TVTMA;
RREP('FEEDCOST','RISK-0.0')     = TFDCST;
RREP('FDR-CST','RISK-0.0')      = TFDRCST;
RREP('PHI','RISK-0.0')          = PHI;
RREP('NET-INC','RISK-0.0')      = INC;
RREP('ST-DEV','RISK-0.0')       = STD;
RREP(F,'RISK-0.0')              = FDIET(F);
RREP(MK,'RISK-0.0')             = MDIET(MK);
RREP('WEIGHT','RISK-0.0')          = WEIGHT;

PHI=0.2;
SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
TFEED(J) = SUM(Z, FEED.L (J,Z));
TVTMA = SUM(Z, VTMA.L (Z));
TFDCST = SUM(Z, FEEDCST.L (Z));
TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
STD = MAD * KL;
INC = OBJ.L + (PHI*STD)-LOSS;
FDIET(F) = SUM(MK, DIET.L (F,MK));
MDIET(MK) = SUM(F, DIET.L (F,MK));
WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
RREP(J,'RISK-0.2')              = TFEED(J);
RREP('VIT-A','RISK-0.2')        = TVTMA;
RREP('FEEDCOST','RISK-0.2')     = TFDCST;
RREP('FDR-CST','RISK-0.2')      = TFDRCST;
RREP('PHI','RISK-0.2')          = PHI;
RREP('NET-INC','RISK-0.2')      = INC;
RREP('ST-DEV','RISK-0.2')       = STD;
RREP(F,'RISK-0.2')              = FDIET(F);
RREP(MK,'RISK-0.2')             = MDIET(MK);
RREP('WEIGHT','RISK-0.2')       = WEIGHT;

PHI=0.4;
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SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
TFEED(J) = SUM(Z, FEED.L (J,Z));
TVTMA = SUM(Z, VTMA.L (Z));
TFDCST = SUM(Z, FEEDCST.L (Z));
TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
STD = MAD * KL;
INC = OBJ.L + (PHI*STD)-LOSS;
FDIET(F) = SUM(MK, DIET.L (F,MK));
MDIET(MK) = SUM(F, DIET.L (F,MK));
WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
RREP(J,'RISK-0.4')              = TFEED(J);
RREP('VIT-A','RISK-0.4')        = TVTMA;
RREP('FEEDCOST','RISK-0.4')     = TFDCST;
RREP('FDR-CST','RISK-0.4')      = TFDRCST;
RREP('PHI','RISK-0.4')          = PHI;
RREP('NET-INC','RISK-0.4')      = INC;
RREP('ST-DEV','RISK-0.4')       = STD;
RREP(F,'RISK-0.4')              = FDIET(F);
RREP(MK,'RISK-0.4')             = MDIET(MK);
RREP('WEIGHT','RISK-0.4')       = WEIGHT;

PHI=0.6;
SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
TFEED(J) = SUM(Z, FEED.L (J,Z));
TVTMA = SUM(Z, VTMA.L (Z));
TFDCST = SUM(Z, FEEDCST.L (Z));
TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
STD = MAD * KL;
INC = OBJ.L + (PHI*STD)-LOSS;
FDIET(F) = SUM(MK, DIET.L (F,MK));
MDIET(MK) = SUM(F, DIET.L (F,MK));
WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
RREP(J,'RISK-0.6')              = TFEED(J);
RREP('VIT-A','RISK-0.6')        = TVTMA;
RREP('FEEDCOST','RISK-0.6')     = TFDCST;
```

```
RREP('FDR-CST','RISK-0.6')      = TFDRCST;
RREP('PHI','RISK-0.6')          = PHI;
RREP('NET-INC','RISK-0.6')      = INC;
RREP('ST-DEV','RISK-0.6')       = STD;
RREP(F,'RISK-0.6')              = FDIET(F);
RREP(MK,'RISK-0.6')             = MDIET(MK);
RREP('WEIGHT','RISK-0.6')       = WEIGHT;

PHI=0.8;
SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
TFEED(J) = SUM(Z, FEED.L (J,Z));
TVTMA = SUM(Z, VTMA.L (Z));
TFDCST = SUM(Z, FEEDCST.L (Z));
TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
STD = MAD * KL;
INC = OBJ.L + (PHI*STD)-LOSS;
FDIET(F) = SUM(MK, DIET.L (F,MK));
MDIET(MK) = SUM(F, DIET.L (F,MK));
WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
RREP(J,'RISK-0.8')              = TFEED(J);
RREP('VIT-A','RISK-0.8')        = TVTMA;
RREP('FEEDCOST','RISK-0.8')     = TFDCST;
RREP('FDR-CST','RISK-0.8')      = TFDRCST;
RREP('PHI','RISK-0.8')          = PHI;
RREP('NET-INC','RISK-0.8')      = INC;
RREP('ST-DEV','RISK-0.8')       = STD;
RREP(F,'RISK-0.8')              = FDIET(F);
RREP(MK,'RISK-0.8')             = MDIET(MK);
RREP('WEIGHT','RISK-0.8')       = WEIGHT;


PHI=1.0;
SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
TFEED(J) = SUM(Z, FEED.L (J,Z));
TVTMA = SUM(Z, VTMA.L (Z));
TFDCST = SUM(Z, FEEDCST.L (Z));
TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
```

```
MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
STD = MAD * KL;
INC = OBJ.L + (PHI*STD)-LOSS;
FDIET(F) = SUM(MK, DIET.L (F,MK));
MDIET(MK) = SUM(F, DIET.L (F,MK));
WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
RREP(J,'RISK-1.0')              = TFEED(J);
RREP('VIT-A','RISK-1.0')        = TVTMA;
RREP('FEEDCOST','RISK-1.0')     = TFDCST;
RREP('FDR-CST','RISK-1.0')      = TFDRCST;
RREP('PHI','RISK-1.0')          = PHI;
RREP('NET-INC','RISK-1.0')      = INC;
RREP('ST-DEV','RISK-1.0')       = STD;
RREP(F,'RISK-1.0')              = FDIET(F);
RREP(MK,'RISK-1.0')             = MDIET(MK);
RREP('WEIGHT','RISK-1.0')       = WEIGHT;

PHI=1.2;
SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
TFEED(J) = SUM(Z, FEED.L (J,Z));
TVTMA = SUM(Z, VTMA.L (Z));
TFDCST = SUM(Z, FEEDCST.L (Z));
TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
STD = MAD * KL;
INC = OBJ.L + (PHI*STD)-LOSS;
FDIET(F) = SUM(MK, DIET.L (F,MK));
MDIET(MK) = SUM(F, DIET.L (F,MK));
WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
RREP(J,'RISK-1.2')              = TFEED(J);
RREP('VIT-A','RISK-1.2')        = TVTMA;
RREP('FEEDCOST','RISK-1.2')     = TFDCST;
RREP('FDR-CST','RISK-1.2')      = TFDRCST;
RREP('PHI','RISK-1.2')          = PHI;
RREP('NET-INC','RISK-1.2')      = INC;
RREP('ST-DEV','RISK-1.2')       = STD;
RREP(F,'RISK-1.2')              = FDIET(F);
RREP(MK,'RISK-1.2')             = MDIET(MK);
```

```
RREP('WEIGHT','RISK-1.2')       = WEIGHT;

PHI=1.4;
SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
TFEED(J) = SUM(Z, FEED.L (J,Z));
TVTMA = SUM(Z, VTMA.L (Z));
TFDCST = SUM(Z, FEEDCST.L (Z));
TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
STD = MAD * KL;
INC = OBJ.L + (PHI*STD)-LOSS;
FDIET(F) = SUM(MK, DIET.L (F,MK));
MDIET(MK) = SUM(F, DIET.L (F,MK));
WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
RREP(J,'RISK-1.4')              = TFEED(J);
RREP('VIT-A','RISK-1.4')        = TVTMA;
RREP('FEEDCOST','RISK-1.4')     = TFDCST;
RREP('FDR-CST','RISK-1.4')      = TFDRCST;
RREP('PHI','RISK-1.4')          = PHI;
RREP('NET-INC','RISK-1.4')      = INC;
RREP('ST-DEV','RISK-1.4')       = STD;
RREP(F,'RISK-1.4')              = FDIET(F);
RREP(MK,'RISK-1.4')             = MDIET(MK);
RREP('WEIGHT','RISK-1.4')       = WEIGHT;

PHI=1.6;
SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
TFEED(J) = SUM(Z, FEED.L (J,Z));
TVTMA = SUM(Z, VTMA.L (Z));
TFDCST = SUM(Z, FEEDCST.L (Z));
TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
STD = MAD * KL;
INC = OBJ.L + (PHI*STD)-LOSS;
FDIET(F) = SUM(MK, DIET.L (F,MK));
MDIET(MK) = SUM(F, DIET.L (F,MK));
WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
```

```
RREP(J,'RISK-1.6')              = TFEED(J);
RREP('VIT-A','RISK-1.6')        = TVTMA;
RREP('FEEDCOST','RISK-1.6')     = TFDCST;
RREP('FDR-CST','RISK-1.6')      = TFDRCST;
RREP('PHI','RISK-1.6')          = PHI;
RREP('NET-INC','RISK-1.6')      = INC;
RREP('ST-DEV','RISK-1.6')       = STD;
RREP(F,'RISK-1.6')              = FDIET(F);
RREP(MK,'RISK-1.6')             = MDIET(MK);
RREP('WEIGHT','RISK-1.6')       = WEIGHT;

PHI=1.8;
SOLVE MOTADF USING LP MAXIMIZING OBJ;
DISPLAY OBJ.L, FEED.L, VTMA.L, DIET.L, FDRR.L, MIX.L, FEEDCST.L,PDEV.L,NDEV.L;
TFEED(J) = SUM(Z, FEED.L (J,Z));
TVTMA = SUM(Z, VTMA.L (Z));
TFDCST = SUM(Z, FEEDCST.L (Z));
TFDRCST = FDRR.L * .01 * L('FEDR','OBA');
MAD = SUM(YR,PDEV.L(YR) + NDEV.L(YR))/CARD(YR);
STD = MAD * KL;
INC = OBJ.L + (PHI*STD)-LOSS;
FDIET(F) = SUM(MK, DIET.L (F,MK));
MDIET(MK) = SUM(F, DIET.L (F,MK));
WEIGHT = SUM(F, (FDIET(F)/100)*LK(F,'END'));
DISPLAY TFEED,TFDCST,TFDRCST,INC,STD,FDIET,MDIET;
RREP(J,'RISK-1.8')              = TFEED(J);
RREP('VIT-A','RISK-1.8')        = TVTMA;
RREP('FEEDCOST','RISK-1.8')     = TFDCST;
RREP('FDR-CST','RISK-1.8')      = TFDRCST;
RREP('PHI','RISK-1.8')          = PHI;
RREP('NET-INC','RISK-1.8')      = INC;
RREP('ST-DEV','RISK-1.8')       = STD;
RREP(F,'RISK-1.8')              = FDIET(F);
RREP(MK,'RISK-1.8')             = MDIET(MK);
RREP('WEIGHT','RISK-1.8')       = WEIGHT;

