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by

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FOREWORD

This report covers an extension of some earlier research by the authors directed at construction of a practical sequential forecasting-programming model for individual beef feedlot activities and the related decisions on placements and sales over a planning period.

Although that model is appropriate for individual firm management decisions over time, the primary objective was to determine whether better forecasting and related programmed decisions could lead to significant profit gains over conventional cash marketing programs when general industry conditions cause high variation in price levels for slaughter cattle and their levels relative to feeder cattle. If the magnitudes of gain were significant, then the final objective was to alter the model to be the basis for a *general* feedlot advisory service that would be useful to *all* operators and not just a single firm.

This bulletin gives analytic information about the structure and use of the basic model and estimates a performance path for a recent period. The gains are significantly large and the pilot development of a "Beef Feedlot Advisory Report" has proceeded with financial support from a grant from the "Old West Regional Commission" during 1976-78.

SUMMARY AND CONCLUSIONS

This bulletin reports on a practical multi-period linear programming procedure as a management tool for decisions on placements and marketings for a beef feedlot operating over time under market uncertainty. Although the conclusions were based on application to an individual firm with uniqueness in time and space, the model should be equally appropriate for any firm's production and marketing decisions through time.

A hypothetical beef feedlot similar in feeding, equipment, and management structure to those operating in the Corn Belt provided the unit of analysis. Expected prices were forecasted for all different animal weight classes, corn, and protein supplement. Historical performances of the estimated optimal paths under uncertainty were evaluated by substituting realized prices for expected prices. The program-derived optimal time paths using expected prices with the respective cumulative net returns were compared to the test comparison and the hindsight optimum time path determined using realized prices to show what the maximum result could have been with perfect foresight. The model was run for two alternative placement-marketing conditions over a time period of 31 months from January, 1975 through July, 1977.

Special attention was given to subperiods of rising and falling price conditions. During the period of rising prices, the optimal strategy placed heavy feeder steers for two to three months duration.

Both strategies, optimal and standard, had positive performance in terms of growth of cumulative net returns. The optimal strategy outperformed the standard strategy by three times. During the period of falling slaughter cattle prices but still rising feeder cattle prices the optimal strategy had a positive cumulative net return whereas the standard strategy experienced a cumulative loss. During the period of falling prices the optimal strategy was on a break-even path in regard to the cumulative net return in contrast to the money-losing standard strategy.

The optimal strategy achieved its high performance through continuous re-evaluation after the initial expected production period based on the opportunity cost principle with the possibility of immediate (monthly) adjustment if the opportunity cost evidence indicated so and the inventory animals had been in the lot for at least 60 days. The introduction of marketing-weight limitations did not alter the optimal path during the study period. The standard strategy's mechanical placement-marketing pattern gave a weak performance even during strong market periods. The performance was disastrous during falling and/or unstable price conditions even though the underlying concept of a dynamic average profit realization over longer periods of time might be applicable.

The historical evidence from the 31-month study period supports the conclusion of the superiority of using imperfect forecasts of future prices and costs and a programming solution for the placement-marketing decisions. Disadvantages of following a mechanical placement-marketing pattern were clearly established.

A Forecasting-Programming Method For Placement-Sales Decisions For A Beef Feedlot

Franz Schwarz
and
J.B. Hassler[1]

INTRODUCTION AND PROBLEM SPECIFICATION

Nature of the Problem

Recurrent phenomena for the cattle feeder are the large fluctuations in price levels between years as well as within years for all weight classes and production stages. These large variations in animal prices over time have not been consistent with changes in the cost of production.

Feedlot operators have experienced excessive losses and profits over time. Feeder steers of 700 pounds (318 kg) fed to a slaughter weight of 1,050 pounds (476 kg) incurred losses up to $60 per animal when purchased during the last three months of 1962, the last half of 1963, April through October of 1966, April through August of 1970, and during August and September of 1973. The same classification of animals purchased during January through April of 1965, November 1968 through February 1969, and during February through June of 1972 returned profits of up to $70 per animal (14).

In general, large commercial feedlot operators have a preference for placing 600-700 pound (272-318 kg) cattle on feed, distributed evenly over the year with steers preferred to heifers.

Historical monthly average live marketing weights for all grades of steers and heifers at Omaha were compared to optimal marketing weights over the same time period. In the aggregate market the actual marketing weights did not conform with the imputed profitability of changing the live marketing weights. The variation in live marketing weights seemed to be associated more with seasonality than changes in the relative price structure. Feeding for constant market weights disregards possible changes in present and future price relationships. The feedlot producer does not significantly change the marketing

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weights and/or the placement weights to take advantage of future price changes and thereby improve his performance.

Risk and uncertainty are dominant characteristics of cattle feeding. Many production and marketing decisions made by the cattle feeder are clouded by uncertainty about feedlot performance and future feed, feeder, and slaughter cattle prices. When the cattle feeder has cattle at "market-ready" weights but is not sure whether to hold them longer or sell and replace with light cattle, he faces a combined marketing and placement decision. For instance, during 1972 with feeder cattle prices reaching unexpectedly high levels, feeders had to choose between replacing with high priced feeder cattle or holding the money-making cattle on feed to heavier weight.

The general problem is that of a producer with a specific cattle inventory and known current prices but uncertain future prices, having to decide whether to sell the whole or part of his inventory and replace with a single or a combination of different classes of animals or make no replacement in the present period, or keep the existing stock until some future period with replacement or no replacement occurring in this future period. Note that the time element enters at two levels: 1) the inventory on hand as well as the possible future placements are undergoing a growth process and 2) the decision process itself is executed over time, that is, implemented at specified time intervals. Decisions made in the present period should be jointly linked with possible decisions in future periods to maximize the stream of returns. Future periods should span a time interval sufficiently far ahead to accommodate the longest production activity under consideration. Future decision periods become present decision periods and new future decision periods must be considered by the manager as he operates through time. Estimated prices change with the passage of time for any particular future decision alternative or period.

The formulation of the decision process as an optimization problem involves four related components, namely, the strategy variables (inventory actions), the objective profit function, the constraints describing the physical changes in the production system over time, and the collection of information over time. Most popular models for optimizing decisions over time are multi-period linear programming and recursive linear programming models. These models are widely used in analyzing farm firm growth. More detailed information about the application of these models is available in the literature (7).

Objectives of the Study

Examination of these dynamic programming models indicated the need to develop a decision model incorporating the best features of these models and providing an optimal strategy for the above defined problem. Objectives of this study were:

1. To structure a dynamic decision model for a commerical cattle feedlot which conforms with economic theory and is as consistent as possible with reality.

2. To use and test this operational decision model during a recent period for the combined marketing and placement decision process and compare economic results with some standard operations.

To achieve these objectives, certain criteria for the model must be met. First, the model should be dynamic and stochastic because the decision process does not take place in an environment of certainty and statics. Secondly, the planning must span many periods, so that later period opportunities can bear on current decisions. Finally, the model should be operational in the sense that a solution is obtainable by means of mathematics and/or computer operations.

DESCRIPTION OF NUMERICAL MODEL AND SOLUTION FORMULATION

Firm Organization and Decision Model

This section describes the representative firm used in the analysis of the combined marketing and placement decision process. A later section will provide detailed explanation of the quantitative model.

The representative firm is a hypothetical beef feedlot with a structure not too different from what can be found anywhere in the United States. The figures used are assumed. However, it is believed that they are similar to those for commercial feedlots operating in the Corn Belt (see Appendix).

The management of the feedlot wishes to maximize the expected net return per unit of capacity through the combined marketing and placement decisions over a specified time period.[2] Expansion or contraction of the feedlot is not considered in this short-run analysis. For accounting purposes a capacity of 15,000 head was used, but under the assumption of constant returns and proportionality of inputs between 3,000 and 15,000 head the analysis could apply to any smaller units in that range. Furthermore, the entrepreneur has estimates of future prices, input as well as output prices (15). There are no credit limits to financing the current and future operation. Independent of operating level, fixed labor costs consisting of manager, assistant manager, and an office clerk will be charged to the firm. Additionally, half of the capital investment cost, half of the equipment and building repair cost and the cost of taxes and insurance on buildings and equipment are charged to unfilled space on a unit basis.[3]

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[2]The expected net returns are not discounted for time. They do, however, include interest charges on investment magnitudes over the projected time periods.

