5-1976

An Economic Analysis of Management Alternatives for Utah Cattle Ranches and Potential Effects on Beef Production

David B. Hewlett
Utah State University

AN ECONOMIC ANALYSIS OF MANAGEMENT ALTERNATIVES FOR UTAH CATTLE RANCHES AND POTENTIAL EFFECTS ON BEEF PRODUCTION

by

David B. Hewlett

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Range Science

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1976

ACKNOWLEDGMENTS

I would like to extend my sincere appreciation to my major professor, Dr. John P. Workman, and the Utah Agricultural Experiment Station who together made this study possible. Dr. Workman's knowledge of the range livestock industry, his continued encouragement, and excellent manuscript review were invaluable to me in completing the study.

To committee members Fee Busby and Dr. Darwin B. Nielsen I extend thanks and appreciation for consultation and reading of the manuscript.

I wish to thank Suliman Abdalla for patiently supplying information, which was important input for this study.

Janet Alderman's excellent typing of the thesis deserves a heartfelt thank-you.

Finally, to my wife, Jill, whose encouragement and financial support ultimately made my graduate study possible, I extend my deepest gratitude.

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ABSTRACT

An Economic Analysis of Management Alternatives for Utah Cattle Ranches and Potential Effects on Beef Production

by

David B. Hewlett, Master of Science

Utah State University, 1976

Major Professor: Dr. John P. Workman
Department: Range Science

The high feed grain prices of the last few years and the resulting high prices for heavy feeder cattle relative to lightweight feeder calves may provide economic incentives to market cattle from rangelands as yearlings. A majority of the economic studies investigating the profitability of retained ownership of beef calves to sell as yearlings have used a budgeting technique to compare a straight cow-yearling operation retaining all calves, to a straight cow-calf operation selling all calves. In this study linear programming was used to develop an optimum combination of various livestock marketing alternatives for maximizing net ranch income.

Two typical Utah ranch sizes (150 and 300 head of brood cows) were modeled and optimum range livestock marketing schemes were developed using linear programming analysis. Based on average Utah cattle prices for 1970-1975 the optimum range livestock management alternatives for both ranch sizes in terms of maximizing net ranch income was to reduce the cow herd 25

percent and use the released feed resources to retain all steer calves for sale as yearlings. Retention of heifer calves was not profitable and they were sold at weaning. Net ranch income for the optimum strategy was only slightly higher than the income of the base cow-calf operation for the small ranch. The large ranch showed a larger gain in net ranch income from retention of yearlings. The capital requirement of the optimum strategies was three to five percent less than for the base cow-calf operations.

A reduction in the size of the breeding herd to accommodate retained yearlings would result in a reduction in the number of feeder livestock marketed. Potential decreases in U. S. beef production from 1 to 4 percent were estimated if 25-100 percent of the ranchers in the 11 western states adopted the optimum management alternative. These reductions would result in an increase in the price of beef in the U. S. of 1 to 6 percent.

(76 pages)

INTRODUCTION

Recent high prices for heavy feeder cattle relative to light-weight feeder calves has stimulated new interest in range livestock management alternatives marketing yearlings rather than weaner calves. Much of this interest has been prompted by the extremely high feed grain prices of 1974 which has made it cheaper for feeders to purchase livestock gain from ranchers than to produce the gain in a feedlot (Stenquist, 1975). This has increased yearling prices relative to calf prices. The low feed grain prices and huge feed grain surpluses of the past may not be in store for the future (Brunk, 1975; Nielsen, 1975). Recent changes in the U. S. Department of Agriculture meat grading system allow cattle to grade choice with less finish. This may encourage feedlot operators to purchase grass-fed yearlings from the rancher instead of light-weight calves requiring large amounts of expensive feed grains for finishing. Considering these possible trends, it may be profitable for the Utah ranching industry to switch from the traditional cow-calf operation to some type of ranching organization in the cow-calf-yearling category with ranches marketing grass fed yearlings.

This study was designed to investigate various range livestock production options and evaluate their effect on net ranch income in Utah. Two typical Utah ranch sizes (150 and 300 head of brood cow) were modeled and optimum range livestock marketing strategies developed using linear programming analysis. An attempt was made to determine

the effects on beef supply and price if the optimum management strategies developed in this study were adopted.

Objectives

The primary objectives of this study were:

1. To test the hypothesis that: In terms of maximizing net ranch income in Utah, the traditional cow-calf operation is not the optimum. Vertical integration of the ranch organization through the retention of X number of weaner calves will be considered as a management alternative to increase net income to the Utah rancher.

2. To develop optimum range livestock management options for each of the two representative size of Utah cattle ranches (150 and 300 head of breeding cows), which will maximize net income to Utah ranches. Maximum income options will dictate optimum herd composition, age, and weight of animals at time of marketing for each of the two representative ranch sizes.

3. To determine the required decrease in the breeding herd for both representative sizes which may result from retention of yearlings to achieve optimum management alternatives.

4. To determine the reduction in Utah calf and beef production which may result upon rancher adoption of the optimum management options.

5. To determine the impact of this reduction on beef supply and price in Utah, the region, and the nation, if similar management shifts occur throughout the western range livestock industry.

Ranch Management Options

The ranch management production and marketing options which were tested independently and then used as the alternatives to be optimized were:

a. A cow-calf operation with calves weaned and sold November 1.

b. A cow-calf-short yearling operation with weaner calves retained and wintered on range, hay, grain, and protein supplement and sold April 1.

c. A cow-calf-short yearling operation with home grown weaner calves retained and wintered as above with the opportunity to purchase additional weaner calves for wintering and sale on April 1.

d. A cow-calf-long yearling operation with weaner calves retained, wintered as above, summered on range and sold October 1.

e. A cow-calf-long yearling operation with home grown weaner calves retained, the opportunity to purchase additional weaner calves, all wintered as above, summered on range, and sold October 1.

f. A cow-calf-long yearling operation with home grown calves retained and wintered as above, along with the opportunity to purchase short yearlings April 1, all summered on range and sold October 1.