DISPLAY RREP;

```

COMPILATION TIME = 1.668 MINUTES

APPENDIX B

MODEL DIET FORMULATION STRUCTURE

Two different formulations of the feedlot model diet structure were considered. The first and more correct formulation is a block diagonal structure, which details a set of nutritional constraints for each production-marketing alternative in the model. Thus, a diet is obtained for each production-marketing alternative in the optimum basic feasible solution. This would be important and necessary information if the feedlot manager wanted to use the model to determine the diets and amounts of feedstuffs to be fed to each of the groups of cattle specified by the production alternatives selected in the optimum solution. The main disadvantage of this formulation is the size of the resultant LP matrix and solution times. A model including all of the 72 production-marketing alternatives was not solvable on a micro-VAX 3600 with 32 megabytes of memory in combination with a micro-VAX server 3600 with 16 megabytes of memory. Production-marketing alternatives had to be reduced to 40 with a resultant matrix size of 440 single equations, 820 single variables and 12,335 non-zero elements before the model would solve.

The second formulation details only one set of nutritional constraints for the set of production-marketing alternatives in the model. The resultant diet in the optimum basic feasible solution then represents a single diet that satifies the nutritional demands imposed by a linear combination of the production-marketing alternatives in the solution. This compact structure poses a problem if the single diet formulation impose some economies to the selection of combinations of production-marketing alternatives in the optimum solution. Total amounts of feedstuffs indicated by the single diet may also underestimate the amount necessary to individually feed the production groups indicated in the optimum solution. Advantages, however, include the ability to easily solve the complete model on the VAX-3600 or IBM-PC XT or AT microcomputer. The LP matrix in the complete model contains 62 single equations, 177 single variables and 3,364 non-zero elements.

The compact formulation was chosen since the solutions obtained from it differed only slightly from those obtained from the block-diagonal formulation. For example, the following solution was obtained at a risk coefficient level of $\alpha=1.8$ for a reduced MOTAD model featuring production alternatives of: LLH, LHH, HHH1, HHH2, HHH3, CLLH, CHHH1, CHHH2, CHHH3 and USCHHH3, with marketing alternatives: CASH, SHEDG, CHEDG and TSP.

HHH2 .BLY	82.175	125.260	33.658
HHH2 .ALF	6.577		
HHH2 .OST	20.541	40.236	10.794
HHH2 .URA	0.552		0.006
HHH2 .RKP	0.058	0.118	0.032
HHH2 .LIM	0.590	1.199	0.322
CHHH2 .BLY	61.609	99.278	151.019
CHHH2 .ALF	7.423		
CHHH2 .OST	13.763	31.890	47.886
CHHH2 .URA	0.418		0.221
CHHH2 .RKP	0.039	0.094	0.139
CHHH2 .LIM	0.366	0.950	1.447
CHHH3 .BLY	2.650	3.987	8.840
CHHH3 .ALF	0.278		
CHHH3 .OST	0.619	1.280	2.769
CHHH3 .URA	0.018	1.700250E-4	0.025
CHHH3 .RKP	0.002	0.004	0.008
CHHH3 .LIM	0.017	0.038	0.065
USCHHH3.BLY	105.533	158.796	352.051
USCHHH3.ALF	11.068		
USCHHH3.OST	24.658	50.990	110.292
USCHHH3.URA	0.714	0.007	0.986
USCHHH3.RKP	0.070	0.150	0.318
USCHHH3.LIM	0.678	1.520	3.379

---- 1122 VARIABLE DIET.L FEEDING AND MARKETING REGIMES (# OF .01 HD PER STAGE)

	CASH	CHEDG
HHH1		35.761
HHH2		20.879
CHHH2	16.011	
CHHH3	0.670	
USCHHH3		26.679

---- 1132 PARAMETER TFEED TOTAL AMOUNT OF FEEDSTUFFS USED (KG PER HD)

BLY 1502.840, ALF 36.610, OST 445.540, URA 4.702, RKP 1.286, LIM 13.306

```
----  1132 PARAMETER TFDCST      =     160.616 TOTAL FEED
           PARAMETER TFDRCST     =     532.667 TOTAL FEEDER STEER COST (DOLLARS)
           PARAMETER INC         =       7.446 MEAN NET INCOME (DOLLARS)
           PARAMETER STD         =      20.044 STANDARD DEVIATION ON NET INCOME (DOLLARS)
```

This solution is very similar to that derived from the compact formulation as follows:

```
----  1144 VARIABLE  FEED.L        FEEDSTUFFS (KG PER HD PER STAGE)
```

	1	2	3
BLY	392.717	563.915	545.568
ALF	36.610		
OST	94.763	180.206	171.740
URA	2.648	0.330	1.238
RKP	0.268	0.527	0.497
LIM	2.663	5.399	5.233

```
----  1144 VARIABLE  DIET.L        FEEDING AND MARKETING REGIMES (# OF .01 HD PER STAGE)
```

	CASH	CHEDG
HHH1		35.761
HHH2		20.879
CHHH2	16.011	
CHHH3	0.670	
USCHHH3		26.679

```
----  1154 PARAMETER TFEED        TOTAL AMOUNT OF FEEDSTUFFS USED (KG PER HD)

BLY 1502.200,   ALF   36.610,   OST  446.710,   URA    4.217,   RKP    1.293,   LIM   13.295

----  1154 PARAMETER TFDCST      =     160.459 TOTAL FEED
           PARAMETER TFDRCST     =     532.667 TOTAL FEEDER STEER COST (DOLLARS)
           PARAMETER INC         =       7.603 MEAN NET INCOME (DOLLARS)
           PARAMETER STD         =      20.044 STANDARD DEVIATION ON NET INCOME (DOLLARS)
```

Total feedcosts per head for the compact model are slightly lower ($160.46 versus $160.62) and mean net income per head slightly higher ($7.60 versus $7.47). However, the diversification percentages, i.e., the amount of cattle in each production-marketing alternative as given by the variable DIET.L, remain the same.

To run the more complete formulation only the following lines need to be substituted for their counterparts in the bottom of the program listing given in Appendix A.

```
1003   FEED(F,J,Z)      FEEDSTUFFS (KG PER HD PER STAGE PER FEEDING REGIME)
1004   VTMA(F,Z)        VITAMIN A (GRAMS PER STAGE) BY FEEDING REGIME
1023   ENRGYBAL(F,Z)     DIGESTIBLE ENERGY BALANCE BY STAGE (MCAL)
1024   DMWTMAX(F,Z)      MAXIMUM DRY MATTER WT (KG DM) OF DIET TO SATISFY ENERGY
1025   CPBAL(F,Z)       CRUDE PROTEIN BALANCE (KG CP) BY STAGE
1026   CABAL(F,Z)       CALCIUM BALANCE (G CA) BY STAGE
1027   PBAL(F,Z)        PHOSPHORUS BALANCE (G P) BY STAGE
1028   CAPBAL(F,Z)      MINIMUM CALCIUM PHOSPHORUS RATIO BALANCE (G) BY STAGE
1029   CAPXBAL(F,Z)     MAXIMUM CALCIUM PHOSPHORUS RATIO BALANCE (G) BY STAGE
1030   UREABAL(F,Z)     MAXIMUM UREA CONCENTRATION BALANCE EQUATION (KG) BY STAGE
1031   BTPBAL(F,Z)      MAXIMUM BEET PULP CONCENTRATION BALANCE EQUATION (KG) BY STAGE
1032   SALTBAL(F,Z)     MAXIMUM SALT CONCENTRATION BALANCE EQUATION (KG) BY STAGE
1033   RAPEBAL(F,Z)     MAXIMUM RAPESEED MEAL CONCENTRATION BALANCE (KG) BY STAGE
1034   LIMBAL(F,Z)      MAXIMUM LIMESTONE CONCENTRATION BALANCE (KG) BY STAGE
1035   MOLSBAL(F,Z)     MAXIMUM MOLASSES CONCENTRATION BALANCE (KG) BY STAGE
1036   VITABAL(F,Z)     VITAMIN A BALANCE (CG) BY STAGE

1046   OJ1..            -(SUM((F,J,Z), P(J,'OBA')* .01 * FEED(F,J,Z))) -
1047                    (SUM((F,Z), VTMA(F,Z) * P('VTA','OBA') * .01)) -
1055   OJ2..            -(SUM((F,J,Z), P(J,'OBA')* .01 * FEED(F,J,Z))) -
1056                    (SUM((F,Z), VTMA(F,Z) * P('VTA','OBA') * .01)) -
1065   OJ3..            -(SUM((F,J,Z), P(J,'OBA')* .01 * FEED(F,J,Z))) -
1066                    (SUM((F,Z), VTMA(F,Z) * P('VTA','OBA') * .01)) -
1073   OJ4..            -(SUM((F,J,Z), P(J,'OBA')* .01 * FEED(F,J,Z))) -
1074                    (SUM((F,Z), VTMA(F,Z) * P('VTA','OBA') * .01)) -
1080   OJ5..            -(SUM((F,J,Z), P(J,'OBA')* .01 * FEED(F,J,Z))) -
1081                    (SUM((F,Z), VTMA(F,Z) * P('VTA','OBA') * .01)) -
```