[3]It was assumed that physical deterioration and repair and maintenance costs could be halved when the facilities were idle compared to full usage.

Operating Rules

The assumed feedlot operating rules are as follows:

1. The decision to sell and replace is made at the beginning of each month, but execution of this decision occurs at the midpoint of the month.
2. Animals at all possible midmonth inventory weights are marketable commodities.
3. Once placed in the feedlot, the cattle must remain there for at least two calendar months before they can be sold.

The manager determines an ex ante plan for the combined marketing and placement alternatives over a 12-month decision period consistent with the operating rules. Although the decision-making period for the manager is restricted to 12 months, the terminal points of the production activities are at least 1, but may reach up to 11 months beyond the 12th month of the decision period. After 1 month (production period) has passed, the manager reformulates a new ex ante plan for a new 12-month decision horizon based on estimates for future prices.

The 12-month planning horizon was chosen to cover the longest possible current production activity (11 production periods) and still make a combined marketing and placement decision within the boundaries of the planning horizon.

The above outlined model can be approximated by a sequence of linear programming problems in which some of the right-hand side parameters depend on the primal solution of the preceding problem in the sequence. Consequently, the model describes how current plans are related to past expectations and actions. In addition to a dependence on preceding linear programming solutions, the current problem may depend on various exogenous or predetermined variables. One might summarize the meaning of the model as the strategy for optimizing over a limited time horizon on the basis of knowledge gained from new information and conditioned by past actions. To initiate solutions for this model one sets initial conditions from which the first decision period solution can be derived, and from which succeeding solutions may proceed.

Activities

Activities in the sequential model are established just as in a single period analysis through a budgeting procedure. The only difference is that production activities can extend over more than one period. The sequential decision model contains 1,140 activities for alternate uses of the available capacity over a decision time span of 12 months. The activities are set up with a decision period from the beginning of the month to the beginning of the next, while the production period starts in the middle of the month and lasts to the middle of the next or later months. Decisions are made and executed at the beginning of the respective defined decision periods.

For this particular decision model, the activities can be divided into three major categories: 1) unused space transfers—activities transferring unused space from initial condition as well as from one decision period to the next in the 12-month decision horizon, 2) decisions on current inventory—activities which consider the current combined marketing and placement decision given the inventory on hand, and 3) decisions on new placements—the activities which describe all possible future placement and marketing decisions in the realm of the 12-month decision span.

Unused Space Transfer. These activities provide the manager with the opportunity to leave feedlot space open at a cost of .62 dollars per unit of capacity per month. The unit cost figure is half of the capital investment cost, half of the equipment and building repair cost, the cost of taxes and insurance on building and equipment, and the fixed labor cost based on 1975 prices. In addition, a 0.375 percent per month inflation rate is assumed with the movement of the decision horizon over time.

Carrying Costs. Before a detailed description of the remaining activities can be given, the underlying assumptions and calculations of carrying costs (production costs) for the animals is appropriate because they are common to both categories of activities.

Non-feed Costs. Non-feed costs are based on 1975 prices with an adjustment over time of 0.375 percent per month reflecting the inflation rate. The figures are based on a 15,000 head capacity feedlot and calculated on a per animal basis. For the exact dollar amount for the individual categories of the non-feed costs see Appendix Table 1. In addition, property taxes are charged on January 1 holdings at a rate of 45 mills. Valuation for property tax purpose is based on 35 percent of the average actual value of cattle marketed at Omaha from November 1 to October 30, the past year, with the proper adjustments for the Property Tax Relief Act of 1971. Death losses are assumed to be 1.75 percent of accumulated carrying costs and the initial value of the animal. Interest is charged at a rate of 8.5 percent per annum on all non-feed and feed inputs. Medical expense is an estimate of the cost of the initial medication and any additional medication necessary for treatment of sickness after the cattle are placed on feed. Cost of the initial treatment is related to the animal's maturity and is $3.65 per animal for cattle less than 600 pounds (272 kg) and $2.80 for cattle more than 600 pounds (272 kg). A flat charge of $0.20 or $0.15 per animal per month is charged for the additional medication after the animals are placed on feed. The marketing expenses of selling the finished animals include transportation cost of $0.40 a hundredweight and $3.12 an animal for yardage and commission fees. The acquiring of the feeder animals is assumed to be direct buying.

Transportation cost to the feedlot is reflected in the price of the delivered animals.

Feed Cost. Feed requirements are based on two different rations. First, a ration for the growing stage (up to a weight of 700 pounds (318 kg) for steers and 640 pounds (290 kg) for heifers) using 50 percent (based on energy requirements for maintenance and growth) concentrate and, secondly, a ration for the fattening stage (animals over 700 pounds (318 kg) for steers and over 640 pounds (290 kg) for heifers) made up at least 80 percent (based on energy requirements for maintenance and growth) concentrate. The rations are computed by production periods according to the marginal gain by periods and the requirements are based on nutrient requirements of beef cattle established by the National Academy of Sciences (18). The established rations do not change over time. During the winter months (December, January, and February) the feed intake of corn for young animals and the intake of silage for older animals increased to secure the required growth. Corn is used as the primary concentrate and corn silage as the roughage.

The average daily gain for the growing stage is assumed to be 2.2 pounds (1.0 kg) per day for steers and 2.0 pounds (.9 kg) for heifers. In the fattening stage the average daily gain per animal varies from 2.6 pounds (1.2 kg) to 2.9 pounds (1.3 kg) per day for steers and 2.4 pounds (1.1 kg) to 2.7 (1.2 kg) pounds for heifers depending on their weight. For newly placed animals the average daily gain in the first month varies from 1.33 to 2.20 pounds (.6 to 1.0 kg) per day depending on weight and sex. For the exact numerical amount of feed intake and average daily gains per animal see Appendix Table 2 and Table 3. The monetary evaluation of the feed cost occurs monthly and is based on expected prices for corn and soybean meal. The monthly expected prices for corn, soybean meal, and corn silage were forecasted by sets of forecasting equations.

Decisions on Current Inventory. These activities allow the current inventory on hand to be put into the decision framework with the alternatives of immediate sale or sale in the future. The costs of arriving at the initial inventory levels have been in the past and have no bearing on the decision for alternative future terminal points of the current inventory. The estimated net additional returns from immediate sales of slaughter cattle in the current inventory are the marketing expenses and the additional net returns from immediate sales of feeder cattle in current inventory are zero.

The future marketing decision on current inventory is evaluated in the decision framework according to the contribution of net return to the space. The value of the contribution is expected gross revenue minus expected total production costs and minus expected value of current inventory. As mentioned earlier, the execution of the decision occurs two weeks after it is made. The valuation of current inventory must be based on expected prices. Expected gross revenue is equal to selling weight times the expected price for that particular weight class.

Decisions on New Placements. This category of activities encompasses all possible placement and marketing combinations during the 12-month decision span. Six possible placement weights for steers and five for heifers are assumed. Furthermore, the animals once bought have to be kept in production for at least two decision periods. The expected net return to the space is the criterion for the selection.

Table 1 presents the assumed weight classification of steers and heifers as possible current inventory, placement, and selling weights.

The activities correspond to all mathematical possibilities of combinations of inventory and/or placement weights and selling weights over the planning horizon. An 878 pound (398 kg) steer as the current inventory has six possible future terminal points, namely, sell now, 965 pounds (438 kg) in one month, 1,050 pounds (476 kg) in two months, 1,132 pounds (513 kg) in three months, 1,215 pounds (551 kg) in four months and 1,295 pounds (587 kg) in five months for selling the current inventory in the planning horizon. Likewise, the placing of 462 pound (210 kg) steer calves results in 10 possible terminal points within the 12-month decision period or in other words the animals can be sold any time within from 2 to 11 months.

Constraints

The rows of the matrix represent the possible distribution of the inventory on hand and the unused capacity which is available for use in the coming decisions periods. They are partially derived from the previous optimal solution in the sequence and the limitations for the period in the planning horizon. All the rows are specified as to their type, that is, they have an equality constraint meaning that the available resources, the inventory on hand, and the unused space, have to

Table 1. Inventory, placement, and selling weight classification for steers and heifers.