LITERATURE REVIEW

In an economic analysis of Wyoming mountain valley cattle ranches, Stevens (1975) briefly compared a group of study ranches receiving 81.8 percent of their income from selling weaner calves to a group selling yearlings. He found that there was little difference in the income of the two groups of ranches and concluded that there is no definite advantage to selling yearlings rather than calves. Kearl (1969) used budgeting to compare various livestock systems in Wyoming involving the retention of calves and found that although a cow-yearling system presented a slight advantage over selling weaner calves, for the twenty years of prices studied the yearly income differential was small. In a later study with economic comparisons of cow-calf and cow-yearling systems on the northern plains, Kearl (1972) reported an advantage of about $4,000 in net ranch income for a cow-yearling operation. Varying price levels and calf crop percentages narrowed the income differential in some situations but the livestock system selling yearlings still retained the advantage.

With a hypothetical example and the assumption of constant total costs, Eisgruber and Nelson (1975) constructed accounting worksheets for various calf retention options such as backgrounding and fall sale of yearlings. They indicated that selling yearlings was more profitable than selling calves. Brownson, McConnen, and Stauber (1975) developed profit functions for both cow-calf and cow-yearling

operations in Montana based on several assumptions unique to their situation. From these equations a "breakeven point," or ratio of steer calf prices to yearling steer prices at which the cow-calf and cow-yearling operations produce equal income, was calculated. Based on the Montana data, they concluded that generally,

> If the price of steer calves is more than 110 percent of the price of yearling steers, the cow-calf system is best. If the price of steer calves is less than 110 percent of the price of yearling steers, the cow-yearling system is best. (Brownson, McConnen, and Stauber, 1975, p. 10)

Gee and Pursley (1972) compared the profitability of retained ownership and deferred marketing of beef cattle in Colorado and found that fattening long yearlings in feedlots was the most profitable enterprise and yielded substantially higher profits than the sale of weaner calves. It must be noted that all of the above mentioned studies involved only all or nothing economic comprisons of various retention options and were not the result of optimization procedures.

A linear programming technique was used by Leistritz and Qualey (1975) to evaluate alternative range and livestock management practices in southwestern North Dakota. The sale of short yearlings in the spring was more favorable than selling calves, but the sale of yearlings was optimum, increasing ranch returns 42 percent over the base cow-calf system. Whitson (1974) studied vertical integration of a Texas cow-calf operation using quadratic programming analysis in an effort to include risk and uncertainty in decision

making. Steer retention options were confined to either grazing wheat pasture or placement in a feedlot. Optimum steer retention increased net income but decreased income stability.

METHODS

Optimization Procedures

Linear programming was the principal analytic tool. Linear programming is a mathematical procedure for maximizing or minimizing an objective function developed by the firm manager. The objective function is of the form:

$$C = X_1P_1 + X_2P_2 + \ldots + X_nP_n$$

where C = net return over variable cost,

X = units of activity (defined subdivisions of production process),

and P = price or cost coefficient of associated activity.

Sets of constraints are fomulated according to the inputs available for production or as specified by the manager, such as a minimum level of production. Alternative production activities can then be optimized to determine the most economically efficient (profitable) method of production. Linear programming techniques are well suited to agricultural decision making involving the allocation of scarce resources to management alternatives in order to maximize income or minimize cost (Agrawal and Heady, 1972; Beneke and Winterboer, 1973; Jameson, D'Aquino, and Bartlett, 1974). For a detailed discussion of linear programming see Truman (1974), Agrawal and Heady (1972), Beneke and Winterboer (1973), and Jameson, D'Aquino, and Bartlett (1974).

Analysis was done on a Burroughs B6700 computer using the TEMPO mathematical programming system. Sensitivity analysis of all computer runs was accomplished by using the TEMPO procedure RANGE which determines the range over which the objective function coefficients and resource constraints can vary without changing the optimal solution (Burroughs Corporation, 1975).

Linear Programming Models

Linear programming models of both ranch sizes were constructed and called 150RANCH and 300RANCH for easy reference and identification. The models differ in the input-output coefficients where the data dictates differences in the two ranch sizes. The format of the matrices and definition of the rows and columns followed Beneke and Winterboer (1973). These authors present a very clear and logical discussion of agricultural uses for linear programming and provide many excellent examples.

The complete model is made up of 25 columns, 22 rows and 137 non-zero matrix entries. The 150RANCH model is shown in Appendix A. Solutions were determined for a straight cow-calf operation as described in option a. and used as the baseline for further comparison. Activities were systematically added or removed from the model to obtain solutions for each of the livestock management options previously mentioned. The entire model with 24 activities was then used to determine the optimum range livestock management strategy from any combination of the separate production and marketing options. Stability of optimum solutions was tested using sensitivity analysis.

The columns and rows of the model are defined as follows:

Columns

B. Resource and production constraints.

A01. A cow-calf production activity grazing private summer range. A unit of activity is one cow.

A02. A cow-calf production activity grazing federal summer range. The unit of activity is one cow.

A03. A heifer calf selling activity. The unit of activity is one 380 pound heifer 7 months old.

A04. A steer calf selling activity. The unit of activity is one 400 pound steer 7 months old.

A05. A replacement heifer raising activity grazing private summer range. The unit of activity is one heifer from weaning November 1 to incorporation into the breeding herd the following November.

A06. A replacement heifer raising activity grazing federal summer range. The unit of activity is one heifer from weaning November 1 to incorporation into the breeding herd the following November.

A07. A cull cow activity. The unit of activity is one 1000 pound cow.

A08. A range bull activity providing bulls for cows grazing private summer range. The unit of activity is one 1350 pound bull.

A09. A range bull activity providing bulls for cows grazing federal summer range. The unit of activity is one 1350 pound range bull.

A10. A short yearling steer raising activity. The unit of activity is one 400 pound steer wintered to 490 pounds at age 12 months.

A11. A short yearling steer selling activity. The unit of activity is one 490 pound steer at age 12 months.