```
1088    ENRGYBAL(F,Z).. SUM(MK, (DIET(F,MK)/100) * DEE(F,Z)) -
1089                    (SUM(J, (A(J,'DE')/A(J,'WT')) * FEED(F,J,Z))) =E= 0;
1090    DMWTMAX(F,Z)..   -(SUM(MK, (DIET(F,MK)/100) * (DEE(F,Z)/DEM(F,Z)))) +
1091                      (SUM(J, FEED(F,J,Z) * A(J,'DM'))) =L= 0;
1092    CPBAL(F,Z)..      SUM(MK, (DIET(F,MK)/100) * CPP(F,Z)) -
1093                      (SUM(J, (A(J,'CP')/A(J,'WT')) * FEED(F,J,Z) * .01)) =L= 0;
1094    CABAL(F,Z)..      SUM(MK, (DIET(F,MK)/100) * MNMX('CAL',Z) * DEE(F,Z)) -
1095                      (SUM(J, (A(J,'CA')/A(J,'WT')) * FEED(F,J,Z))) =L= 0;
1096    PBAL(F,Z)..       SUM(MK, (DIET(F,MK)/100) * MNMX('PHO',Z) * DEE(F,Z)) -
1097                      (SUM(J, (A(J,'PH')/A(J,'WT')) * FEED(F,J,Z))) =L= 0;
1098    CAPBAL(F,Z)..     SUM(J, (A(J,'CA')/A(J,'WT'))* FEED(F,J,Z))
1099                     -(SUM(J, (A(J,'PH')/A(J,'WT')) * FEED(F,J,Z) * CALP)) =G= 0;
1100    CAPXBAL(F,Z)..    SUM(J, (A(J,'CA')/A(J,'WT')) * FEED(F,J,Z))
1101                     -(SUM(J, (A(J,'PH')/A(J,'WT')) * FEED(F,J,Z) * CALPX)) =L= 0;
1102    UREABAL(F,Z)..   -(SUM(J $ NJU(J),FEED(F,J,Z) * (1/A(J,'WT')) * MNMX('URE',Z))) +
1103                      (FEED(F,'URA',Z) * (1 - MNMX('URE',Z))) =L= 0;
1104    BTPBAL(F,Z)..    -(SUM(J $ NJB(J),FEED(F,J,Z) * (1/A(J,'WT')) * MNMX('BEP',Z))) +
1105                      (FEED(F,'BTP',Z) * (1 - MNMX('BEP',Z))) =L= 0;
1106    SALTBAL(F,Z)..   -(SUM(J $ NJS(J),FEED(F,J,Z) * (1/A(J,'WT')) * MNMX('NCL',Z))) +
1107                      (FEED(F,'SLT',Z) * (1 - MNMX('NCL',Z))) =L= 0;
1108    RAPEBAL(F,Z)..   -(SUM(J $ NJR(J),FEED(F,J,Z) * (1/A(J,'WT')) * MNMX('RMM',Z))) +
1109                      (FEED(F,'RPM',Z) * (1 - MNMX('RMM',Z))) =L= 0;
1110    LIMBAL(F,Z)..    -(SUM(J $ NJL(J),FEED(F,J,Z) * (1/A(J,'WT')) * MNMX('LIME',Z))) +
1112                      (FEED(F,'LIM',Z) * (1 - MNMX('LIME',Z))) =L= 0;
1113    MOLSBAL(F,Z)..    FEED(F,'MOL',Z) =L=
1114                      SUM(J $ MC(J), FEED(F,J,Z) * MNMX('MOLC',Z)) +
1115                      SUM(J $ FM(J), FEED(F,J,Z) * MNMX('MOLF',Z));
1116    VITABAL(F,Z)..    SUM(MK, (DIET(F,MK)/100) * MNMX('VIT',Z) * DAY(F,Z) / 1000) -
1117                      (10 * VTMA(F,Z)) =E= 0;
1168             TFEED(J) = SUM((F,Z), FEED.L (F,J,Z));
1169             TVTMA = SUM((F,Z), VTMA.L (F,Z));
1194    TFEED(J) = SUM((F,Z), FEED.L(F,J,Z));
1195    TVTMA = SUM((F,Z), VTMA.L (F,Z));
1219    TFEED(J) = SUM((F,Z), FEED.L(F,J,Z));
1220    TVTMA = SUM((F,Z), VTMA.L (F,Z));
1269    TFEED(J) = SUM((F,Z), FEED.L(F,J,Z));
1270    TVTMA = SUM((F,Z), VTMA.L (F,Z));
1295    TFEED(J) = SUM((F,Z), FEED.L(F,J,Z));
1296    TVTMA = SUM((F,Z), VTMA.L (F,Z));
1320    TFEED(J) = SUM((F,Z), FEED.L(F,J,Z));
1321    TVTMA = SUM((F,Z), VTMA.L (F,Z));
1345    TFEED(J) = SUM((F,Z), FEED.L(F,J,Z));
1346    TVTMA = SUM((F,Z), VTMA.L (F,Z));
1370    TFEED(J) = SUM((F,Z), FEED.L(F,J,Z));
1371    TVTMA = SUM((F,Z), VTMA.L (F,Z));
1395    TFEED(J) = SUM((F,Z), FEED.L(F,J,Z));
1396    TVTMA = SUM((F,Z), VTMA.L (F,Z));
```

APPENDIX C

TSP ESTIMATED PAYOUTS AND LEVIES

Table C-1 Slaughter Cattle (GM90) Quarterly Support and Market Prices (Guaranteed Margin)