Classification Code	Mid-month inventory lb/animal (kg/animal)		Placement weights lb/animal (kg/animal)		Selling weights lb/animal (kg/animal)	
	steers	heifers	steers	heifers	steers	heifers
1	506 (230)	460 (209)	462 (210)	420 (191)	506 (230)	460 (209)
2	572 (259)	520 (236)	528 (239)	480 (218)	572 (259)	520 (236)
3	638(289)	580 (263)	656 (298)	598 (271)	638 (289)	580 (263)
4	704 (319)	640 (290)	728 (330)	663 (301)	704 (319)	640 (290)
5	791 (359)	721 (327)	812 (368)	743 (337)	791 (359)	721 (327)
6	878 (398)	802 (364)	899 (408)		878 (398)	802 (364)
7	965 (438)	880 (399)			965 (438)	880 (399)
8	1050 (476)	955 (433)			1050 (476)	955 (433)
9	1132 (513)	1029 (467)			1132 (513)	1029 (467)
10	1215 (551)				1215 (551)	1101 (499)
11					1295 (587)	

be used up either by active production activities or non-production activities (unused space transfer).

There are functionally two sets of constraint rows—the endogenously determined constraints in the sequence of the linear programming solutions (the current inventory and the current unused space in regard to the planning horizon) and the exogenously determined capacity limitations.

Solution Procedure

This section summarizes the solution procedures for the placement-marketing decision model.

The basic linear programming model encompasses a decision period of 12 months in advance. It consists of 34 rows and 1,140 columns with the "right hand side" (RHS) indicative of all possible inventory usage of current feedlot capacity and future capacity transitions. The columns are transfer and placement-sale activities with specific selling alternatives for all possible production programs. The C_j values represent the estimated net returns for these activities based on forecasted cattle and feed prices and other estimated non-feed and marketing costs. The longest activities require 12 monthly production periods and in conjunction with the 12-month planning horizon, forecasts of up to 2 years are necessary for the latest decisions. A file of sets of 1,140 different C_j's for each of the sequence of solutions was computed and ordered by a computer program for the 31 historical months covered.

Although the optimal solution for the first planning period indicates the entire optimal sequence of present and future activities for the first 12-month period, only those for the current month are activated and thereby generate (in conjunction with the old RHS) the new RHS for the next 12-month planning period. Because of these conditional inventories and newly forecasted prices and costs which alter the C_j values, the optimal solution for the second planning period can alter plans for some of the previous month's placements or continuations for future marketing points, including immediate sale and a new placement or leave-empty decision. This illustrates the dynamic nature of the sequenced poly-period programming approach.

It was stated that the sequence of RHS sets were related to prior solutions and old RHS values. Under the usual programming process it would have been necessary to stop, calculate the new RHS's and insert them manually for the next planning period. To avoid this and to achieve a more efficient way of arriving at the successive solutions, a MPSX control program was formulated for a sequential MPSX run with access to a Fortran routine. The Fortran routine calculates the new RHS from the level of last month's activities and the previous RHS, reads the respective set of C_j values and transfers the former and the latter into a revised file which is accessible to the MPSX routine in a repetitive fashion.

RESULTS AND PERFORMANCE EVALUATIONS

The model was run for two different situations and one starting position over a 31-month time period, from January, 1975, through July, 1977. The starting condition was an open feedlot. The freedom to select alternative activities was either constrained so that all sales were restricted to slaughter cattle weight groups or all activities as specified in the original formulation were free to compete for the available space and with a sale within two months or longer.

The optimal placement-marketing decision path for the feedlot was evaluated by substituting the actual prices and costs for the expected prices and costs to calculate the realized net returns over the 31-month period. The comparative standard for evaluating the performance of the optimal models was the performance of a standard strategy for the placement-marketing decisions. The accumulated realized net returns were used as the basic criteria for the performance comparisons. In calculating the realized net returns the same assumptions were applied for feed requirements, non-feed cost, property taxes and marketing cost as for the expected net return case.

There were some inherent simplifications in the evaluation procedure. The realized net returns reflected average conditions faced by an individual producer. No consideration was given to the fact that the actual conditions could deviate significantly from the average environmental situation for disease or weather conditions.

Solution for Standard Strategy

In the standard strategy's replacement decision process, the 15,000 head feedlot capacity contained five different inventory weight classes at one time. These five inventory weight classes at the middle of the current decision month were always 3,000 head of 791 pound (359 kg) Choice feeder steers, 3,000 head of 878 pound (398 kg) Choice feeder steers, 3,000 head of 965 pound (438 kg) Good slaughter steers, 3,000 head of 1,050 pound (476 kg) Choice slaughter steers and 3,000 head of 1,132 pound (513 kg) Choice slaughter steers.

The strategy was that each month over the 31-month evaluation period 3,000 head of 1,132 pound (513 kg) Choice slaughter steers were sold and replaced with 3,000 head of 728 pound (330 kg) Choice feeder steers. The feeding period for each 3,000 head replacement lot was five months resulting in 1,132 pound (513 kg) Choice slaughter steers. The accounting was handled as in a continuous operation with time referring to the month when the animals were marketed. The net return in January, 1975, is calculated as the gross revenue of a 1,132 pound (513 kg) Choice slaughter steer minus the purchase cost of a 728 pound (330 kg) Choice feeder steer in August, 1974, and minus the carrying costs for the five months. The net return figure in July, 1977, represents the net return from the sale of a 1,132 pound (513 kg) Choice slaughter steer sold in July which was placed on feed in February, 1977, as a 728 pound (330 kg) Choice feeder steer.

The feedlot operator started with five different inventory weight classes and employed a fixed placement-marketing strategy as described above. Table 2 provides a detailed accounting of this strategy for the number of cattle placed and sold, the purchase cost, the gross revenue, the production costs (feed cost and non-feed cost) and the net return to the feedlot for the month when the decision was made and the accumulated net returns to the feedlot through time.

The strategy performed well during the strong market period from April, 1975, through January, 1976 with rising slaughter and feeder cattle prices. Thirty thousand head were marketed with a cumulative net return to the feedlot of $3,101,580. During the first three months of 1975 and from February, 1976, through July, 1977, slaughter cattle prices were either falling and/or at relatively low levels with moderate fluctuations between months whereas feeder cattle prices experienced the decline six months later in June, 1976. The total cumulative net return to the feedlot from January, 1975, through March, 1975, was a loss of $692,850 and from February, 1976, through July, 1977, a loss of $2,205,860. The cumulative net return to the feedlot by the end of the study period in July, 1977, was a positive net return of $202,870.

Solution for Optimal Strategy (Condition I) (Using Forecasted Prices)

In developing an optimal strategy for the placement-marketing decision process for the individual feedlot operator all possible placement-marketing opportunities should be permitted to achieve the goal of maximizing the net returns over time. In this model all possible placement-marketing combinations were active in the linear-programming run. The initial condition was specified as an empty feedlot and the first decision to be derived was the placement in January, 1975.

Table 3 presents the optimal strategy with regard to the placement-marketing decisions and the performance evaluation by substituting realized prices for expected prices. The first column indicates the current month for each of the 31 planning months. The second column states the action taken and/or the state of the system for the current month sequentially through time. The meanings of the other columns are explained by the table headings.

For example, consider March, 1975, as the current month. The optimal strategy was to sell 15,000 head of 1,050 pound (476 kg)

Table 2. Net returns to the feedlot for standard strategy, in dollars.