A12. A steer calf purchasing activity. The unit of activity is one 410 pound steer.

A13. A long yearling steer raising activity grazing private summer range. The unit of activity is one short yearling steer at age 12 months grazed to 740 pounds at age 18 months.

A14. A long yearling steer raising activity grazing federal summer range. The unit of activity is one short yearling steer at age 12 months grazed to 740 pounds at age 18 months.

A15. A long yearling steer selling activity. The unit of activity is one 740 pound steer at age 18 months.

A16. A short yearling steer purchasing activity. The unit of activity is one 502 pound steer.

A17. A 6 month capital borrowing activity. The unit of activity is one dollar.

A18. A 12 month capital borrowing activity. The unit of activity is one dollar.

A19. A capital accounting activity totaling the cash production costs for all activities. The unit of activity is one dollar.

A20. A short yearling heifer raising activity. The unit of activity is one 380 pound heifer wintered to 470 pounds at age 12 months.

A21. A short yearling heifer selling activity. The unit of activity is one 470 pound heifer at age 12 months.

A22. A long yearling heifer raising activity grazing private summer range. The unit of activity is one short yearling heifer at age 12 months, grazed to 680 pounds at age 18 months.

A23. A long yearling heifer raising activity grazing federal summer range. The unit of activity is one short yearling heifer at age 12 months, grazed to 680 pounds at age 18 months.

A24. A long yearling heifer selling activity. The unit of activity is one 680 pound heifer at age 18 months.

Rows

C. The objective function coefficients. The units are dollars.

RO1. The hay constraint. The units are pounds.

RO2. The feed grain constraint. The units are pounds.

RO3. The crop aftermath constraint. The units are Animal Unit Months (AUM).

R04. The winter range constraint. The units are AUM.

R05. The spring range constraint. The units are AUM.

R06. The private summer range constraint. The units are AUM.

R07. The federal summer range constraint. The units are AUM.

R08. A heifer calf transfer row. The units are 380 pound heifers.

R09. A steer calf transfer row. The units are 400 pound steers.

R10. A replacement heifer transfer row. The units are 1-1/2 years old heifers (November 1) bred to calve as two year olds.

R11. A cull cow transfer row. The units are 1000 pound cull cows.

R12. A range bull transfer row. The units are range bulls for activity A01.

R13. A range bull transfer row. The units are range bulls for activity A02.

R14. A short yearling steer transfer row. The units are 490 pound steers.

R15. A long yearling steer transfer row. The units are 740 pound steers.

R16. A capital transfer row for capital borrowed six months. The units are dollars.

R17. A capital transfer row for capital borrowed 12 months. The units are dollars.

R18. A capital transfer row for capital accounting. The units are dollars.

R19. A minimum constraint on the size of the breeding herd. The units are cows.

R20. A short yearling heifer transfer row. The units are 470 pound heifers.

R21. A long yearling heifer transfer row. The units are 680 pound heifers.

Livestock production alternatives were separated into production and selling activities to facilitate movement of cattle from production options to either a selling or retaining alternative. In addition, this allowed total varaible costs and gross returns to be specified directly with the production and sellings options and independent of each other. This was necessary for cost accounting when transferring livestock into retention activities. It was assumed that only steer calves would be purchased for both cattle purchasing activities. A subjective constraint on the minimum size of the breeding herd was placed at 75 cows for the 150RANCH and 150 cows for the 300RANCH. This was assumed to be consistent with the preference of Utah ranchers in retaining a portion of their breeding herd.

The cow-calf, replacement heifer, range bull, and long yearling activities all graze summer range and were divided into two activities each. These were summer grazing on private summer range or the alternative of grazing federal summer range. This was done to allow expression of various income and forage use penalties incurred by the different options when grazing federally controlled rangeland.

Input-Output Data

Inventory and budget data from Workman (1970) and Roberts and Gee (1963) for the two representative sizes of Utah cattle ranches (150 and 300 head of breeding cows) were updated and provided the basic input for the linear programming analysis.

Numerous stuides in the literature were used to substantiate the data and fill in where data were absent. Resource constraints (Table 1) were formulated for hay, barley, crop aftermath, winter range, spring range, private summer range, and federal summer range, from forage balance charts and typical feed use patterns of the two representative ranch sizes formulated by Abdalla (1976). Protein supplement was treated as a cash cost rather than as a constraint.

Table 1. Resource constraints for the 150 and 300 head ranches (feed for horses already subtracted).

Resource	Constraint	
	150RANCH	300RANCH
Hay	141 tons	198 tons
Barley	11.73 tons	36 tons
Winter range	780 AUM	1772 AUM
Spring range	417 AUM	780 AUM
Summer range		
Private summer range	130 AUM	671 AUM
Federal summer range	530 AUM	825 AUM

It was assumed that machinery use would remain constant since crop production decisions were not involved in the optimization. Labor requirements were assumed to be highest for the normal cow-calf operation and therefore not constraining any of the options. In a study by the University of Wyoming Agricultural Experiment Station (1965) some ranchers preferred yearling operations because of fewer cows calving in the spring. Branding and castrating of calves, which is an important use of ranch labor, would also be reduced due to fewer calves being born from a reduced cow herd.

Calf crop percentage

Calf crop percentage as used in this study is defined as the number of calves weaned expressed as a percent of the number of cows in the herd on January 1 which were given opportunity to breed. The data in the literature varies considerably from source to source. Data showing a calf crop percentage of about 85 percent for the intermountain area are numerous (Roberts and Gee, 1963; Stevens, 1968, 1975; Cook, 1970; Kearl, 1969). It must be noted that Cook (1970) collected his data on experimental animals and Kearl (1969) cautions that when heifers coming two years old are counted as part of the breeding herd, the calf crop is lowered to less than 74 percent. Kearl (1971) also states that the calf crop in Wyoming drops to 70-75 percent when calculated on the basis of calves weaned.