SLAUGHTER YEAR	DATE YYQ	PRICE ($/CWT)	CURRENT CASH COST ($/CWT)	AVG. PRICE ($/CWT)	AVG. COST ($/CWT)	SUPPORT LEVEL	PAYOUT ($/CWT)	PAYOUT PER HEAD	NUMBER MARKETED	TOTAL PAYOUT
1972	7201	33.7281	26.9703	.	.	.	.	.	512,188	.
1972	7202	33.7289	26.2083	.	.	.	.	.	561,976	.
1972	7203	32.7131	27.3128	.	.	.	.	.	579,480	.
1972	7204	34.2151	29.9625	.	.	.	.	.	558,733	.
1973	7301	39.5387	30.8589	33.7281	26.9703	36.9409	.	.	543,134	.
1973	7302	42.6096	30.1152	33.7289	26.2083	36.8837	.	.	545,003	.
1973	7303	47.6405	31.6625	32.7131	27.3128	36.5228	.	.	547,634	.
1973	7304	43.8222	38.1596	34.2151	29.9625	41.9869	.	.	569,195	.
1974	7401	45.3108	41.6187	36.6334	28.9146	48.5656	$3.25	$39.15	550,240	$21,544,556
1974	7402	44.1789	40.9603	38.1692	28.1617	49.9670	$5.79	$70.05	605,568	$42,421,747
1974	7403	46.1058	40.0094	40.1768	29.4876	49.6296	$3.52	$42.41	599,218	$25,412,448
1974	7404	45.2285	38.6734	39.0186	34.0610	43.1352	.	.	545,395	.
1975	7501	37.0337	35.5394	39.5259	33.1493	41.2783	$4.24	$49.32	634,760	$31,305,172
1975	7502	42.7323	32.4543	40.1725	32.4279	39.4244	.	.	622,995	.
1975	7503	43.5207	32.1757	42.1531	32.9949	40.4181	.	.	640,511	.
1975	7504	42.2729	33.9555	41.0886	35.5985	38.8966	.	.	576,754	.
1976	7601	37.1770	33.3535	38.9028	33.7468	37.9939	$0.82	$9.54	680,362	$6,493,879
1976	7602	39.8701	31.0843	40.8124	32.4345	38.6244	.	.	677,699	.
1976	7603	36.0488	32.6779	42.4950	32.7901	41.4123	$5.36	$64.67	723,726	$46,801,994
1976	7604	36.0019	34.0432	41.3847	35.1877	39.6204	$3.62	$43.66	711,566	$31,866,29
1977	7701	34.7088	31.8850	38.5577	33.6682	36.2855	$1.58	$18.84	734,625	$13,840,534
1977	7702	38.4194	30.3504	40.6240	32.1645	37.9639	.	.	740,947	.
1977	7703	40.0974	31.4789	41.2058	32.7677	39.0732	.	.	740,629	.
1977	7704	42.8712	34.2362	40.3081	34.9588	39.0506	.	.	663,390	.
1978	7801	44.5211	35.4210	38.7538	34.6511	39.1134	.	.	707,358	.
1978	7802	59.4692	34.3660	41.5621	32.9929	42.0782	.	.	661,388	.
1978	7803	59.3566	39.0474	42.6826	33.6009	47.2210	.	.	647,918	.
1978	7804	61.3816	50.2007	42.0393	35.8136	55.8039	.	.	634,173	.
1979	7901	72.6131	54.5014	39.7503	35.5635	58.2695	.	.	586,530	.
1979	7902	77.3615	55.9894	44.9340	33.8431	65.9712	.	.	604,012	.
1979	7903	71.7462	62.6820	45.0259	35.0779	71.6352	.	.	608,191	.
1979	7904	73.3705	69.2163	45.5512	38.2218	75.8128	$2.44	$30.63	564,990	$17,305,823
1980	8001	74.6105	68.2897	45.2107	38.1401	74.6533	$0.04	$0.53	562,263	$299,328
1980	8002	69.7256	68.3821	51.5705	36.8489	81.6316	11.91	147.59	631,528	$93,210,116
1980	8003	74.6133	67.0323	50.1539	39.6124	76.5197	$1.91	$23.11	635,224	$14,677,727
1980	8004	77.8839	65.9584	51.1796	44.3304	72.1227	.	.	594,316	.
1981	8101	73.8214	68.8146	52.7261	44.6901	76.0470	$2,23	$27.51	625,186	$17,197,042
1981	8102	75.7192	67.0509	56.9692	44.0344	78.6921	$2.97	$36.25	655,018	$23,743,460
1981	8103	72.7556	67.0985	56.3725	46.5837	75.9084	$3.15	$37.94	642,360	$24,373,348
1981	8104	69.3490	66.8378	58.3018	50.7310	73.6516	$4.30	$53.58	611,804	$32,779,377
1982	8201	67.9498	62.8164	60.0550	51.7823	70.2618	$2.31	$28.07	627,861	$17,623,29
1982	8202	79.0872	57.7898	64.1390	51.2278	69.4099	.	.	634,037	.