Time	Action and/or situation[a]	No. of animals	Purchase cost	Gross revenue	Feed cost	Non/feed cost	Net return	Net returns to the feedlot[b]
				$/head			$/head	Dollars
1974								
Aug.	Place 728 lb Ch. F. St. (330 kg)	3,000	260.76					
Sept.	Place 728 lb Ch. F. St. (330 kg)	3,000	243.37					
Oct.	Place 728 lb Ch. F. St. (330 kg)	3,000	232.09					
Nov.	Place 728 lb Ch. F. St. (330 kg)	3,000	223.28					
Dec.	Place 728 lb Ch. F. St. (330 kg)	3,000	216.58					
1975								
Jan.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		413.18	191.77	48.23	−87.58	−262,740
	Place 728 lb Ch. F. St. (330 kg)	3,000	202.46					
Feb.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		393.94	189.13	49.22	−85.78	−257,340
	Place 728 lb Ch. F. St. (330 kg)	3,000	193.87					(−520,080)
Mar.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		405.26	183.89	46.87	−57.59	−172,770
	Place 728 lb Ch. F. St. (330 kg)	3,000	209.88					(−692,850)
Apr.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		478.04	173.94	47.72	33.10	99,300
	Place 728 lb Ch. F. St. (330 kg)	3,000	230.85					(−593,550)
May	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		558.75	165.95	48.91	127.31	381,930
	Place 728 lb Ch. F. St. (330 kg)	3,000	256.40					(−211,620)
June	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		599.73	159.63	45.45	192.19	576,570
	Place 728 lb Ch. F. St. (330 kg)	3,000	279.33					(364,950)
July	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		585.81	153.43	44.70	193.81	581,430
	Place 728 lb Ch. F. St. (330 kg)	3,000	258.44					(946,380)
Aug.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		548.67	152.42	44.54	141.83	425,490
	Place 728 lb Ch. F. St. (330 kg)	3,000	242.06					(1,371,870)
Sept.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		562.60	156.93	45.62	129.20	387,600
	Place 728 lb Ch. F. St. (330 kg)	3,000	282.10					(1,759,470)
Oct.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		556.83	158.73	46.46	95.24	285,720
	Place 728 lb Ch. F. St. (330 kg)	3,000	285.08					(2,045,190)

Table 2—Continued

Time	Action and/or situation[a]	No. of animals	Purchase cost	Gross revenue	Feed cost	Non/feed cost	Net return	Net returns to the feedlot[b]
				$/head			$/head	Dollars
Nov.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		522.98	157.82	46.73	39.10	117,300
	Place 728 lb Ch. F. St. (330 kg)	3,000	285.52					(2,162,490)
Dec.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		503.17	153.86	45.62	45.25	135,750
	Place 728 lb Ch. F. St. (330 kg)	3,000	285.08					(2,298,240)
1976								
Jan.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		477.48	151.21	47.38	36.83	110,490
	Place 728 lb Ch. F. St. (330 kg)	3,000	281.95					(2,408,730)
Feb.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		440.57	147.14	48.01	−36.68	−110,040
	Place 728 lb Ch. F. St. (330 kg)	3,000	292.80					(2,298,690)
Mar.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		400.61	144.91	47.34	−76.72	−230,160
	Place 728 lb Ch. F. St. (330 kg)	3,000	293.97					(2,068,530)
Apr.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		470.68	142.94	47.38	−5.16	−15,480
	Place 728 lb Ch. F. St. (330 kg)	3,000	322.07					(2,053,050)
May	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		464.23	142.96	47.28	−11.09	−33,270
	Place 728 lb Ch. F. St. (330 kg)	3,000	327.38					(2,019,780)
June	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		451.67	143.07	45.27	−18.62	−55,860
	Place 728 lb Ch. F. St. (330 kg)	3,000	296.66					(1,963,920)
July	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		426.54	145.56	45.19	−57.01	−170,030
	Place 728 lb Ch. F. St. (330 kg)	3,000	298.41					(1,793,890)
Aug.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		414.31	150.08	45.06	−74.80	−224,400
	Place 728 lb Ch. F. St. (330 kg)	3,000	297.82					(1,569,490)
Sept.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		417.71	150.52	46.22	−101.10	−303,300
	Place 728 lb Ch. F. St. (330 kg)	3,000	268.92					(1,266,190)
Oct.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		423.25	156.32	46.63	−107.08	−321,240
	Place 728 lb Ch. F. St. (330 kg)	3,000	278.46					(944,950)

Table 2—Continued

Time	Action and/or situation[a]	No. of animals	Purchase cost	Gross revenue	Feed cost	Non/feed cost	Net return	Net returns to the feedlot[b]
				$/head			$/head	Dollars
Nov.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		442.49	153.79	45.90	−53.86	−161,580
	Place 728 lb Ch. F. St. (330 kg)	3,000	279.19					(783,370)
Dec.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		452.01	145.71	46.06	−38.17	−114,510
	Place 728 lb Ch. F. St. (330 kg)	3,000	282.46					(668,860)
1977								
Jan.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		436.61	140.45	45.61	−47.27	−141,816
	Place 728 lb Ch. F. St. (330 kg)	3,000	293.38					(527,050)
Feb.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		430.61	138.89	44.35	−21.55	−64,656
	Place 728 lb Ch. F. St. (330 kg)	3,000	288.29					(462,400)
Mar.	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		420.88	137.97	44.40	−39.95	−119,850
	Place 728 lb Ch. F. St. (330 kg)	3,000	296.22					(342,550)
Apr.	Sell 1132 lb Ch. Sl. St. (513 kg)	3,000		447.59	139.19	44.93	−15.72	−47,160
	Place 728 lb Ch. F. St. (330 kg)	3,000						(295,390)
May	Sell 1132 lb Ch. Sl. St. (513 kg)	3,000		473.40	142.30	45.62	3.02	9,060
	Place 728 lb Ch. F. St. (330 kg)	3,000						(304,450)
June	Sell 1,132 lb Ch. Sl. St. (513 kg)	3,000		451.78	141.35	45.68	−28.63	−85,890
	Place 728 lb Ch. F. St. (330 kg)	3,000						(218,560)
July	Sell 1132 lb Ch. Sl. St. (513 kg)	3,000		466.16	137.43	45.67	−5.23	−15,690
								(202,870)

[a]Abbreviations used are as follows: Ch. = Choice Grade
F. = Feeder Cattle
Sl. = Slaughter Cattle
St. = Steer
H. = Heifers

[b]The numbers in parentheses are the cumulative net returns over time.

Choice slaughter steers which were placed on feed in January, 1975, as 899 pound (408 kg) Choice feeder steers and to place 15,000 head of 899 pound (408 kg) Choice feeder steers. The evaluation of the combined placement-marketing decision is in columns 4 through 9. The animals were purchased in January, 1975, at a cost of $215.76 per head. The gross revenue resulting from the sale was $375.69 per head. The production costs for the two-month feeding period were $72.22 per head for feed cost and $25.76 per head for non-feed cost resulting in a positive net return of $61.95 per head or a positive net return of $929,250 to the feedlot.

From January through September, 1975, the estimated optimal path placed heavy feeder steers (899 pound (408 kg) Choice) for two production periods for sale as 1,050 pound (476 kg) Choice slaughter steers. The cumulative realized net return to the feedlot using the estimated optimal path would have been $6,367,050 by September, 1975. The estimated optimal path left the feedlot empty at a cumulative cost of $48,450 from September, 1975, until February, 1976. In February, 1976, 743 pound (337 kg) Choice feeder heifers were placed on feed and sold as 955 pound (433 kg) Choice slaughter heifers in May, 1976, with a contribution of $14.88 per head to the cumulative net return. The estimated optimal path left the feedlot empty until December, 1976, at a cumulative cost of $69,900. In December, 1976, 812 pound (368 kg) Choice feeder steers were placed on feed and sold in June, 1976, as 1,295 pound (587 kg) Prime slaughter steers with a realized net return of $2.54 per head. At the end of the study period, July, 1977, the estimated optimal path intended to sell the June placement of 899 pound (408 kg) Choice feeder steers in August as 1,050 pound (476 kg) Choice slaughter steers. Because the terminal point lies outside the study period it is assumed that the July decision would have not been revised in August and the realized net return for July was calculated as a monthly average. The performance of the estimated optimal path with no placement and/or marketing restrictions would have been a cumulative net return of $6,518,100 by July, 1977.

Solution for Optimal Strategy (Condition II) (Using Forecasted Prices)

Under Condition II a marketable animal was defined as being of slaughter weight, that is 965 pounds (438 kg) or more for steers and 880 pounds (399 kg) or more for heifers. All activities allowing a sale below these weight classes were bound at zero levels. The initial condition in January, 1975 was an open feedlot.

The decision path and the realized net returns under Condition II were the same as under Condition I during the study period but unpublished work done by the authors substantiates the inclusion of this strategy alternative (16,17).

Table 3. Net returns to the feedlot for optimal strategy (conditionI), in dollars.