Rogers and Helming (1967) report calf crop percentages in north-eastern Nevada to be 76 percent on small ranches averaging 167 head of brood cows and 73 percent on medium ranches averaging 430 head of brood cows. Production and sales data from Workman (1970) was used to calculate an approximately 76 percent calf crop for the two sizes of ranches in this study. To make the calculation, the number of cull cows was assumed to be equal to the number of heifer calves retained for replacement. The number of yearling steers sold was assumed to be equal to the number of steer calves retained. These were added to the number of heifers and steer calves sold at weaning to approximate the total number of calves weaned. Due to the approximate nature of these calculations and

after consideration of both the high and low estimates reported in the literature, it was decided to use 80 percent as the calf crop percentages on both ranch sizes in this study.

Weaning weights of calves

Cook (1970), in his study of the energy budgets of range livestock in Utah, reported that calves were weaned in October weighing 400 pounds. Stevens (1975) lists sale weights of calves in Wyoming averaging 380 pounds for heifers and 410 pounds for steers. Sales information for both typical Utah ranch sizes from Workman (1970) shows heifer calves sold in October weighing 380 pounds and steer calves weighing 400 pounds. In the models, calves were weaned November 1 at the weights reported by Workman (1970).

Bull to cow ratios

Roberts and Gee (1963) reported that the typical 150RANCH operation kept one bull for every 25 brood cows while the 300RANCH ran one bull for every 20 brood cows. Workman (1970) presented inventory data for the two ranch sizes showing 6 bulls on the 150RANCH and 15 bulls on the 300RANCH which are exactly the ratios Roberts and Gee (1963) reported, and were used for this study.

Replacement rate

Rate of replacement, as used in the study, is the percentage of brood cows which are replaced each year by heifers. Homegrown heifer calves for replacement are retained at weaning, bred at

one year of age to calve at two, and incorporated into the breeding herd as a mature cow on November 1, one year after weaning.

In Wyoming, 15-20 percent of the cow herd are two year old heifers (Kearl, 1971). Data from northeastern Nevada (Rogers, 1967) shows a replacement rate of 15 percent and 14 percent for small and medium sized ranches, respectively. From inventory data on west-central Wyoming cattle ranches (Peryam and Olson, 1975), calculations were made to determine replacement rates. The yearling heifer inventory was divided by the total number of cows to obtain an approximately replacement rate of 14-15 percent. Roberts and Gee (1963) report a replacement rate of 17 percent on intermountain cattle ranches. A replacement rate of 15 percent for both ranch sizes was used in this study as it is most representative of the rates presented in the literature.

Animal units

An animal unit (AU) is defined as a 1000 pound cow or the equivalent and an animal unit month (AUM) is the amount of feed required for one animal unit for one month. By expressing all classes of livestock in terms of animal units, monthly or seasonal feed requirements become additive and total requirements are easily determined. All classes of livestock contained in the model were assigned animal unit coefficients (Table 2) according to the formula $AU = W^{.75} \div 1000^{.75}$ from Lewis et al. (1956). W is the average of the monthly weights for the time period concerned.

Table 2. Animal unit equivalent for the different classes of livestock.

Class of livestock	Average Wt. (lbs.)	Animal Units
Bull	1350	1.250
Cow	1000	1.000
Replacement heifer	550	.639
Calf[a]	325	.430
Short yearling steer	445	.545
Short yearling heifer	435	.526
Long yearling steer	615	.694
Long yearling heifer	575	.660

[a]Calves are counted initially on August 1 at 4 months of age.

Feed use coefficients on private vs. federal rangeland

For livestock grazing private rangeland, the feed requirement was the animal unit coefficient multiplied by the number of months that type of rangeland was grazed and expressed in animal unit months. Calves 4 months of age were counted as removing forage from private land. However, on rangeland administered by federal agencies (winter range, spring range, and a portion of summer range), calves under the age of 6 months are not counted, while calves and yearlings 6 months and older are counted as a full animal unit and charged accordingly. For example, a cow and calf grazing on U. S. Forest Service summer rangeland during the month of September is counted as, and charged for, 1 animal unit month of forage, while actual forage removal is approximately 1.43 animal unit months (the coefficient used for private rangeland). On the other hand, a 650 pound yearling steer grazing the same rangeland is also counted as 1 animal unit while it actually represents only

.73 animal units (the coefficient used for private rangeland). Bulls were counted as 1.5 animal units while on federally owned rangeland. For use of federal spring and summer range, these coefficients were expressed directly in terms of the length of time these lands were grazed because they were used exclusive of other feed during the season of use. However, during the winter feeding period, a major portion of the feed is supplemental, the balance being provided by federally owned winter range. The animal unit months of feed provided by hay, grain, and protein supplement were subtracted from the total animal unit months required by the particular class of livestock for the entire winter period, and this represented the balance of feed to be obtained from grazing winter range. To determine the amount of time a retained calf must graze federal winter range to consume the balance of feed required, the formula MONTHS = AUM ÷ AU was used. By substituting the known animal unit months required from winter range and the animal unit coefficient of the retained calf, the amount of grazing time required for the calf to remove the needed forage was determined. For example, if a calf is .6 animal units and requires 1.8 animal unit months of feed from federal winter range, it must grazed for 1.8 ÷ .6 = 3 months to remove this much forage. Since the federal agencies count the over 6 month old calf as 1 animal unit, its forage requirement for federal winter range must be 3 animal unit months instead of 1.8.

Feed use and weight gains

Annual feed use requirements for all classes of livestock are summarized in Table 3.

Cows. Specific winter diets of cows on the two typical ranch sizes were not available, but Kearl (1970) presented a typical winter ration for cows in Wyoming for a 150 day winter period. Cows were fed 1200 pounds of hay, 150 pounds of protein supplement, and range forage. Based on forage balance charts and typical feed use on the 150 and 300 head ranches (Abdalla, 1976) and the data from Kearl (1970), feed use requirements and dates were constructed for the models. Cows on the 150RANCH were allotted 1200 pounds of hay, 120 pounds of barley, and the balance in range forage from December 15 to April 15. Only 960 pounds of hay per cow was allotted on the 300RANCH with 120 pounds of barley, 33 pounds of protein supplement, and range forage providing the balance. Spring range was grazed from April 15 to June 20 at which time the cows and calves were placed on either private or federal summer range and left until October 1. During October, the cows and calves graze crop aftermath and winter range in the same proportion they are available in the forage balance charts of Abdalla (1976). After calves were weaned on November 1, the cows were placed on range forage until the winter feeding program began (December 15).