1982	8203	73.2637	58.0043	63.7138	53.4678	67.2257	.	.	652,288	.
1982	8204	68.4620	62.8573	64.9712	57.2899	69.7705	$1.31	$15.93	618,712	$9,858,33
1983	8301	70.2681	62.4096	66.7032	57.9686	70.2707	$0.00	$0.03	606,627	$19,362
1983	8302	75.3764	59.0477	72.2725	56.7156	73.0489	.	.	632,919	.
1983	8303	68.8339	59.8972	70.3471	58.7729	70.3140	$1.48	$18.05	664,633	$11,996,591
1983	8304	71.3445	64.5832	70.0894	63.0141	70.9510	.	.	579,578	.
1984	8401	76.9508	63.3022	71.8526	63.3663	70.9398	.	.	565,638	.
1984	8402	76.7547	63.1792	75.4540	61.6520	75.6010	.	.	625,078	.
1984	8403	75.4636	66.0889	72.2425	62.9429	74.4586	.	.	601,567	.
1984	8404	77.4835	67.7213	72.0820	65.8906	73.2935	.	.	530,644	.
1985	8501	78.1527	67.7222	72.7201	65.1265	74.5565	.	.	554,819	.
1985	8502	74.8240	66.2260	75.3326	63.0899	77.2444	$2.42	$29.73	614,761	$18,273,672
1985	8503	67.4175	65.7987	72.9860	63.6242	74.2243	$6.81	$87.02	621,977	$54,124,139
1985	8504	76.5721	66.2492	72.9046	65.5916	72.8309	.	.	510,026	.
1986	8601	72.6130	66.1857	73.4286	65.0130	73.7597	$1.15	$13.96	582,348	$8,132,034
1986	8602	70.2731	63.5605	76.3523	62.6587	75.8847	$5.61	$67.50	656,433	$44,308,462
1986	8603	75.2128	62.9033	71.5469	63.3775	70.2557	.	.	623,489	.
1986	8604	79.7366	65.3226	72.6422	65.6498	71.6158	.	.	570,495	.
1987	8701	77.3158	67.7383	73.1069	64.4872	75.9680	.	.	566,951	.
1987	8702	84.0866	66.7474	75.2631	61.9606	78.7196	.	.	591,922	.

Table C-2 Slaughter Cattle - Revised (GM90) Levy Report
Quarterly Price Supports and Market Prices (Guar. Margin)

SLAUGHTER YEAR	DATE YYQ	GROSS REVENUE	OPENING BALANCE	TOTAL LEVY	INTEREST EARNED	TOTAL PAYOUT	END BALANCE	UNIT LEVY PER HEAD	UNIT LEVY ($/CWT)	FEDERAL SHARE OF TOT LEVY
1972	7201	$210,281,497	.	.	.	.	.	.	.	.
1972	7202	$231,485,890	.	.	.	.	.	.	.	.
1972	7203	$231,272,259	.	.	.	.	.	.	.	.
1972	7204	$234,452,181	.	.	.	.	.	.	.	.
1973	7301	$263,583,993	$0	$6,541,243	$30,294	.	$6,571,538	$12.04	$0.98	$2,180,412
1973	7302	$281,826,559	$6,571,538	$6,993,961	$117,500	.	$13,682,998	$12.83	$1.06	$2,331,31[illegible]
1973	7303	$317,149,880	$13,682,998	$7,870,563	$243,397	.	$21,796,958	$14.37	$1.18	$2,623,512
1973	7304	$305,092,423	$21,796,958	$7,571,339	$370,502	.	$29,738,799	$13.30	$1.09	$2,523,777
1974	7401	$299,924,743	$29,738,799	$7,443,095	$471,793	$21,544,556	$16,109,132	$13.53	$1.12	$2,481,02[illegible]
1974	7402	$323,790,180	$16,109,132	$8,035,352	$377,680	$42,421,747	$-17,899,583	$13.27	$1.10	$2,678,442
1974	7403	$332,496,063	$-17,899,583	$8,251,402	$-280,471	$25,412,448	$-35,341,100	$13.77	$1.14	$2,750,465
1974	7404	$295,091,146	$-35,341,100	$7,323,142	$-544,571	.	$-28,562,529	$13.43	$1.12	$2,441,865
1975	7501	$273,133,775	$-28,562,529	$6,778,236	$-358,532	$31,305,172	$-53,447,998	$10.68	$0.92	$2,259,41[illegible]
1975	7502	$312,127,085	$-53,447,998	$7,745,915	$-770,021	.	$-46,472,104	$12.43	$1.06	$2,581,96[illegible]
1975	7503	$320,124,881	$-46,472,104	$7,944,392	$-756,077	.	$-39,283,788	$12.40	$1.08	$2,648,122
1975 7643	7504	$282,388,799	$-39,283,788	$7,007,913	$-679,459	.	$-32,955,334	$12.15	$1.05	$2,335,96[illegible]
1976	7601	$295,535,500	$-32,955,334	$7,334,169	$-581,008	$6,493,879	$-32,696,052	$10.78	$0.92	$2,444,72[illegible]