Time	Action and/or situation[a]	No. of animals	Purchase cost	Gross revenue	Feed cost	Non/feed cost	Net return	Net returns to the feedlot[b]
			$/head				$/head	Dollars
1975								
Jan.	Place 899 lb Ch. F. St. (408 kg)	15,000	215.76					
Feb.	C. Inv. 965 lb G. Sl. St. (438 kg)	15,000						
	Continue feeding							
Mar.	Sell 1,050 lb Ch. Sl. St. (476 kg)	15,000		375.69	72.22	25.76	61.95	929,250
	Place 899 lb Ch. F. St. (408 kg)	15,000	264.48					
Apr.	C. Inv. 965 lb G. Sl. St. (438 kg)	15,000						
	Continue feeding							
May	Sell 1,050 lb Ch. Sl. St. (476 kg)	15,000		512.72	61.84	28.74	157.66	2,364,900
	Place 899 lb Ch. F. St. (408 kg)	15,000	338.65					(3,294,150)
June	C. Inv. 965 lb G. Sl. St. (438 kg)	15,000						
	Continue feeding							
July	Sell 1,050 lb Ch. Sl. St. (476 kg)	15,000		531.51	63.84	30.14	98.88	1,483,200
	Place 899 lb Ch. F. St. (408 kg)	15,000	298.56					(4,777,350)
Aug.	C. Inv. 965 lb G. Sl. St. (438 kg)	15,000						
	Continue feeding							
Sept.	Sell 1,050 lb Ch. Sl. St. (476 kg)	15,000		501.69	68.07	29.08	105.98	1,589,700
	Keep empty							(6,367,050)
Oct.	Empty feedlot					.64	−.64	−9,600
	Keep empty							(6,357,450)
Nov.	Empty feedlot					.64	−.64	−9,600
	Keep empty							(6,347,850)
Dec.	Empty feedlot					.65	−.65	−9,750
	Keep empty							(6,338,100)

Table 3—Continued

Time	Action and/or situation[a]	No. of animals	Purchase cost	Gross revenue	Feed cost	Non/feed cost	Net return	Net returns to the feedlot[b]
				$/head			$/head	Dollars
1976								
Jan.	Empty feedlot					.65	−.65	−9,750
	Keep empty							(6,328,350)
Feb.	Empty feedlot					.65	−.65	−9,750
	Place 743 lb Ch. H.F. (337 kg)	15,000	259.08					(6,318,600)
Mar.	C. Inv. 802 lb Ch. F.H. 364 kg)	15,000						
	Continue feeding							
Apr.	C. Inv. 880 lb G. Sl. H. (399 kg)							
	Continue feeding	15,000						
May	Sell 955 lb Ch. Sl. H. (433 kg)	15,000		387.06	81.78	31.32	14,88	223,200
	Keep empty							(6,541,800)
June	Empty feedlot					.66	−.66	−9,900
	Keep empty							(6,531,900)
1976								
July	Empty feedlot					.66	−.66	−9,000
	Keep empty							(6,522,000)
Aug.	Empty feedlot					.66	−.66	−9,900
	Keep empty							(6,512,100)
Sept.	Empty feedlot					.67	−.67	−10,050
	Keep empty							(6,502,050)
Oct.	Empty feedlot					.67	−.67	−10,050
	Keep empty							(6,492,000)
Nov.	Empty feedlot					.67	−.67	−10,050
	Keep empty							(6,481,950)
Dec.	Empty feedlot					.67	−.67	−10,050
	Place 812 lb Ch. F. St. (368 kg)	15,000	291.51					(6,471,900)

Table 3—Continued

Time	Action and/or situation[a]	No. of animals	Purchase cost	Gross revenue	Feed cost	Non/feed cost	Net return	Net returns to the feedlot[b]
				$/head			$/head	Dollars
1977								
Jan.	C. Inv. 878 lb Ch. F. St. (398 kg)	15,000						
	Continue feeding							
Feb.	C. Inv. 965 lb G. Sl. St. (438 kg)	15,000						
	Continue feeding							
Mar.	C. Inv. 1,050 lb Ch. Sl. St. (476kg)	15,000						
	Continue feeding							
Apr.	C. Inv. 1,132 lb Ch. Sl. St. (513kg)	15,000						
	Continue feeding							
May	C. Inv. 1,215 lb Ch. Sl. St. (551kg)	15,000						
	Continue feeding							
June	Sell 1,295 lb P. Sl. St. (587 kg)	15,000		530.30	181.87	54.38	2.54	38,100
	Place 899 lb Ch. F. St. (408 kg)	15,000	341.17					(6,516,000)
July[c]	C. Inv. 965 lb G. Sl. St. (438 kg)	15,000					.54	8,100
	Continue feeding							(6,518,100)

[a]Abbreviations used are as follows: P = Prime Grade
Ch. = Choice Grade
G. = Good Grade
F. = Feeder Cattle
Sl. = Slaughter Cattle
St. = Steers
H. = Heifers
C. Inv. = Current Inventory

[b]The numbers in parentheses are the cumulative net returns over time.

[c]Allocation for the month of July for a prospective sale in August of 1050 pounds.

Solution for Optimal Strategy Under Price Certainty

The models (Condition I and Condition II) with no marketing restrictions and marketing restrictions, respectively, were run assuming certainty of prices. The expected coefficients of the objective function variables in the linear programming model were replaced by estimated returns based on realized prices and costs. The purpose was to determine with hindsight what the absolute optimal decision path and the performance for the feedlot operator could have been, if he had correct knowledge of future prices, cattle as well as input prices. The same physiological and technical requirements were assumed to prevail as in the models under forecasted prices.

Table 4 presents the optimal decision path with the respective net returns to the feedlot under no marketing restrictions. Only the beginning and terminal months of the activities are reported with their numerical evaluation. During the strong market period up to December, 1975, the cumulative net return to the feedlot was $7,200,000. The preferred placements were heavy feeder steers of two to three months duration. In December, 1975, 420 pound (191 kg) Choice heifer calves were placed and sold in July, 1976, as 802 pound (364 kg) Choice heifer feeders. The feedlot was empty during July, 1976 and August, 1976. In September, 1976, and January, 1977, heavy feeder steers were placed on feed for two and three months, respectively, with the feedlot kept empty in December, 1976, and May, 1977. In June, 1977, 462 pound (210 kg) Choice steer calves were placed for sale as 1,295 pound (587 kg) Prime slaughter steers in May, 1978. With hindsight, the highest net returns would have been earned by the feedlot operator by exploiting the price changes associated with changes in grades in conjunction with the proper timing of the placements.

In Table 5 the optimal decision path with the respective net returns to the feedlot under the marketing restrictions is reported. The optimal path of the certainty model under Condition II was the same as under Condition I with the exception of the December, 1975, placement. Instead of heifer calves being placed for seven months (December through July), the certainty model under Condition II placed heifer feeders for five months for sale as slaughter heifers in May, 1976, and left the feedlot empty during the remaining two months, May and June, 1976. The imposition of the marketing constraints knowing future prices and costs for certain was a cost to the feedlot of $205,950, compared to the unrestricted solution.

Performance Evaluation of the Optimal Strategies under Uncertainty

This study has concentrated on developing a computerized decision model for a cattle feeding firm for practical management pur-

Table 4. Net returns to the feedlot for optimal strategy under no marketing restrictions and certain prices, in dollars.

Time (Yr-Mo)	Action and/or situation[a]	No. of animals	Net return dollars/head	Net return to the feedlot/dollars[b]
1975				
Jan.	Place 899 lb (408 kg) Ch. F. Steers	15,000		
Mar.	Sell 1,050 lb (476 kg) Ch. Sl. Steers	15,000	61.95	929,250
	Place 899 lb (408 kg) Ch. F. Steers	15,000		
May	Sell 1,050 lb (476 kg) Ch. Sl. Steers	15,000	157.66	2,369,900
	Place 899 lb (408 kg) Ch. F. Steers	15,000		(3,294,150)
July	Sell 1,050 lb (476 kg) Ch. Sl. Steers	15,000	98.88	1,483,200
	Place 899 lb (408 kg) Ch. F. Steers	15,000		(4,777,350)
Oct.	Sell 1,132 lb (513 kg) Ch. Sl. Steers	15,000	108.40	1,626,000
	Place 899 lb (408 kg) Ch. F. Steers	15,000		(6,403,350)
Dec.	Sell 1,050 lb (476 kg) Ch. Sl. Steers	15,000	53.11	796,650
1976				
Jan.	Place 420 lb (181 kg) Ch. C. Hfrs	15,000		(7,200,000)
July	Sell 802 lb (364 kg) Ch. H. Feeders	15,000	28.20	423,000
	Leave feedlot empty			(7,623,000)
Aug.	Empty feedlot		−.66	−9,900
	Leave feedlot empty			(7,613,100)
Sept.	Empty feedlot		−.66	−9,900
	Place 812 lb (368 kg) Ch. F. Steers	15,000		(7,603,200)
Dec.	Sell 1,050 lb (476 kg) Ch. Sl. Steers	15,000	21.38	320,700
	Leave feedlot empty			(7,923,900)
1977				
Jan.	Empty feedlot		−.67	−10,050
	Place 812 lb (368 kg) Ch. F. Steers	15,000		(7,913,850)
May	Sell 1,132 lb (513 kg) Ch. Sl. Steers	15,000	29.61	444,150
	Leave feedlot empty			(8,358,000)
June	Empty feedlot		−.67	−10,050
	Place 462 lb (210 kg) Ch. C. Steers	15,000		(8,347,950)
July	Continue feeding	15,000	20.31[c]	304,650
				(8,652,600)

[a]Abbreviations used are as follows: Ch. = Choice Grade
C. = Calf
F. = Feeder
Sl. = Slaughter

[b]The numbers in parentheses are the cumulative net returns over time.