Bulls. Bulls were fed 1485 pounds of hay from November 1 to December 15 and 3240 pounds of hay, 240 pounds of protein supplement, and 240 pounds of barley from December 15 to April 15. From April 15 to June 20 they graze spring range and summer range forage from

Table 3. Feed requirement coefficients for the various classes of livestock.

Class of livestock	Hay (lbs.)	Barley (lbs.)	Crop aftermth (AUM)	Winter range (AUM)	Spring range (AUM)	Private summer OR range (AUM)	Federal summer range (AUM)
Cow (150RANCH)	1200	120	.3	4.455	2.167	3.333	3.333
Cow (300RANCH)	960	120	.3	4.713	2.167	3.333	3.333
Calf[a]	0	0	.103	0	0	.688	0
Replacement heifer	900	120	.235	2.687	2.167	2.370	3.333
Bull	4725	240	1.250	0	3.225	4.166	5.000
Short yearling steer	900	150	0	1.905	0	0	0
Short yearling heifer	900	150	0	1.792	0	0	0
Long yearling steer	200	0	0	0	2.167	2.433	3.333
Long yearling heifer	200	0	0	0	2.167	2.263	3.333

[a]Feed used by calves was adjusted for an 80 percent calf crop.

June 20 to October 1. Bulls grazed crop aftermath during October until hay feeding began November 1.

Replacement heifers. After weaning on November 1, replacement heifers were placed on range forage until December 15. From December 15 to April 15, they received 900 pounds of hay, 120 pounds of barley, 120 pounds of protein supplement, and range forage. The replacement heifers grazed spring range from April 15 to June 20, summer range from June 20 to October 1, and crop aftermath and range forage during October. On November 1 the year following weaning they were counted as mature cows.

Short yearlings. Kearl (1970) reported that typical winter rations (150 days) fed to calves in Wyoming were comprised of 900 pounds of hay, 125 pounds of protein supplement, 150 pounds of grain, and range forage. The winter period for short yearlings in this study was November 1 to April 1 (150 days) and the ration was the same as above. Cook (1970) indicated that calves studied in Utah gained approximately 70 pounds between weaning in October and April 1. They were fed 2 pounds of protein supplement per day and grazed desert range forage for the remainder of their diet. For this study a conservative estimate of gain was 90 pounds (.6 pounds per day) for short yearlings. Short yearling steers weighed 490 pounds on April 1 and short yearling heifers weighed 470 pounds.

Long yearlings. After April 1 the retained yearlings were called long yearlings. They received 200 pounds of hay and 20 pounds of protein supplement according to Kearl (1970), before being placed on spring range April 15. They grazed spring range until June 20 and

summer range (private or federal) from June 20 to sale on October 1. Cook (1970) reported that yearling steers in his Utah study gained 2.25 pounds per day from April 5 to July 15 and 1.75 pounds per day from July 16 to September 30 while grazing range forage. This is 344 pounds of gain during the summer period alone which seems high when compared to other studies. Calves wintered slightly above maintenance and grazed through the summer gained 337 pounds in the 11 months after weaning in Wyoming (Kearl, 1969). Brownson, McConnen, and Stauber (1975) presented data from Montana on weaning weights of calves and sale weights of yearlings 11 months after weaning. The calves gained a total of 347 pounds in 11 months. Based on these studies, a conservative 340 pounds of gain was assumed for this study for the 11 months after weaning (November 1 to October 1 the following year). Ninety pounds of this was attributed to the winter period (70 pounds for heifers) and 250 pounds were gained during the spring and summer (210 pounds for heifers). The long yearlings were sold on October 1 at weights of 740 pounds for steers and 680 pounds for heifers.

Costs and Returns

Cost of production

Current budget data for cattle ranching enterprises in Utah were not available; however, Workman (1970) presented detailed data on the costs of production for the two typical sizes of cow-calf operations in Utah for 1968. Cash costs of production for short and long yearlings were calculated from data published by Kearl

(1969). It was one of the few studies expressing yearling costs independent of cow costs and was also the data from which the yearling diets were constructed. This insured that feed costs and feed use were consistent. Total cash costs, less depreciation, were divided by the number of yearlings to determine costs per yearling. Federal indices of prices paid by farmers for production items with both farm and non-farm origin (United States Department of Agriculture, 1976) were used to update all of the data to May 1976. Bureau of Land Management and U. S. Forest Service grazing fees were then adjusted to 1976 rates of $1.51 per animal unit month and $1.63 per animal unit month, respectively. The cost of production items for the normal complement of bulls and replacement heifers were included in per cow cost as a necessary expenditure on a cow-calf operation. However, interest on investment in livestock, depreciation, and federal grazing fees were calculated independently for all classes of livestock.

Costs of production for a cow-calf unit were higher for the 300RANCH than for the 150RANCH. Workman (1970) said this increase in costs is due to differences in management practices and a more than proportionate increase in expenditures for feeds and veterinary services. The 300RANCH also ran more bulls per cow and used bulls for a shorter life than the 150RANCH due to a 6 percent death loss reported by Roberts and Gee (1963). Yearling costs were taken from an external source (Kearl, 1969) and there was no valid reason to show a difference in these costs between the two ranch sizes.