1976	7602	$326,373,697	$-32,696,052	$8,099,466	$-578,154	.	$-25,174,739	$11.95	$0.99	$2,699,8[illegible]9
1976	7603	$314,560,545	$-25,174,739	$7,806,305	$-435,694	$46,801,994	$-64,606,122	$10.79	$0.89	$2,602,09[illegible]
1976 7743	7604	$309,088,135	$-64,606,122	$7,670,499	$-1,173,182	$31,066,290	$-89,175,095	$10.78	$0.89	$2,556,83[illegible]
1977	7701	$304,669,931	$-89,175,095	$7,560,854	$-1,487,782	$13,840,534	$-96,942,557	$10.29	$0.86	$2,520,222
1977	7702	$341,025,842	$-96,942,557	$8,463,082	$-1,508,865	.	$-89,988,340	$11.42	$0.95	$2,821,025
1977	7703	$347,396,014	$-89,988,340	$8,621,168	$-1,373,849	.	$-82,741,021	$11.64	$1.00	$2,873,72[illegible]
1977 7843	7704	$335,837,582	$-82,741,021	$8,334,327	$-1,277,016	.	$-75,683,709	$12.56	$1.06	$2,778,106
1978	7801	$375,502,259	$-75,683,709	$9,318,667	$-1,180,430	.	$-67,545,472	$13.17	$1.10	$3,106,2[illegible]
1978	7802	$470,578,490	$-67,545,472	$11,678,131	$-1,140,802	.	$-57,008,144	$17.66	$1.48	$3,892,7[illegible]
1978	7803	$461,160,082	$-57,008,144	$11,444,398	$-1,024,312	.	$-46,588,058	$17.66	$1.47	$3,814,79[illegible]
1978 7943	7804	$479,688,025	$-46,588,058	$11,904,198	$-934,726	.	$-35,618,585	$18.77	$1.52	$3,968,062
1979	7901	$519,978,399	$-35,618,585	$12,904,066	$-712,901	.	$-23,427,421	$22.00	$1.80	$4,301,35[illegible]
1979	7902	$579,207,929	$-23,427,421	$14,373,938	$-395,129	.	$-9,448,612	$23.80	$1.92	$4,791,308
1979	7903	$543,496,276	$-9,448,612	$13,487,698	$-69,641	.	$3,969,445	$22.18	$1.78	$4,495,895
1979 8043	7904	$519,898,600	$3,969,445	$12,902,085	$319,570	$17,305,823	$-114,723	$22.84	$1.82	$4,300,69[illegible]
1980	8001	$521,653,052	$-114,723	$12,945,625	$201,663	$299,328	$12,733,237	$23.02	$1.85	$4,315,2[illegible]
1980	8002	$545,872,181	$12,733,237	$13,546,660	$542,917	$93,210,116	$-66,387,303	$21.45	$1.73	$4,515,54[illegible]
1980	8003	$574,460,404	$-66,387,303	$14,256,121	$-1,400,000	$14,677,727	$-68,208,908	$22.44	$1.85	$4,752,0[illegible]
1980	8004	$565,829,466	$-68,208,908	$14,041,931	$-1,955,877	.	$-56,122,855	$23.63	$1.93	$4,680,63[illegible]
1981	8101	$570,416,951	$-56,122,855	$14,155,776	$-1,843,968	$17,197,042	$-61,008,089	$22.64	$1.83	$4,718,527
1981	8102	$604,731,654	$-61,008,089	$15,007,348	$-2,191,403	$23,743,460	$-71,935,603	$22.91	$1.88	$5,002,444
1981	8103	$562,454,508	$-71,935,603	$13,958,176	$-2,945,448	$24,373,348	$-85,296,224	$21.73	$1.81	$4,652,72[illegible]
1981	8104	$528,338,858	$-85,296,224	$13,111,543	$-2,801,579	$32,779,377	$-107,765,637	$21.43	$1.72	$4,370,51[illegible]
1982	8201	$517,954,774	$-107,765,637	$12,853,846	$-3,327,449	$17,623,290	$-115,862,530	$20.47	$1.69	$4,284,6[illegible]
1982	8202	$593,577,084	$-115,862,530	$14,730,530	$-3,774,077	.	$-104,906,077	$23.23	$1.96	$4,910,172
1982	8203	$569,941,558	$-104,906,077	$14,143,978	$-3,058,286	.	$-93,820,385	$21.68	$1.82	$4,714,655
1982	8204	$515,788,072	$-93,820,385	$12,800,076	$-2,080,392	$9,858,331	$-92,959,032	$20.69	$1.78	$4,266,682

Table C-3 Slaughter Cattle - Revised (GM90) Quarterly Support and Market Prices Calculations (Guar. Margin)