[c]Average monthly contribution to net return for sale as 1295 pound (587 kg) prime slaughter steers in May, 1978.

poses over time. Accordingly, the operational model must approximate the framework within which the decisions are actually made, so that it can be used in actual practice. Because of the nature of the model, it is contended that the procedure of historical validation is sufficient for comparative performance ranking.

The accumulated net returns over time of the estimated optimal paths under Condition I and Condition II, the accumulated net returns of the optimal paths under Condition I and Condition II derived with hindsight, and the accumulated net returns of the standard

Table 5. Net returns to the feedlot for optimal strategy under marketing restrictions and certain prices, in dollars.

Time (Yr-Mo)	Action and/or situation[a]	No. of animals	Net return dollars/head	Net return to the feedlot/dollars[b]
1975				
January through November—Same as Table 4.				
Dec.	Sell 1,050 lb (476 kg) Ch. Sl. Steers	15,000	53.11	796,650
	Place 598 lb (271 kg) Ch. H. Feed-ers		15,000	
(7,200,000)				
1976				
May	Sell 955 lb (433 kg) Ch. Sl. Heifers	15,000	15.79	236,850
	Leave feedlot empty			(7,436,850)
June	Empty feedlot		−.66	9,900
	Leave feedlot empty			(7,426,950)
July	Empty feedlot		−.66	9,900
	Leave feedlot empty			(7,417,050)
Aug.	Empty feedlot		−.66	9,900
	Leave feedlot empty			(7,407,150)
Sept.	Empty feedlot		−.66	9,900
	Place 812 lb (368 kg) Ch. F. Steers	15,000		(7,397,250)
October 1976 through July, 1977—Same as Table 8.				

[a]Abbreviations used are as follows: Ch. = Choice Grade
C. = Calf
F. = Feeder
Sl. = Slaughter

[b]The numbers in parentheses are the cumulative net returns over time.

strategy are tabulated in Table 6. A graphical comparison of the cumulative net returns of Condition I and Condition II under price forecasting as well as price certainty and of the cumulative net returns of the standard strategy is presented in Figure 1. Each incremental value to the cumulative net return function represents the net return from the sale of 15,000 animals except for the standard strategy where the incremental value stems from the sale of 3,000 animals.

The evaluation of the performance of the derived optimal strategies under price forecasting will proceed as follows: 1) Each derived optimal path under imperfect knowledge will be compared in relation to the optimal path under perfect knowledge, which is considered to be the absolute maximum achievable performance, and to the standard strategy which is executed independent of present and future price relationships for inputs and outputs. 2) The performance of the derived optimal paths under imperfect knowledge will be discussed in relation to each other. 3) All comparisons will have specific interpretations for subperiods of rising and falling price conditions. 4) The performance criteria are the cumulative net returns over the study period as an absolute measure and as a performance rating when the cumulative net return is expressed relative to the maximum achievable net return under certainty.

Table 6. Cumulative net returns for the optimal strategies under uncertainty and certainty and for the standard strategy, in dollars.

	Optimal strategies			
	Price uncertainty	Price certainty		
Time (Yr-Mo)	Condition I and Condition II	Condition I	Condition II	Standard Strategy
		Dollars		
1975				
Jan.				−262,740
Feb.				−520,080
Mar.	929,250	929,250	929,250	−692,850
Apr.				−593,550
May	3,294,150	3,294,150	3,294,150	−211,620
June				364,950
July	4,777,350	4,777,350	4,777,350	946,380
Aug.				1,371,870
Sept.	6,367,050			1,759,470
Oct.	6,357,450	6,403,350	6,403,350	2,045,190
Nov.	6,347,850			2,162,490
Dec.	6,338,100	7,200,000	7,200,000	2,298,240
1976				
Jan.	6,328,350			2,408,730
Feb.	6,318,600			2,298,690
Mar.				2,068,530
Apr.				2,053,050
May	6,541,800		7,436,850	2,019,780
June	6,531,900		7,426,950	1,963,920
July	6,522,000	7,623,000	7,417,050	1,793,890
Aug.	6,512,100	7,613,100	7,407,150	1,569,490
Sept.	6,502,050	7,603,200	7,397,250	1,266,190
Oct.	6,492,000			944,950
Nov.	6,481,950			783,370
Dec.	6,471,900	7,923,900	7,717,950	668,860
1977				
Jan.		7,913,850	7,707,900	527,050
Feb.				462,400
Mar.				342,550
Apr.				295,390
May		8,358,000	8,152,050	304,450
June	6,510,000	8,347,950	8,142,000	218,560
July	6,518,100	8,652,600	8,446,650	202,870

Optimal Strategy Condition I

The optimal strategy Condition I (open feedlot in January, 1975, and no marketing restrictions) with imperfect knowledge of future prices and costs would have returned to the feedlot a cumulative net return of $6,518,100 by July, 1977. A feedlot operator using the standard strategy as his decision framework would have achieved a cumulative net return of only $202,870 by July, 1977. The application of forecasts of future prices and costs in the programming decision framework improved the performance by $6,315,230 by *the end of*

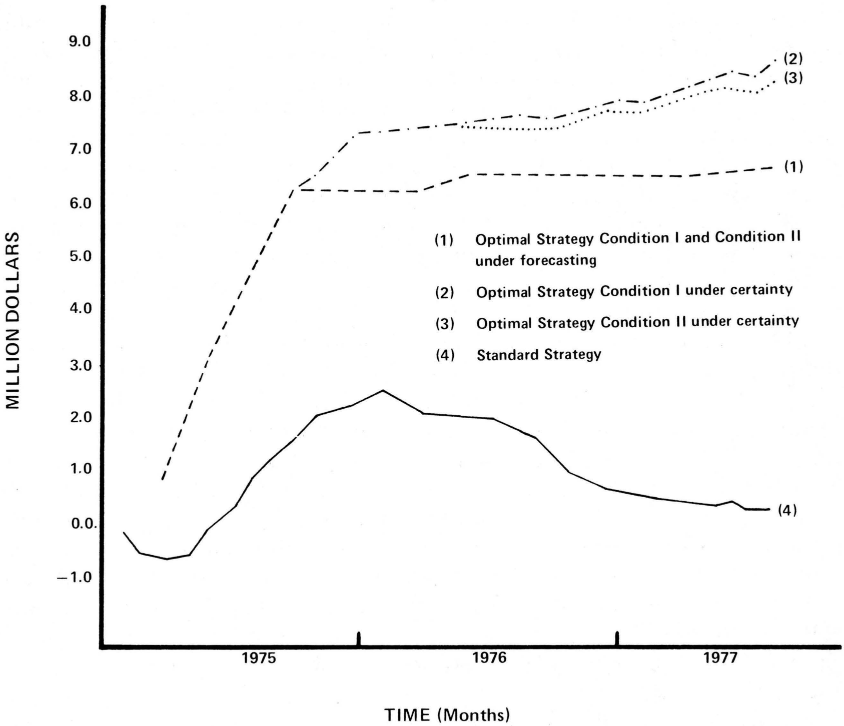

Figure 1. Cumulative net returns to beef feedlot for various optimal and standard strategies (1975-1977).

the study period. Assuming the producer had perfect knowledge of future prices and costs, he could have achieved a cumulative net return of $8,652,600, the highest possible net return under these circumstances. A value of $2,134,500 could be attributed to the benefit of perfect knowledge over the forecasting structure.