Interest on cash costs of production was computed at 8 percent* for 6 months. Interest on investment was based on the portion of a year the animals were on the ranches and their average value. The time period of cows, bulls, and replacement heifers was 1 year, for short yearlings 5 months (November 1 to April 1), and for long yearlings 6 months (April 1 to October 1). Value was determined from 1965-74 average prices for cattle in Utah as reported in "Utah Agricultural Statistics 1975" and the average weights of the various livestock classes. Bulls were treated as capital items and depreciation was calculated on the basis of a $750 new value, a $350 salvage value, and, according to Roberts and Gee (1963), a 3-year breeding life on the typical 300 head ranches and 4 years on the 150 head ranches. Interest on investment in bulls was computed at 8 percent annually on an average value of $550.

For optimization purposes, only those costs that affect the optimum allocation of resources were included. Depreciation on buildings, machinery, and horses was not included in the cost figures used in the models. These costs remain essentially constant regardless of the type of operation. They must be paid from what is reported as net ranch income.

Grazing fees were calculated by multiplying the appropraite rate per animal unit month times the animal unit months of federal grazing required by any production activity. Because spring range was not divided into private and federal portions, the charge

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*Interest rate quoted by the Production Credit Association of Logan, Utah during a personal telephone conversation in July, 1976.

was based on the proportion of federal to private summer range which made up the total amount of spring range. For example, the long yearling activities graze spring range for approximately 2 months. Federal rangeland made up approximately 58 percent of the total spring range available and thus the grazing fee was charged for 58 percent of the 2 months. All costs are presented in Tables 4 and 5.

Calf and yearling purchasing costs

Steer calves purchased in the fall for any of the various options were purchased weighing 410 pounds and short yearlings purchased in April weighed 502 pounds. This allowed for an average of 2.42 percent shrinkage for procurement of calves and yearlings at auctions 100 miles from the ranch (Kearl, 1969). Transportation costs cited by Kearl (1969) were updated using price indices (United States Department of Agriculture, 1976) and were $3.12 per head for calves and $3.82 per head for short yearlings. Based on the adjustments and 1970-75 average Utah prices for cattle on these dates (complete explanation of prices is included in the following section of this thesis), steer calves were purchased for $177.99 and short yearlings cost $221.39.

Borrowed capital

Capital for the purchase of weaner calves was borrowed for 12 months at 8 percent and for the purchase of short yearlings for 6 months. Interest on cash costs of production was added to the costs presented in Tables 4 and 5.

Table 4. Variable cash costs, grazing fees, interest on cash costs, interest on investment, bull depreciation, and total costs for the various livestock production activities for the 150RANCH model. Variable costs for bulls and replacement heifers are included in cow costs.

Livestock production activity	Variable costs	Grazing fees	Interest on cash costs	Interest on investment	Bull depreciation	Total costs
Cow-calf (private summer range)	$75.96	$ 8.55	$ 3.37	$15.01	---	$102.89
Cow-calf (federal summer range)	75.96	13.98	3.59	15.01	---	108.54
Bulls (private summer range)	---	2.63	.11	44.00	$100.00	146.74
Bulls (federal summer range)	---	10.78	.43	44.00	100.00	155.11
Replacement heifers (private summer range)	---	5.99	.24	13.11	---	19.34
Replacement heifers (federal summer range)	---	11.42	.45	13.11	---	24.98
Short yearlings (steers and heifers)	35.88	2.88	1.55	4.21	---	44.52
Long yearlings (steers and heifers, private summer range)	21.35	1.77	.92	7.30	---	31.34
Long yearlings (steers and heifers, federal summer range)	21.35	7.20	1.14	7.30	---	36.99

Table 5. Variable cash costs, grazing fees, interest on cash costs, interest on investment, bull depreciation, and total costs for the various livestock production activities for the 300RANCH model. Variable costs for bulls and replacement heifers are included in cow costs.

Livestock production activity	Variable costs	Grazing fees	Interest on cash costs	Interest on investment	Bull depreciation	Total costs
Cow-calf (private summer range)	$84.87	$ 9.13	$ 3.75	$15.01	---	$112.76
Cow-calf (federal summer range)	84.87	14.56	3.97	15.01	---	118.41
Bulls (private summer range)	---	2.82	.11	44.00	$133.33	180.26
Bulls (federal summer range)	---	10.97	.44	44.00	133.33	188.74
Replacement heifers (private summer range)	---	6.12	.24	13.11	---	19.47
Replacement heifers (federal summer range)	---	11.55	.46	13.11	---	25.12
Short yearlings (steers and heifers)	35.88	2.88	1.55	4.21	---	44.52
Long yearlings (steers and heifers, private summer range)	21.35	1.90	.93	7.30	---	31.48
Long yearlings (steers and heifers, federal summer range)	21.35	7.33	1.15	7.30	---	37.13

Gross returns

Six year (1970-75) average prices for cattle in Utah (Table 6) were used as the prices received for calves, short yearlings, and long yearlings. Prices for 1972-75 were compiled from the weekly "Market News" for the North Salt Lake Stockyards published by the Agricultural Marketing Service, U. S. Department of Agriculture. Data for 1970 and 1971 were presented by Christensen, Davis, and Richards (1973) and came from the same livestock sales. The price of cull cows was the 1965-74 average January price for cows in Utah from "Utah Agricultural Statistics 1975." Cull cows were sold for $187.60 (1000 pounds at $18.76 per hundredweight).

For sale dates of April 1 (short yearlings), October 1 (long yearlings), and November 1 (calves), the high and low quoted prices for each class of livestock for the sales the week preceding and following the above dates were averaged. This was done for all 6 years mentioned above and then averaged to obtain the prices used in this study.

The analyses were also done at 1973 prices which were very favorable to calves and at 1975 prices which were favorable to yearlings. Prices paid for cattle in Utah during 1973 were quite different than the 1970-75 average. Prices paid for all classes of livestock were high, but lightweight weaner calves received exceptionally high returns. In 1975, prices for cattle exhibited a very rare phenomena. Calf prices were considerably lower than the 1970-75 average, while 700-800 pound yearling prices were

Table 6. The average price, weight, and gross returns for livestock marketed in this study.