SLAUGHTER YEAR	DATE YYQ	GROSS REVENUE	OPENING BALANCE	TOTAL LEVY	INTEREST EARNED	TOTAL PAYOUT	END BALANCE	UNIT LEVY PER HEAD	UNIT LEVY ($/CWT)	FEDERAL SHARE OF TOT LEVY
1983	8301	$522,486,126	$-92,959,032	$12,966,299	$-1,814,703	$19,362	$-81,826,798	$21.37	$1.74	$4,322,095
1983	8302	$576,364,460	$-81,826,798	$14,303,373	$-1,542,414	.	$-69,065,840	$22.60	$1.87	$4,767,786
1983	8303	$557,930,787	$-69,065,840	$13,845,913	$-1,295,684	$11,996,591	$-68,512,202	$20.83	$1.71	$4,615,300
1983	8304	$505,566,274	$-68,512,202	$12,546,406	$-1,327,096	.	$-57,292,892	$21.65	$1.77	$4,182,131
1984	8401	$529,401,640	$-57,292,892	$13,137,918	$-1,144,336	.	$-45,299,310	$23.23	$1.91	$4,379,302
1984	8402	$574,105,649	$-45,299,310	$14,247,317	$-973,193	.	$-32,025,186	$22.79	$1.90	$4,749,101
1984	8403	$545,964,482	$-32,025,186	$13,548,950	$-698,433	.	$-19,174,668	$22.52	$1.87	$4,516,312
1984	8404	$502,118,700	$-19,174,668	$12,460,850	$-308,333	.	$-7,022,151	$23.48	$1.92	$4,153,612
1985	8501	$531,570,639	$-7,022,151	$13,191,745	$-9,965	.	$6,159,628	$23.78	$1.94	$4,397,244
1985	8502	$564,907,630	$6,159,628	$14,019,054	$282,578	$18,273,672	$2,187,589	$22.80	$1.86	$4,673,013
1985	8503	$536,068,793	$2,187,589	$13,303,374	$177,404	$54,124,139	$-38,455,773	$21.39	$1.67	$4,434,453
1985	8504	$492,889,718	$-38,455,773	$12,231,818	$-645,663	.	$-26,869,617	$23.98	$1.90	$4,077,269
1986	8601	$514,946,652	$-26,869,617	$12,779,195	$-495,973	$8,132,034	$-22,718,430	$21.94	$1.80	$4,259,727
1986	8602	$554,865,062	$-22,718,430	$13,769,832	$-304,480	$44,308,462	$-53,561,539	$20.98	$1.74	$4,589,939
1986	8603	$583,173,490	$-53,561,539	$14,472,349	$-866,512	.	$-39,955,703	$23.21	$1.87	$4,824,112
1986	8604	$539,608,098	$-39,955,703	$13,391,207	$-618,139	.	$-27,182,635	$23.47	$1.98	$4,463,731
1987	8701	$535,649,190	$-27,182,635	$13,292,960	$-328,375	.	$-14,218,049	$23.46	$1.92	$4,430,982
1987	8702	$578,154,804	$-14,218,049	$14,347,803	$-129,754	.	$-0	$24.24	$2.09	$4,782,596

APPENDIX D

ADDITIONAL FIGURES

LIST OF APPENDIX D FIGURES

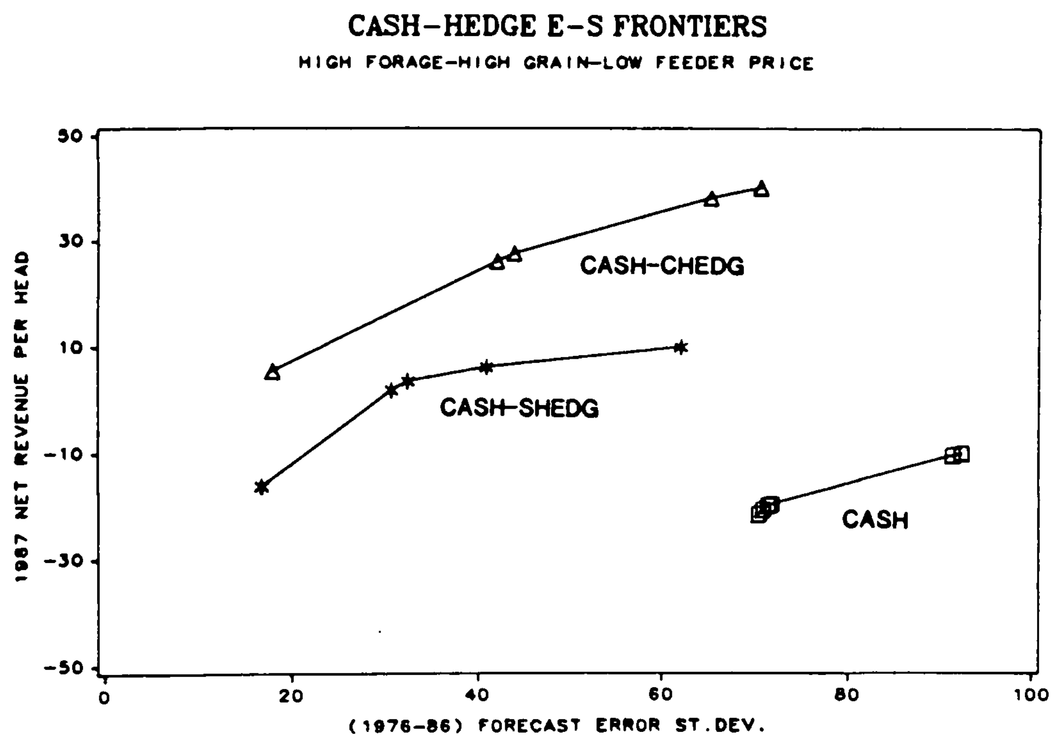


Figure D-1 Es Frontiers for CASH, CASH-SHEDG and CASH-CHEDG Risk Reducing Alternatives for High Forage-High Grain-Low Feeder Prices

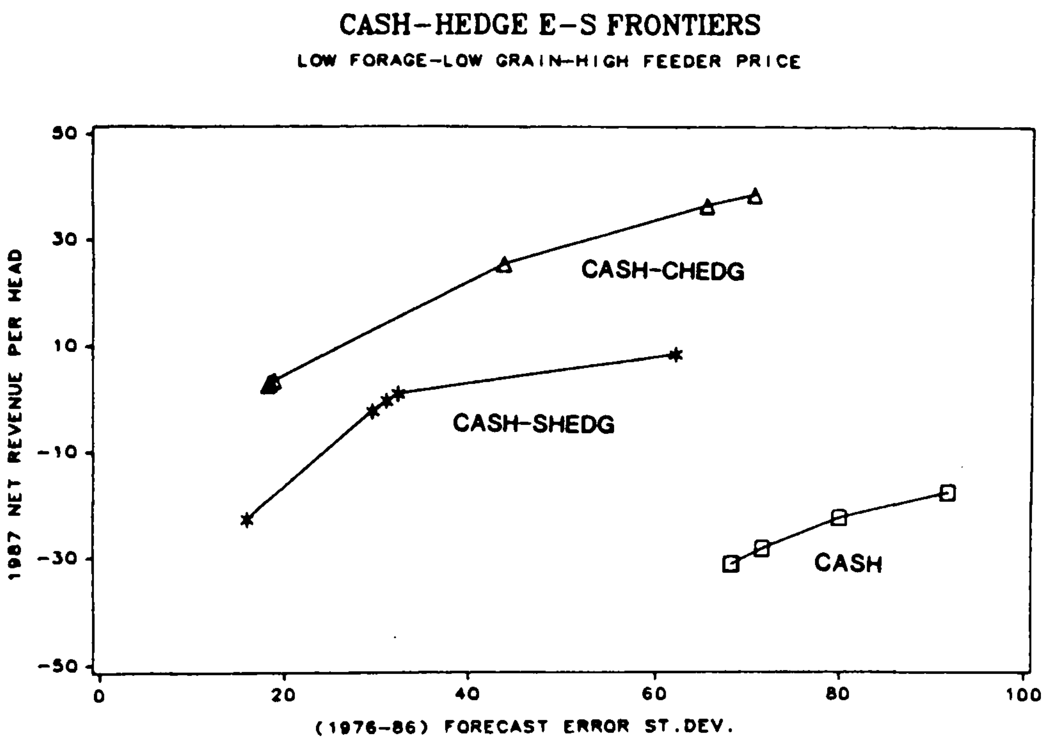


Figure D-2 Es Frontiers for CASH, CASH-SHEDG and CASH-CHEDG Risk Reducing Alternatives for Low Forage-Low Grain-High Feeder Prices

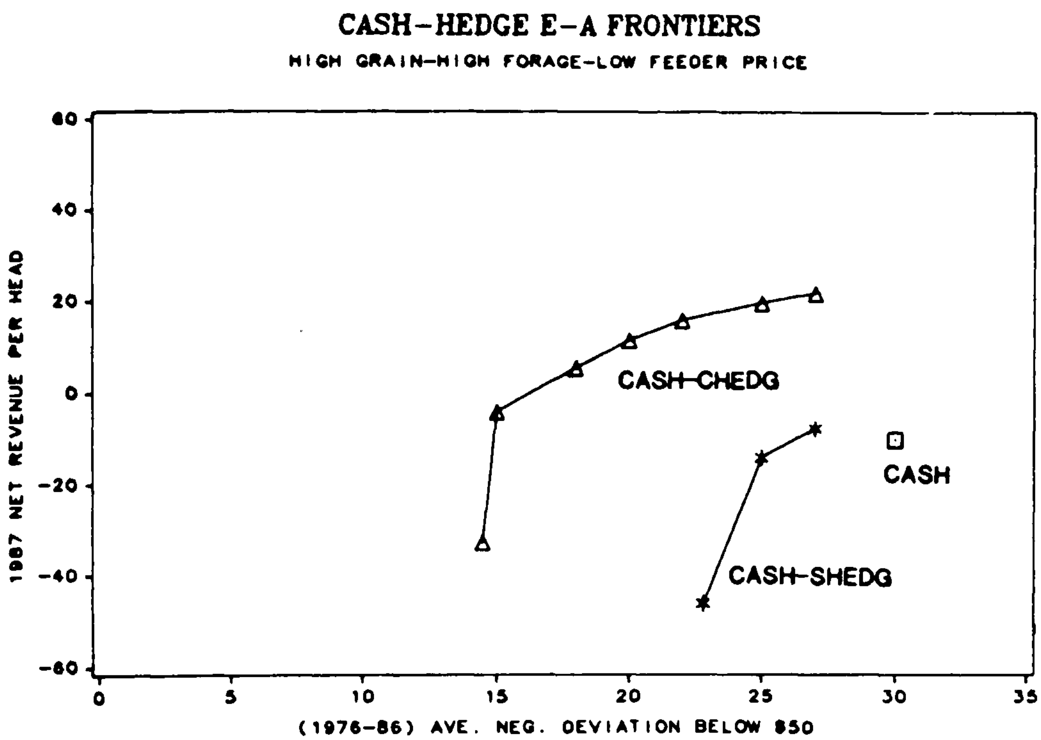


Figure D-3 EA Frontiers for CASH, CASH-SHEDG and CASH-CHEDG Risk Reducing Alternatives for High Forage-High Grain-Low Feeder Prices

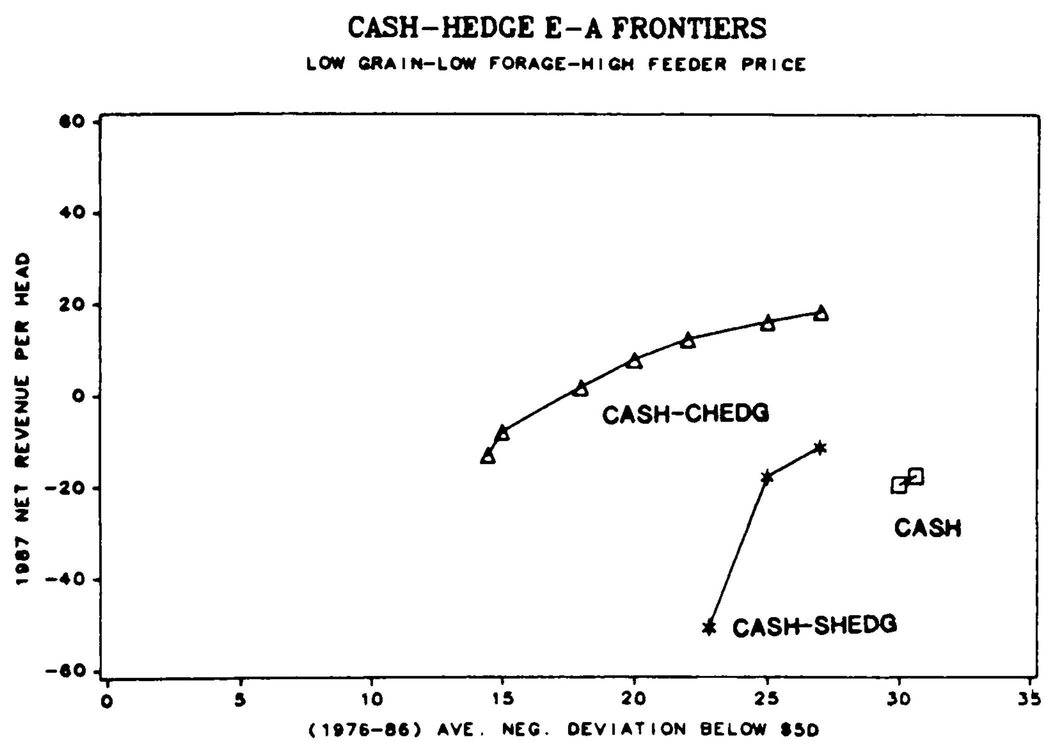


Figure D-4 EA Frontiers for CASH, CASH-SHEDG and CASH-CHEDG Risk Reducing Alternatives for Low Forage-Low Grain-High Feeder Prices

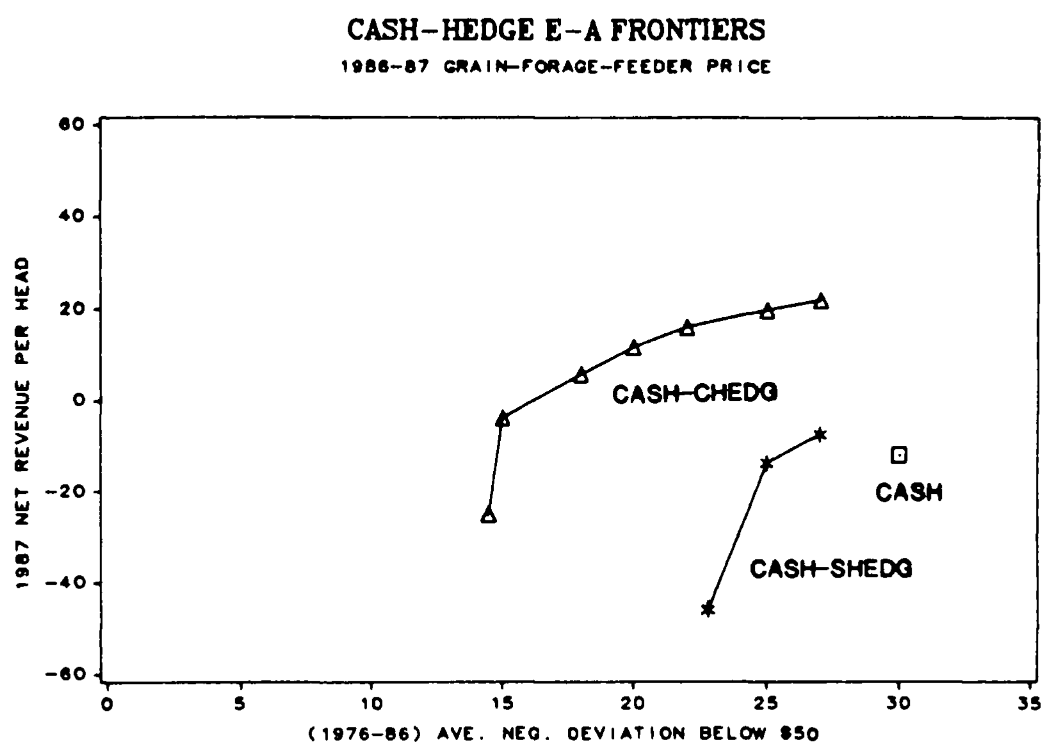


Figure D-5 EA Frontiers for CASH, CASH-SHEDG and CASH-CHEDG Risk Reducing Alternatives for 1986-87 Grain-Forage-Feeder Prices

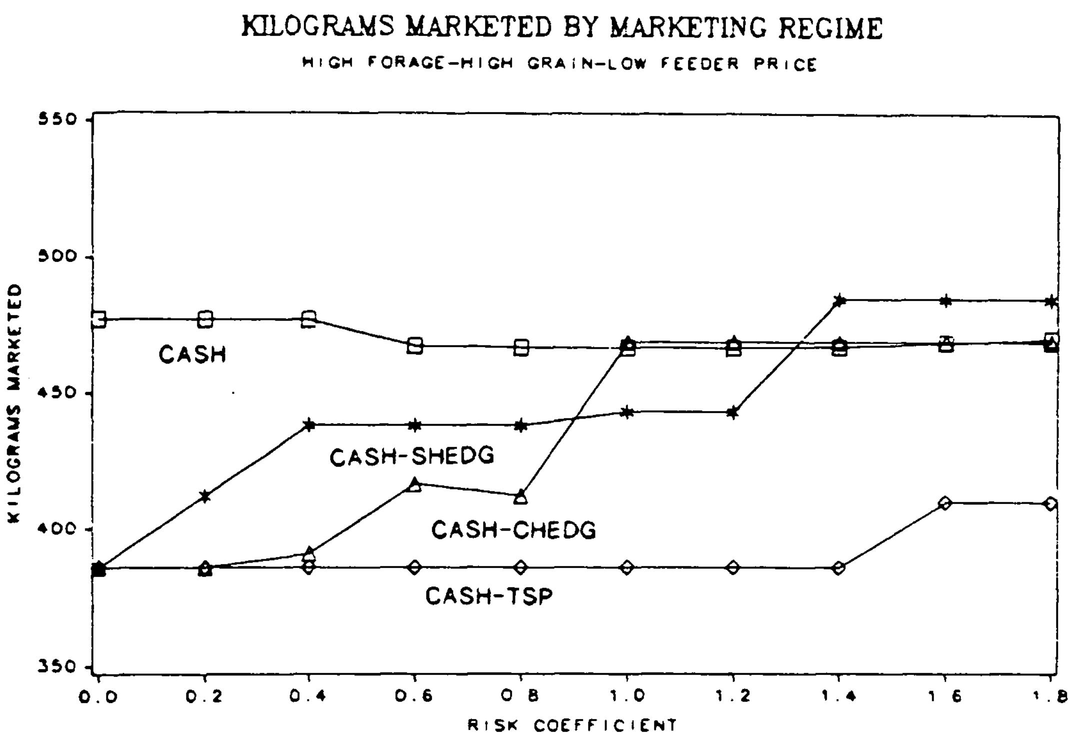


Figure D-6 Market Weight (Kilograms) by Marketing Regime for High Forage-High Grain-Low Feeder Prices

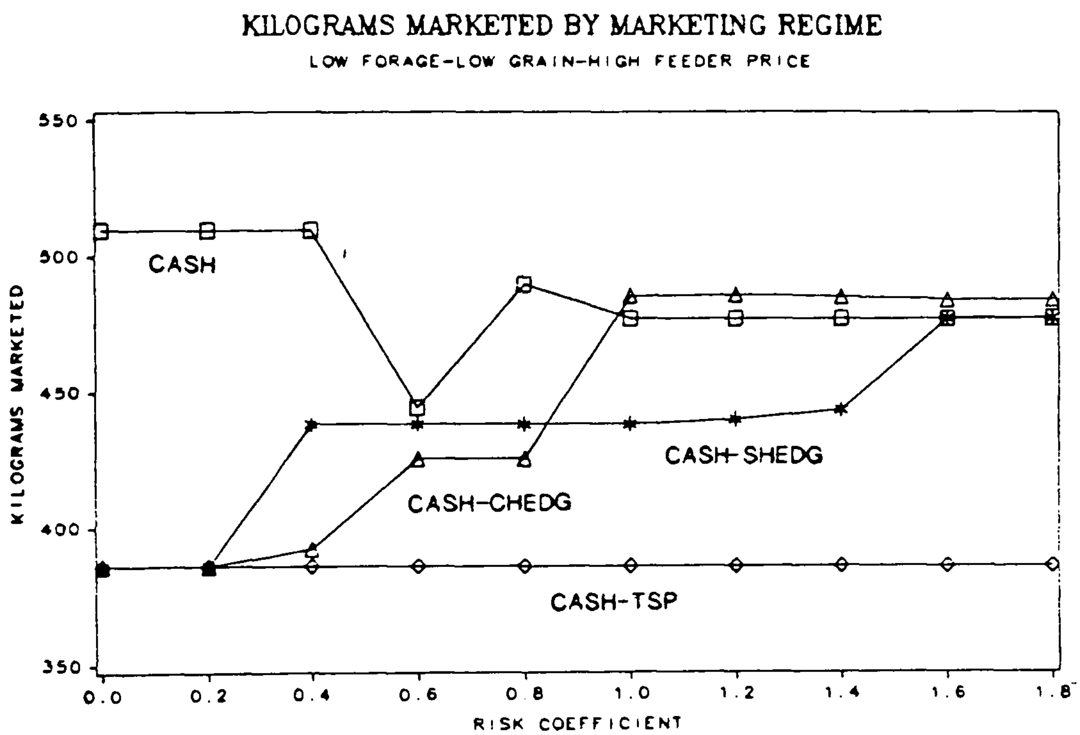
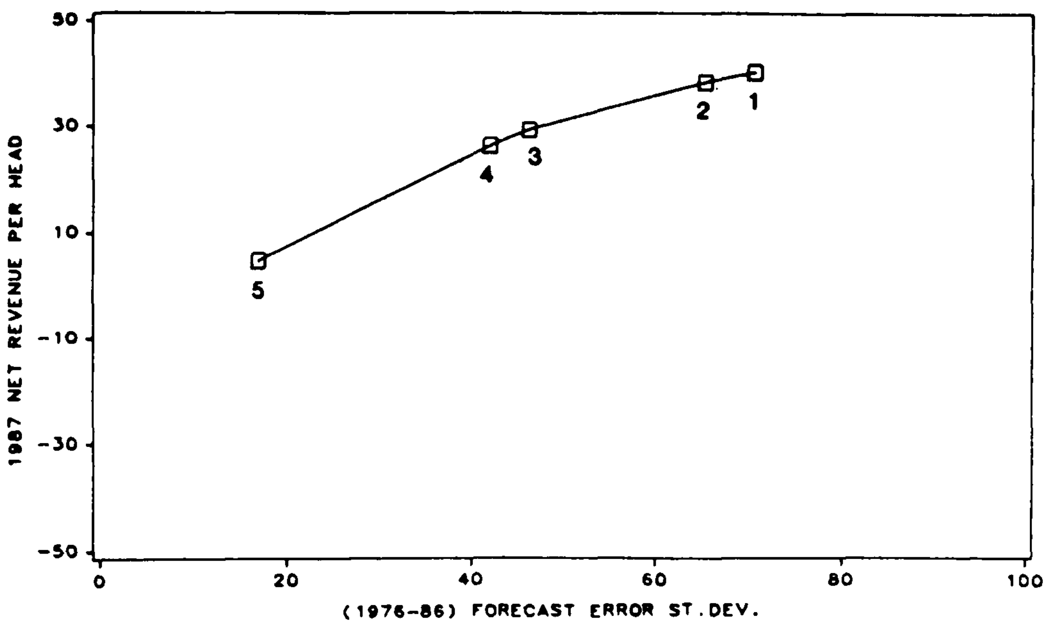