During the period of rising cattle prices, from January through October, 1975, the optimal strategy Condition I under uncertainty had a performance rating of 0.99 as compared to the standard strategy with a performance rating equal to 0.32. It is also of interest to note that the optimal paths under the uncertainty and certainty model are the same until September, 1975. The optimal strategy under uncertainty returned $42.38 and the standard strategy $13.63 per capacity month.[4] Slaughter cattle prices were rising at a rate faster than feeder cattle prices. The higher performance of the optimal strategy under uncertainty was achieved by placing heavy feeder

[4]Capacity months is defined as number of feedlot capacity units used by an activity times number of months that capacity is used.

steers for two months to take advantage of intertemporal price increases as well as the price change associated with the change in grade.

Some individual lots under the standard strategy had higher net returns per head than the optimal strategy, but based on a common unit (capacity month) the optimal strategy out performed the standard strategy. In July, 1975, the standard strategy sold 3,000 head of 1,132 pound (513 kg) Choice slaughter steers with a net return of $193.81 per head which is $38.76 per capacity month whereas the optimal strategy sold 15,000 head of 1,050 pound (476 kg) Choice slaughter steers with a net return of $98.88 per head which is $49.44 per capacity month.

The period November, 1975, through July, 1976, had a sharp drop in slaughter cattle prices with feeder cattle prices still rising with the peak in May, 1976. The absolute optimal way was to have a two months placement of heavy feeder steers and a seven months placement of light heifer calves resulting in a net return of $1,219,650. In contrast the optimal strategy under uncertainty with a three months placement of heavy feeder heifers and with an empty lot the remaining six months would have returned $164,550, whereas the standard strategy had a loss of $251,300, with performance ratings of 0.13 and −0.21, respectively. By July, 1976, the overall performance ratings fell to 0.86 for the optimal strategy with a cumulative net return of $6,522,000 and to 0.24 for the standard strategy with a cumulative net return of $1,793,890.

From August, 1976, through July, 1977, cattle prices were at relatively low levels with moderate fluctuations between months and by April, 1977, a slight recovery in prices had developed. The best a producer could have done during this period under certain prices was a cumulative net return of $1,029,000 or $5.12 per capacity month. The optimal strategy under uncertainty leaving the feedlot open five months and placing heavy feeder steer for six months experienced a cumulative loss of $3,900 or a loss of $0.02 per capacity month. On the other hand, the standard strategy accumulated a loss of $1,591,020 or a loss of $8.84 per capacity month. The optimal strategy under uncertainty received a slightly negative performance rating of −0.004 whereas the standard strategy experienced a very poor performance with a rating of −1.55. By the end of the study period in July, 1977, the cumulative performance rating of the optimal strategy under uncertainty was 0.75 and that of the standard strategy 0.02.

For the following discussion consider Figure 1 (cumulative net return graphs of standard strategy, optimal strategy Condition I under uncertainty and certainty).

Performance of the optimal strategy with imperfect information in a flexible decision framework was very close to the absolute maximum performance on the upturn as well as on the downturn of the market. The cumulative net return graph of the optimal strategy Condition I under uncertainty coincides with the cumulative net return graph under certainty with the split occurring in October, 1975. As evidenced by the graph the optimal strategy under uncertainty anticipated the unfavorable price structure three months too early by closing the feedlot. During the remaining months of the study period the slopes of the two cumulative net return graphs (uncertainty and certainty model) are almost horizontal indicating nominal net returns or an empty feedlot. Performance of the standard strategy was far below the optimal strategy under uncertainty as the positions of the respective cumulative net return graphs indicate. Even during the strong market period, the incremental gains to the cumulative net return were less than those for the optimal strategy under uncertainty as evidenced by the different slopes of the two graphs. In the first three months during the period of falling slaughter cattle prices and still rising feeder cattle prices the standard strategy out performed the optimal strategy under uncertainty but the performance was far below the certainty model. After January, 1976, the standard strategy experienced incremental negative net returns and by July, 1977, had almost used up the previously accumulated net returns.

Optimal Strategy Condition II

The optimal strategy Condition II (open feedlot in January, 1975, and marketing weight restrictions) with imperfect knowledge of future prices and costs was equal to the optimal strategy Condition I during the chosen historical time period. The certainty model under Condition II had the same derived optimal path as under Condition I with the exception of the December, 1975, placement of 598 pound (271 kg) Choice feeder heifers for five months (420 pound (191 kg) Choice heifer calves for seven months under Condition I). The cost of the imposition of the marketing weight restrictions under perfect knowledge of future prices and cost would have been $205,950. The same is valid as was said for the uncertainty model under Condition I for the uncertainty model under Condition II.

General Remarks

Because the cumulative net returns were based on average conditions of technical requirements, environmental conditions, and physiological performance of the animals, any individual producer (depending on the efficiency of his operation) could have been below or above the estimated cumulative net return paths. Hence, instead of a single point, multiple points for the cumulative net return for each decision made can be envisioned to exist.

Considering the absolute evaluation and the relative evaluation between the strategies in question, the best management strategy appears to be the use of price forecasts combined with a flexible placement and marketing pattern. It also becomes obvious in the analysis that in a rising market, intertemporal price changes between nearby weight groups as well as price changes associated with a change in grade (conversion of heavy feeder steers to light Choice slaughter steers during this unique time period) play a major role in the placement-marketing decision realm which the flexible strategy could use advantageously. Furthermore, during a more unfavorable price period the timing of the placement or no-placement and the particular weight group to be placed exercise a profound influence on the profitability of the feedlot operation. At the beginning of the price decline, slaughter cattle prices fall fastest with feeder cattle prices lagging behind, but sooner or later the break in the feeder cattle market occurs and the feedlot operation in a strict sense becomes profitable again.

The placement-marketing decision is a complex one for the feedlot operator. With increasing sophistication in the other phases of the feedlot management, the replacement decision is of increasing importance. Historically, management errors on placement and sale (caused by major changes in future cattle prices and feeding costs) have had much larger effects on realized profits and losses than have minor errors in animal rations, health maintenance, or physical plant. In essence, the feedlot operator should recognize the opportunity cost of continuing to hold the current cattle, this cost being the potential of larger contributions to the profit from a replacement lot through time. If the feedlot operator can determine with effective accuracy, the time when the replacement cattle offer more profit potential, he can improve his profit position over time by replacing on or near these time points. The placement-marketing decision model which was developed in this study is structured to select the animal weight group which will give the greatest expected potential to increased profit over time. A continuing re-evaluation is possible over the initial expected feeding period to alter the final selling point if the opportunity cost evidence indicates such adjustment is preferrable.

IMPLICATIONS

Economic efficiency, on the part of the producer, implies that he should react to present and future price signals in production and marketing decisions so as to achieve maximum returns to his resources. It is recommended that the individual producer use forecasts of future prices and costs in his decision-making process of placing and marketing with continuous evaluation by repetitive linear programming solutions of the expected opportunity cost of holding the current animals compared with a replacement lot. Because of the numerous placement-marketing possibilities at any one time and the need for future price forecasts, a computerized model is necessary to handle the job.

It would be feasible for an individual producer or a group of producers to use the developed decision model in making their placement-marketing decisions. The heart of the model is the linear programming matrix representing all possible placement-marketing combinations for steers and heifers on a discrete monthly time basis with the planning period spanning 23 months. All placement-marketing activities not acceptable to a producer can be bounded at zero levels or other upper and lower bounds on the activities can be inserted. Estimated price equations can be used to make the necessary price forecasts. The price forecasting equations should be re-estimated each year to adjust for possible structural changes and to be current.

The computational aspect of the model is best done at some type of agricultural management center with the necessary computer soft- and hardware. The individual feedlot operator has to be aware of the physical transformation functions for his animals and of all non-feed costs particular to his operation. A dynamic coordination between recommended actions and actual outcomes is necessary. At discrete time points an information flow between the producer and the agricultural management center should take place, with the former reporting the physical progress of the production unit and the latter recommending the actions to be taken over the coming planning period. This process would be repeated at each discrete time point through time. Once the agricultural management center has been established, the variable costs of providing such management advisory programs would be minimal.