Class of livestock	Weight (cwt.)	Dollars per cwt.			Gross return		
		1970-75	1973	1975	1970-75	1973	1975
Steer calves	4.0	42.65	61.38	34.30	170.60	245.52	137.20
Heifer calves	3.8	35.90	52.00	24.26	136.42	197.60	92.19
Short yearling steers	4.9	43.34	60.75	30.63	212.37	297.68	150.09
Short yearling heifers	4.7	38.00	52.16	23.60	178.60	245.15	110.92
Long yearling steers	7.4	35.57	46.19	35.88	263.22	341.81	265.51
Long yearling heifers	6.8	31.58	40.25	32.06	214.74	273.70	218.01

slightly above average and these heavy feeder livestock were receiving a higher price per pound than the lightweight feeder calves. These non-typical situations were studied to determine their effects on optimum production and marketing strategies. The prices, livestock weights, and gross returns for all activities are presented in Table 6.

Net ranch income

Net ranch income as defined for this study is gross returns (Table 6) minus all of the variable, interest, and depreciation costs reported above (Tables 4 and 5). Depreciation on buildings, machinery, and horses, and operator and family wages have not been subtracted. These costs must be paid from the net ranch income determined in the linear programming solutions.

Required Decrease in Breeding Herd

The required decrease in the breeding herd to accommodate retained yearlings was dictated by the linear programming analysis as resource constraints were met. The decrease was the difference between the number of brood cows as specified in the baseline cow-calf operation and the number of cows in the optimum ranch organization.

The Effects on Beef Production and Price

A decrease in the cow herd to accommodate retained yearlings for the optimum strategy may result in a corresponding decrease in beef production and increase in the price of beef because fewer

calves and yearlings would be available for feeding and slaughter. The possible reduction in pounds of beef produced in Utah and the region (11 western states--Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming) were evaluated at four arbitrary levels of rancher adoption of the optimum strategy. Assuming that all ranches in the region are currently cow-calf operations selling weaner calves, the reduction in the number of calves produced as a result of smaller breeding herds was calculated for situations where 25, 50, 75, and 100 percent of these operations adopted the optimum strategy. The percent reduction in herd size required for the two representative ranch sizes was assumed to be the same required for all ranch sizes to adopt the optimum strategy.

The number of calves marketed was taken to be the number of beef calves weaned, in the state or region, minus 15 percent for replacements (Abdalla, 1976). The percent reduction in herd size multiplied by the number of calves marketed by 25, 50, 75, and 100 percent of the ranches was used as the number of calves which would not be marketed if these levels of rancher adoption occurred. In order to estimate the effect of this reduction in the number of calves marketed on total pounds (live weight) of beef produced in the U.S., it was assumed that all calves and yearlings are fed to 1,100 pounds for slaughtering. Thus, the number of calves not marketed multiplied by 1,100 pounds is an estimate of the maximum possible reduction in pounds of beef produced in the U. S. due to rancher adoption of the optimum strategy in Utah and the region.

The effect of the possible reduction in beef production in the 11 western states on the price of beef in the U.S. was then evaluated using the economic concept of price elasticity of demand. The price elasticity of demand is defined as the percentage change in the quantity of a product divided by the percentage change in the price of the product (Leftwich, 1973). Workman, King, and Hooper (1972) calculated the price elasticity of demand for beef in the U.S. to be -0.67. This indicates that the quantity of beef consumed (produced) would decrease by 0.67 percent as the result of a one percent price increase. It is the inverse of the price coefficient, -1.49, which is of use here. It indicates that a one percent decrease in the quantity of beef produced would cause a 1.49 percent increase in the price of beef (Workman, King, and Hooper, 1972). Thus, the percentage change in the price of beef resulting from rancher adoption of the optimum strategy is -1.49 times the percentage change in the quantity of beef produced.

RESULTS AND DISCUSSION

Solutions to Baseline Cow-Calf Operations

150RANCH

The baseline solution of the 150RANCH model represented the data well with a breeding herd of 159 cows. Of these 159 cows, 17 were placed on private summer range with the remainder (142) grazing federal summer range. All 24 replacement heifers were kept on private summer range. Because of differences in method of calculating forage requirements between private and federal summer range grazing options, this allocation of younger animals to private range and cow-calf pairs to federal range came about as the linear programming technique maximized the use of scarce resources in producing income.

Resource constraints were met nearly simultaneously, but spring forage was the limiting resource. The capital requirement (total annual cash costs) was $14,420. Net ranch income was $2,148.

300RANCH

The initial solutions for the 300RANCH model indicated that the cost ($118.41) of the cow-calf activity (A02) of grazing federal summer range was too high for the activity to enter into the solution. The number of cows was limited to 150 (minimum constraint) and thus it was not a suitable baseline solution. Examination of the sensitivity analysis revealed that if this

cost was reduced to $117.67 (a reduction of $.74) that the activity would enter into the solution at the level allowed by the resource constraints. Therefore, the cost of activity A02 was reduced to $117.67 for the baseline solution and all subsequent analyses.

Spring range limited the 300RANCH baseline cow-calf operation at 294 head of brood cows. As with the 150RANCH, all replacement heifers were grazed on private summer range, while 134 cows grazed private summer range and 160 cows grazed federal summer range. Capital required for production was $28,879 and net ranch income was only $849. This low net return was due to the significantly higher costs of production on the 300 head ranches than on the 150 head ranches. These higher costs were the result of a more than proportionate use of purchased feeds and veterinary services by the 300RANCH (Workman, 1970). Slightly higher bull costs were also incurred because of running more bulls per cow and for a shorter life than the 150RANCH. Solutions for the baseline cow-calf operations of both ranch sizes are summarized in Table 7.

Solutions to Fixed Retention Options

b and c --Short Yearlings

Fixed retention options b and c required that all homegrown calves be retained and sold as short yearlings in the spring. These options were very inferior to the cow-calf operation in terms of net ranch income. Additional costs incurred by retaining the calves to sell as short yearlings, exceeded the increase in gross return. Because the options were required to retain the weaner

Table 7. Organization of the baseline cow-calf operations for both ranch sizes.