Figure D-7 Market Weight (Kilograms) by Marketing Regime for Low Forage-Low Grain-High Feeder Prices

COMPLETE E-S FRONTIERS

HIGH FORAGE-HIGH GRAIN-LOW FEEDER PRICE



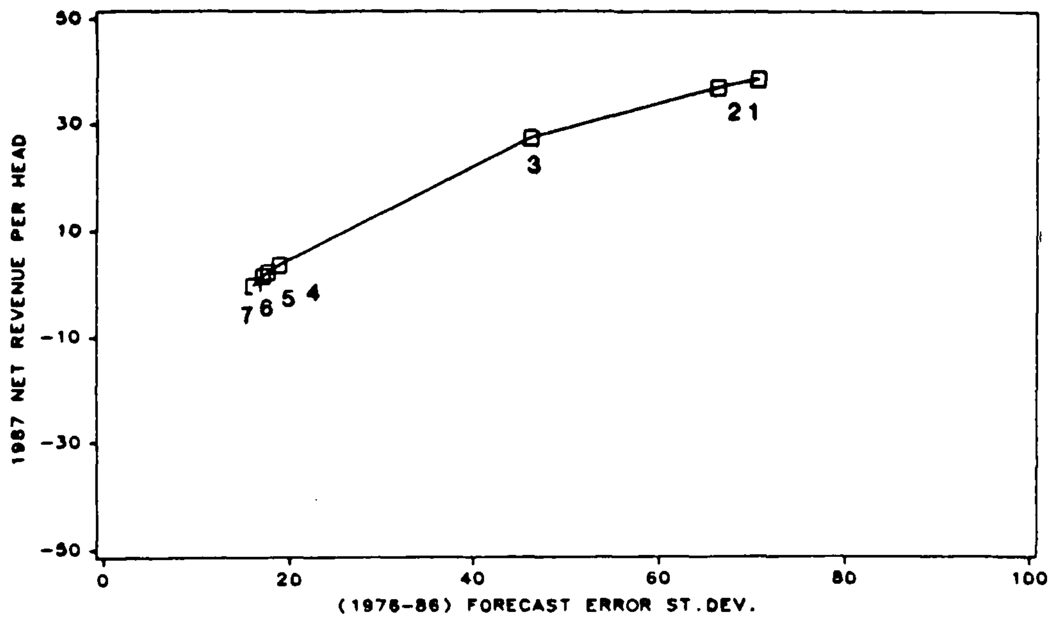
PERCENT OF CATTLE IN EACH FEEDING-MARKETING PLAN

		CASH	CHEDG	TSP	WEIGHT
1/	HHH1		100.000		386.0
2/	MMM	2.104			390.9
	HHH1		96.218		
	CHHH2	1.678			
3/	MMM	2.206			391.2
	HHH1		69.469	26.565	
	CHHH2	1.760			
4/	LMH	5.670			412.0
	MMM	17.904			
	HHH1		66.367		
	HHH2		10.059		
5/	LMH	12.062			463.5
	HHH1		31.987	16.515	
	HHH2		12.201		
	CHML		1.242		
	USHHH3		25.992		

Figure D-8 Complete Es Frontier for
High Forage-High Grain-Low Feeder Prices

COMPLETE E-S FRONTIERS

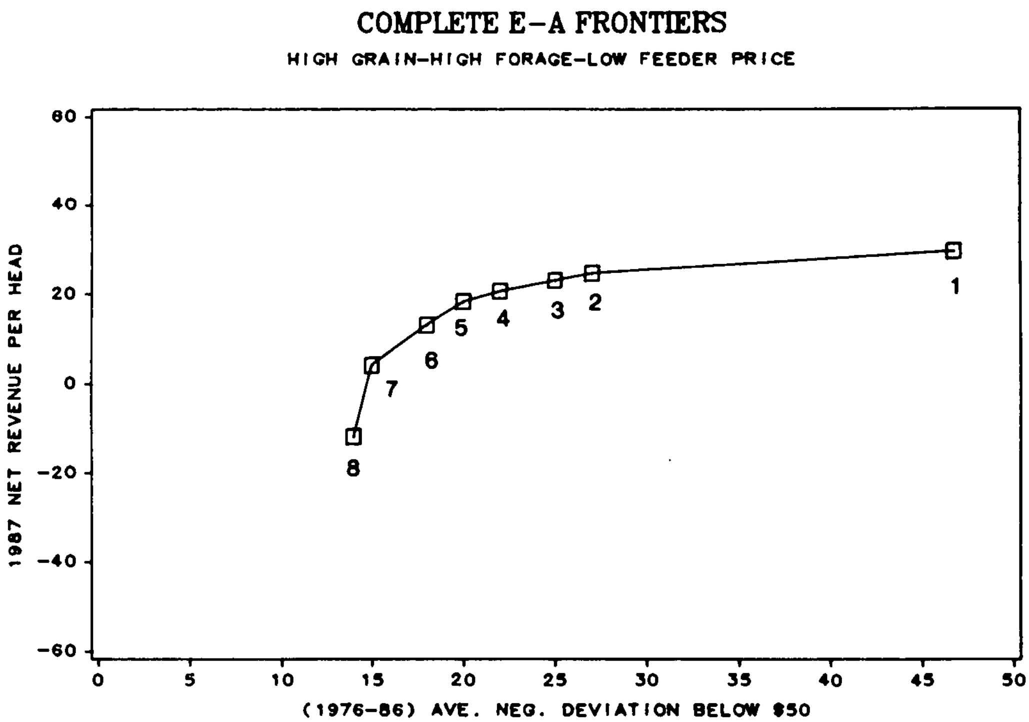
LOW FORAGE-LOW GRAIN-HIGH FEEDER PRICE



PERCENT OF CATTLE IN EACH FEEDING-MARKETING PLAN

		CASH	CHEDG	TSP	SHEDG	WEIGHT
1/	HHH1		100.000			386.0
2/	HHH1		97.243			391.6
	CHHH2	1.305				
	CHHH3			1.452		
3/	HHH1		69.764	26.410		392.9
	CHHH2	3.826				
4/	LMH	2.398				466.0
	HHH1		35.243	18.957		
	HHH2		11.073			
	CHHH2	2.091				
	USHHH3		30.239			
5/	LMH	7.887				472.2
	HHH1		33.181	10.485		
	HHH2		15.661			
	CHHH2	6.269				
	USHHH3		26.517			
6/	LMH	11.381				463.1
	HHH1		32.356	17.653		
	HHH2		11.684			
	USHHH3		26.927			
7/	LMH	10.922				463.7
	HML		3.869			
	HHH1		31.716	15.608		
	HHH2				7.186	
	USHHH3		25.726			

Figure D-9 Complete Es Frontiers for
Low Forage-Low Grain-High Feeder Prices



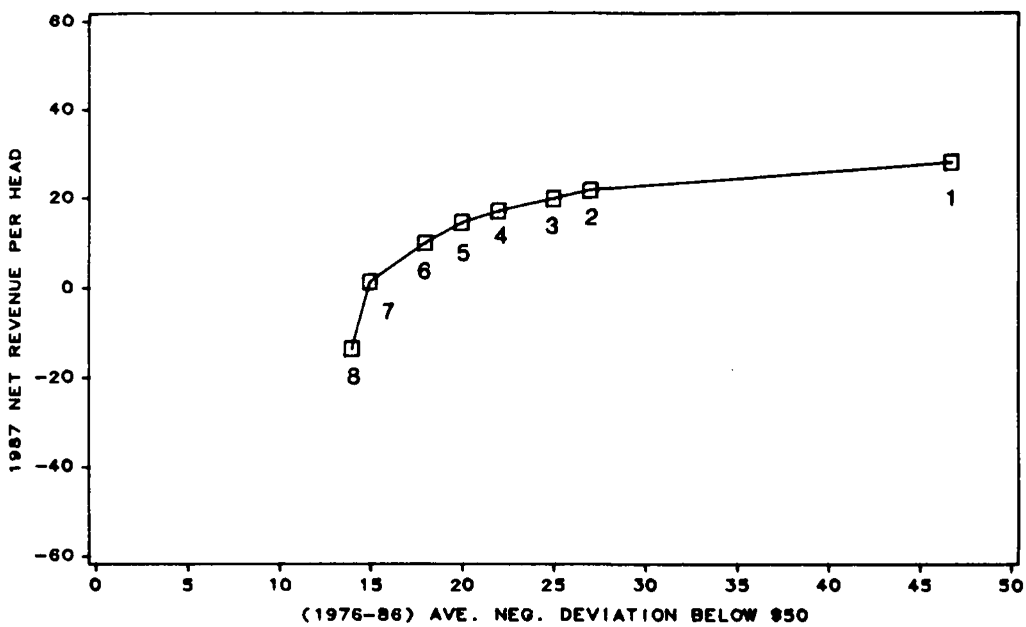
PERCENTAGE OF CATTLE IN EACH FEEDING-MARKETING PLAN

		CHEDG	TSP
1/	HHH1	100.000	
2/	MMM		31.218
	HHH1	47.661	
	HHH2	21.121	
3/	MMM		34.131
	HHH1	40.521	
	HHH2	25.348	
4/	MMM		38.121
	HHH1	27.700	
	HHH2	34.179	
5/	MMM		33.551
	HHH1	13.125	
	HHH2	46.659	
	CHHH2	6.665	
6/	MMM		9.070
	HHH1	12.238	
	HHH2	40.011	25.230
	CHHH2	13.450	
7/	HHH1	30.830	
	HHH2		47.862
	CHHH2	21.307	
8/	HHH1	18.275	
	HHH3		10.615
	CHHH2	71.111	

Figure D-10 Complete EA Frontiers for High Forage-High Grain-Low Feeder Prices

COMPLETE E-A FRONTIERS

LOW GRAIN-LOW FORAGE-HIGH FEEDER PRICE



PERCENTAGE OF CATTLE IN EACH FEEDING-MARKETING PLAN

		CHEDG	TSP
1/	HHH1	100.000	
2/	MMM		5.576
	HHH1	58.840	
	HHH2	10.774	
	CHHH2		24.810
3/	MMM		13.308
	HHH1	41.269	
	HHH2	26.620	
	CHHH2		18.803
4/	MMM		24.906
	HHH1	14.913	
	HHH2	50.388	
	CHHH2		9.793
5/	MMM		33.551
	HHH1	13.125	
	HHH2	46.659	
	CHHH2	6.665	
6/	MMM		6.575
	HHH1	10.596	
	HHH2	42.364	26.664
	CHHH2	13.801	
7/	HHH1	30.830	
	HHH2		47.862
	CHHH2	21.307	
8/	HHH1	18.275	
	HHH3		10.615
	CHHH2	71.111	

Figure D-11 Complete EA Frontiers for
Low Forage-Low Grain-High Feeder Prices

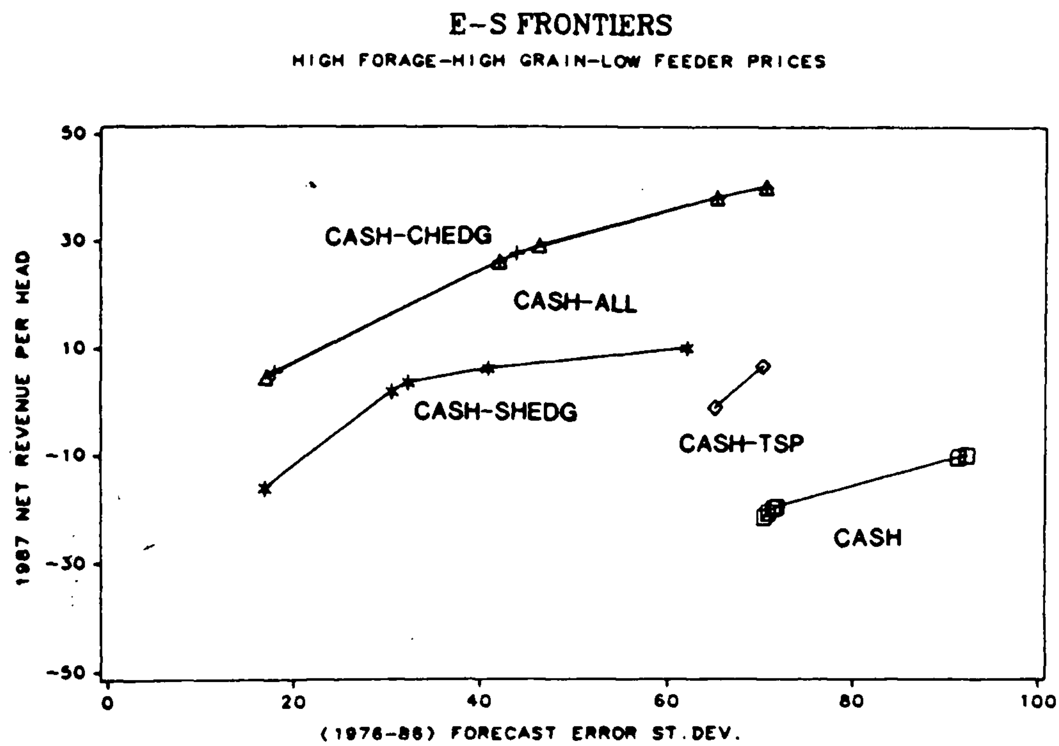


Figure D-12 Es Frontiers for All Risk Reducing Alternatives for High Forage-High Grain-Low Feeder Prices

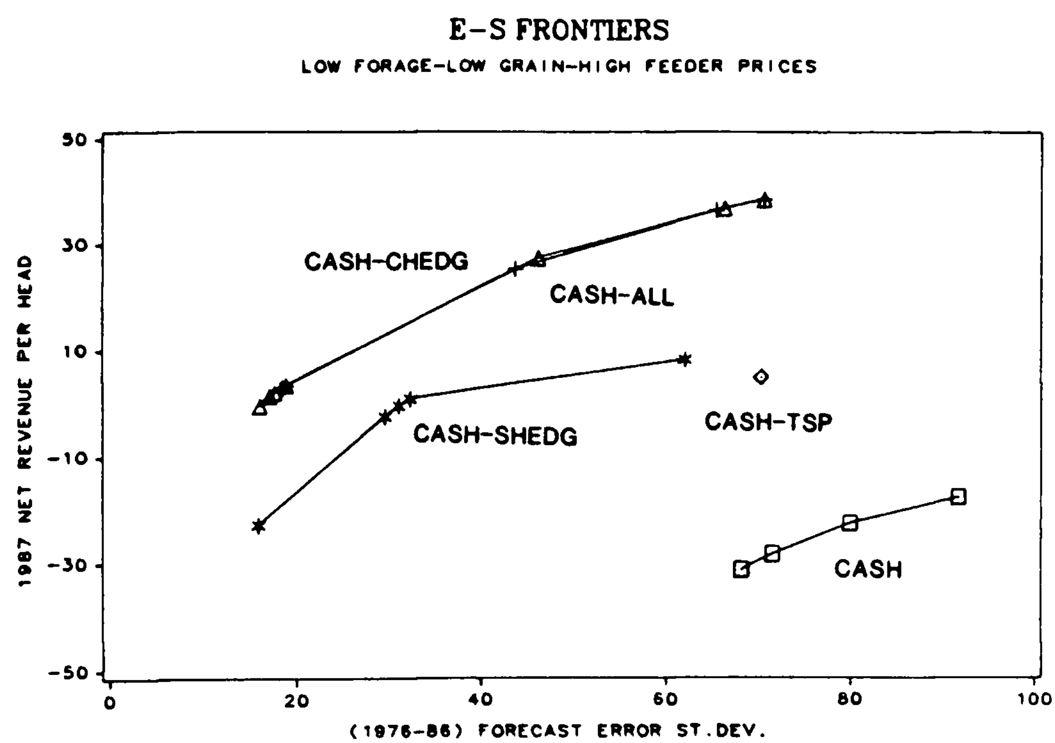


Figure D-13 Es Frontiers for All Risk Reducing Alternatives for Low Forage-Low Grain-High Feeder Prices

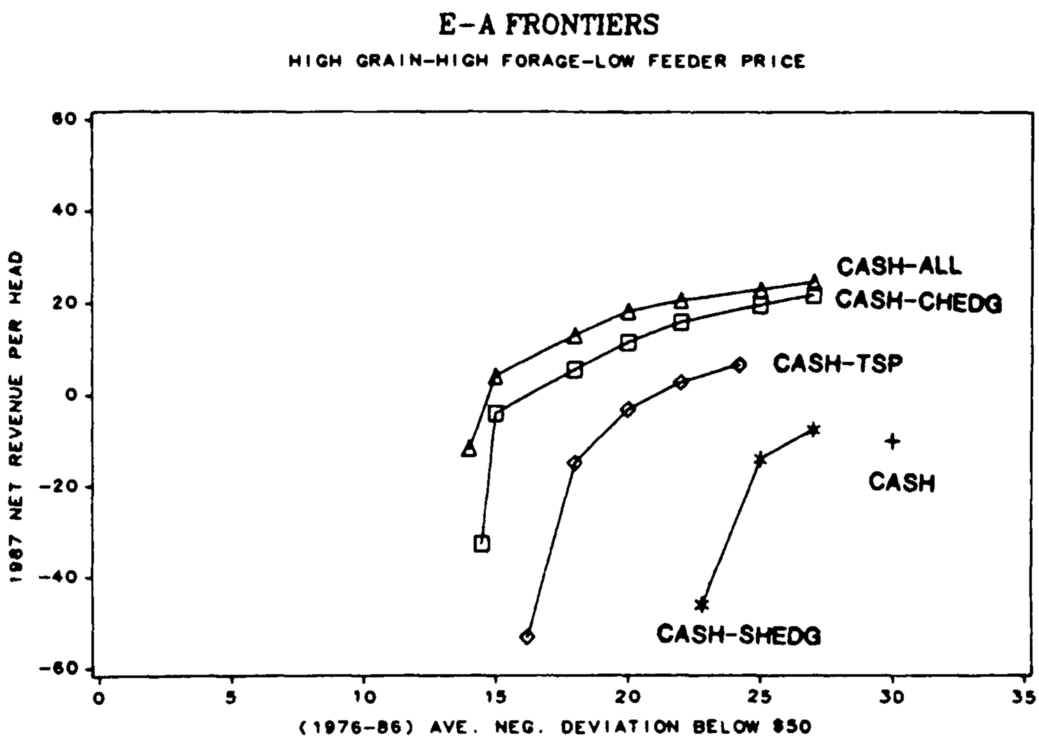


Figure D-14 EA Frontiers for All Risk Reducing Alternatives for High Forage-High Grain-Low Feeder Prices

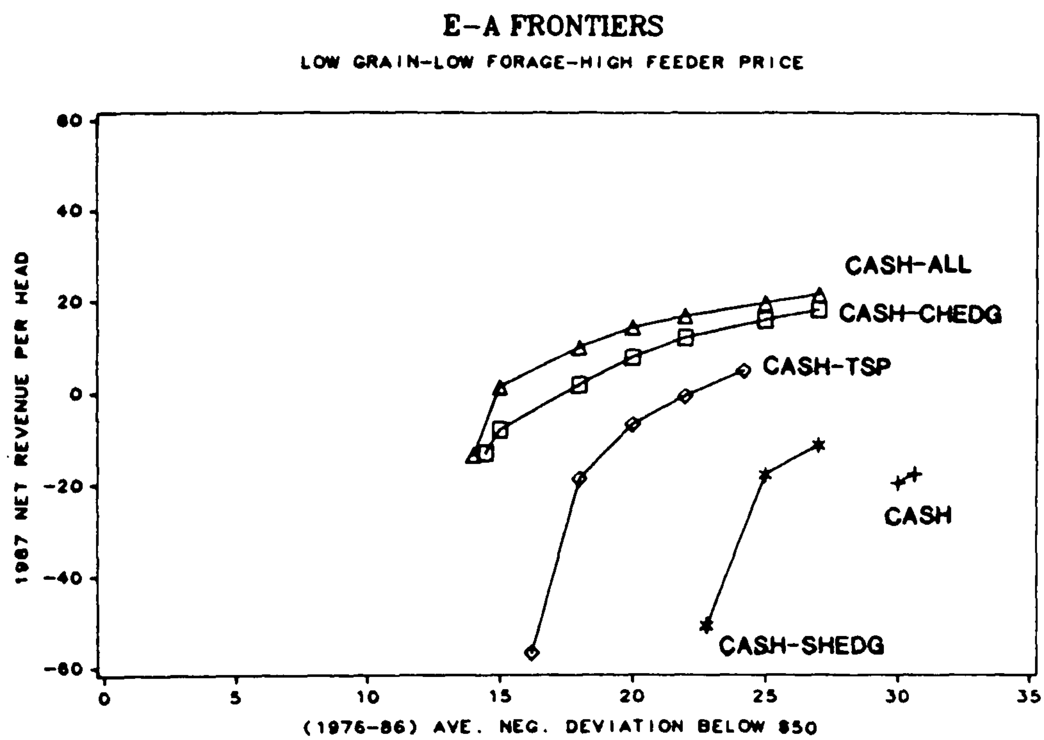


Figure D-15 EA Frontiers for All Risk Reducing Alternatives for Low Forage-Low Grain-High Feeder Prices