The economic implications of the application of the management decision model are two-fold. First, if only a small number of producers use it, they should enjoy improved profits through time with no visible impact on the industry. Secondly, if the number of producers involved were large enough, the recommended actions would bring a quicker adjustment in aggregate disorderly production and marketing patterns by inducing price adjustment and volume flows more consistent with equality between marginal returns and costs in time and form.

APPENDIX

Assumptions and Calculations for Carrying Costs

1. Non-feed Costs (6, 8, 9, 23)

Assumed is a 15,000 head feedlot with $67.78 capital investment per head of capacity based on replacement costs in 1975 with a 10-year life span. The land is valued at $1,200 per acre ($3,000/ha). The interest on capital investment, operating expenses, capital inputs, and feed inputs is assumed to be 8.5 percent per annum. In addition, a 4.5 percent inflation rate per annum is charged over time. Death losses are assumed to be 1.75 percent of accumulated carrying costs and the initial value of the animal. Property taxes are charged at a level of 45 mills on the assessed value of cattle in the feedlot on January 1 (adjustments are made by factors of .625 for 1975 taxes, .5 for 1976 and .375 for 1977 taxes according to the Property Tax Relief Act of 1971).

For empty space, half of the capital investment cost, half of the equipment and building cost, the cost of taxes and insurance on building and equipment, and the fixed labor cost will be charged.

2. Feed Requirements

Nutrients, maintenance and production energy requirements are taken from the "National Academy of Sciences"(18). Since performance of beef cattle depends on their environment, rations are adjusted for colder temperatures during the months of December, January, and February to maintain the desired rate of growth by increasing the intake of corn for young animals and silage for older animals (19). The first month's feed requirements are based on actual weight gains, the difference between purchase weights minus shrinkage of that weight class and weights after one month. The feeds used in the ration are: corn (dent yellow, U.S. No. 2, minimum of 54 pounds (24.5 kg) per bushel), corn silage (aerial part ensiled, maximum of 30 percent dry matter) and soybean meal (solvent extracted, 43.8 percent digestable protein). Rations are calculated so that in the growing stage the feed is made up of approximately 50 percent concentrates and in the fattening stage of at least 80 percent concentrates (the percents are based on energy requirements for maintenance and growth).

Appendix Table 1. Non-feed costs for cattle feeding.

Item		Dollars per head of capacity per month
Capital investment		0.5648
Equipment and building repairs		0.1164
Taxes and insurance on building and equipment		0.0896
Gasoline and oil		0.1082
Electricity		0.0981
Miscellaneous (insect., dues, etc.)		0.2023
Fixed labor (manager, assistant manager, office clerk)		0.1870
Variable labor (0.011 hours/head and day @ $2.50)		1.1178
Veterinary and medicine	<600 lb (272 kg)	.20
	>600 lb (272 kg)	.15
Initial medicine and treatment	<600 lb (272 kg)	3.65
	>600 lb (272 kg)	2.80

Appendix Table 2. Consumption of feed per month per animal from the second month on.

Monthly initial and final weights pounds (kilograms)	Average daily gain (lb/day) (kg/day)	Corn (bu/mo) (kg/mo)	Silage (tons/mo) (t/mo)	Protein supplement (cwt/mo) (kg/mo)	Additional winter feed
Steers					
506-572 (230-259)	2.2 (1.0)	3.34 (81.8)	0.2045 (.1855)	0.303 (13.7)	0.53[a] (13.0)[a]
572-638 (259-289)	2.2 (1.0)	3.50 (85.7)	0.2287 (.2075)	0.316 (14.3)	0.57 (14.0)
638-704 (289-319)	2.2 (1.0)	3.62 (88.7)	0.2472 (.2243)	0.327 (14.8)	0.60 (14.7)
704-791 (319-359)	2.9 (1.3)	7.54 (184.7)	0.1364 (.1237)	0.261 (11.8)	0.0388 (.0352)[b]
791-878 (359-398)	2.9 (1.3)	8.17 (200.1)	0.1486 (.1348)	0.317 (14.4)	0.0430 (.0390)
878-965 (398-438)	2.9 (1.3)	8.93 (218.7)	0.1551 (.1407)	0.290 (13.2)	0.0460 (.0417)
965-1050 (438-476)	2.9 (1.3)	9.43 (230.9)	0.1613 (.1463)	0.290 (13.2)	0.0480 (.0435)
1050-1132 (476-513)	2.8 (1.3)	9.61 (235.3)	0.1676 (.1520)	0.315 (14.3)	0.0496 (.0450)
1132-1215 (513-551)	2.7 (1.2)	9.67 (236.8)	0.1743 (.1581)	0.359 (16.3)	0.0508 (.0461)
1215-1295 (551-587)	2.6 (1.2)	9.84 (241.0)	0.1773 (.1608)	0.432 (19.6)	0.0511 (.0463)
Heifers					
460-520 (209-236)	2.0 (.9)	2.64 (64.7)	0.2131 (.1933)	0.362 (16.4)	0.70 (17.1)[a]
520-580 (236-263)	2.0 (.9)	2.94 (72.0)	0.2302 (.2088)	0.414 (18.8)	0.63 (15.4)
580-640 (263-290)	2.0 (.9)	3.08 (75.4)	0.2699 (.2449)	0.388 (17.6)	0.53 (13.0)
640-721 (290-327)	2.7 (1.2)	7.42 (181.7)	0.1314 (.1192)	0.219 (9.9)	0.0426 (.0386)[b]
721-802 (327-364)	2.7 (1.2)	8.13 (199.1)	0.1422 (.1290)	0.198 (9.0)	0.0432 (.0392)
802-880 (364-399)	2.6 (1.2)	8.41 (206.0)	0.1555 (.1411)	0.297 (13.5)	0.0519 (.0471)
880-955 (399-433)	2.6 (1.2)	8.76 (214.5)	0.1614 (.1464)	0.305 (13.8)	0.0538 (.0488)
955-1029 (433-467)	2.5 (1.1)	9.07 (222.1)	0.1664 (.1510)	0.306 (13.9)	0.0561 (.0509)
1029-1101 (467-499)	2.4 (1.1)	9.34 (228.7)	0.1705 (.1547)	0.303 (13.7)	0.0563 (.0511)

[a]Bushels of corn per month per animal (kg/mo/animal).

[b]Tons of corn silage per month per animal (t/mo/animal).

Table 3. Purchase weights, first month's performance, and feed consumption.

Purchase weight (pounds) (kg)	Weight after first month (pounds) (kg)	Average daily gain (lb/day) (kg/day)	Corn (bu/mo) (kg/mo)	Silage (tons/mo) (t/mo)	Protein supplement (cwt/mo) (kg/mo)	Additional winter feed
Steers						
462 (210)	506 (230)	1.47 (.67)	2.65 (64.9)	.1892 (.1716)	.256 (11.6)	.61 (14.9)[a]
528 (239)	572 (259)	1.47 (.67)	3.34 (81.8)	.2045 (.1855)	.303 (13.7)	.53 (13.0)
656 (298)	704 (319)	1.60 (.73)	3.62 (88.7)	.2472 (.2242)	.327 (14.8)	.60 (14.7)
728 (330)	791 (359)	2.10 (.95)	7.54 (184.7)	.1364 (.1237)	.261 (11.8)	.0388 (.0352)[b]
812 (368)	878 (398)	2.20 (1.00)	8.17 (200.1)	.1486 (.1348)	.317 (14.4)	.0430 (.0390)
899 (408)	965 (438)	2.20 (1.00)	8.93 (218.7)	.1551 (.1407)	.290 (1.32)	.0460 (.0417)
Heifers						
420 (191)	460 (209)	1.33 (.60)	2.49 (61.0)	.2045 (.1855)	.336 (15.2)	.73 (17.9)[a]
480 (218)	520 (236)	1.33 (.60)	2.64 (64.7)	.2131 (.1933)	.362 (16.4)	.70 (17.1)
598 (271)	640 (290)	1.40 (.64)	3.08 (75.4)	.2699 (.2448)	.388 (17.6)	.53 (13.0)
663 (301)	721 (327)	1.94 (.88)	7.42 (181.7)	.1314 (.1192)	.219 (9.9)	.0426 (.0386)[b]
743 (337)	802 (364)	1.97 (.89)	8.13 (199.1)	.1422 (.1290)	.198 (9.0)	.0432 (.0392)

[a]Bushels of corn per month per animal (kg/mo/animal).

[b]Tons of corn silage per month per animal (t/mo/animal).

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