Item	150RANCH	300RANCH
Cows		
Private[a]	17	134
Federal[b]	142	160
Bulls		
Private	1	7
Federal	6	8
Replacement heifers		
Private	24	44
Federal	0	0
Livestock marketed		
Cull cows	24	44
Steer calves	64	118
Heifer calves	40	73
Limiting resource	Spring range	Spring range
Operating capital requirement	$14,420	$28,879
Net ranch income	$ 2,148	$ 849

[a]Graze private summer range.

[b]Graze federal summer range.

calves (heifers and steers) this loss was forced upon the solution and net ranch income decreased. Results are included here for comparison with the baseline cow-calf and optimal solutions. Winter feeding rations of brood cows had to be adjusted for both ranch sizes before the solutions were realistically constrained. No weaner calves were purchased for winter feeding on either ranch size and therefore the solutions to options b and c were identical.

150RANCH

Feed grain became the limiting resource for options b and c while other sources of winter feed were still available. The cow herd was limited to only 96 cows to accommodate the retained calves. This solution was unrealistic considering the availability of alternative winter feeds. In order to allow the options to be constrained by a more realistic constraint, such as the total feed available for a time period, the barley requirement was relaxed. It was assumed that alfalfa hay (50 percent total digestible nutrients) could be substituted for barley (75 percent total digestible nutrients) in the winter diets of brood cows at the rate of 1.5 pounds of hay for 1 pound of barley. Therefore, 91.5 pounds of hay were substituted for 61 pounds of barley in the brood cow rations and total AUMs of available winter feed (hay, barley, and winter range) became the solution constraint.

The cow-calf-short yearling organization requiring the retention of all weaner calves, decreased net ranch income 28

percent below that of the cow-calf operation to $1,546 and operating capital increased $346. The cow herd decreased from 159 to 128 cows to accommodate 32 heifer calves and 51 steer calves, retained and sold as short yearlings on April 1. All replacement heifers grazed private summer range. The characteristics of these solutions are summarized in Table 8.

300RANCH

Activity A02 (cow-calf grazing federal summer range) would not enter the solution until the cost was reduced to $116.12. This slightly lower cost was used in order to obtain a solution which was bounded by resource constraints allowing comparison with ranch organization of the other options. To obtain a valid comparison of net ranch income with the other options for which a cost of $117.67 was used, the $1.55 per cow difference in the cost of activity A02 was subtracted from the net return of options b and c

Hay then became severely limiting for options b and c while winter range and barley were still available for winter feeding. The cow herd was limited to only 207 cows. To overcome the unrealistic hay constraint, .5 animal unit months of winter range were substituted for .5 animal unit months of hay in the winter diets of the brood cows. Hay and winter range then simultaneously restrained the solution at 257 head of brood cows. Net ranch income was reduced 29 percent from that of the baseline cow-calf operation to $601 and the capital requirement increased $2,683. Solutions to these options are summarized in Table 8.

Table 8. Organization of the short yearling options for both ranch sizes.

Item	150RANCH	300RANCH
Cows		
Private[a]	20	137
Federal[b]	108	120
Bulls		
Private	1	7
Federal	4	6
Replacement heifers		
Private	19	39
Federal	0	0
Livestock marketed		
Cull cows	19	39
Short yearling steers	51	103
Short yearling heifers	32	64
Limiting resource	Hay, barley, winter range	Hay, winter range
Operating capital requirement	$14,766	$31,562
Net ranch income	$ 1,546	$ 601

[a] Graze private summer range.

[b] Graze federal summer range.

Solutions to Fixed Retention Options d, e, and f --Long Yearlings

Retaining short yearlings in the spring for sale October 1 as long yearlings was more profitable than selling them after the winter period, and net ranch income for options d, e, and f increased above that of options b and c. Although available as an option, the program did not purchase any weaner calves or short yearlings for options e or f and the solutions were, therefore, the same as option d. Not optimum strategies, but fixed strategies requiring the retention of all calves for sale as long yearlings, these results are included for comparison with the other alternatives and with the optimum strategy.

150RANCH

In the initial solutions for these options barley again became limiting, but not so severely as in options b and c above. The amount of barley required in the winter ration of brood cows was relaxed slightly and 27 pounds of hay was substituted for 18 pounds of barley. Barley was still totally utilized, but spring range became the limiting resource. All 103 cows utilized federal summer range in the solution, 26 long yearling heifers and 29 long yearling steers were sold from summer grazing on private land and an additional 12 long yearling steers were sold from summer grazing on federal rangeland. All replacement heifers for these options were placed on federal summer range.

Net income increased substantially over options b and c but at $1,925 was still 10 percent less than that for the baseline cow-calf operation. After optimization of the complete model, to be discussed later, it was apparent that the retention of weaned heifer calves for sale as long yearlings caused net income to be less than for the baseline. The capital requirement for the long yearling options was $658 less than for a cow-calf operation because of the substitution of lower cost yearlings for brood cows. These organizations are summarized in Table 9.

300RANCH

Spring range was the limiting resource for options d, e, and f. for the 300RANCH model, with a herd of 192 brood cows--73 summered on private rangeland and 119 summered on federal rangeland. With more available private summer range than the 150RANCH, all 77 long yearling steers, 48 long yearling hefiers, and 11 replacement heifers were summered on private rangeland.

Net ranch income for these options increased 19 percent above the baseline cow-calf operation to $1,863, and operating capital was $2,188 less. This was the result of replacing brood cows, which were expensive in terms of annual cash operating costs, with less expensive yearling steers. Net ranch income for the 300RANCH was higher for these options than for the baseline, while on the 150RANCH it was slightly less for these options than for the baseline. This was the result of substantially higher savings from reducing brood cow numbers due to their

Table 9. Organization of the long yearling options for both ranch sizes.

Item	150RANCH	300RANCH
Cows		
Private[a]	0	73
Federal[b]	103	119
Bulls		
Private	0	4
Federal	4	6
Replacement heifers		
Private	0	29
Federal	16	0
Livestock marketed		
Cull cows	16	29
Long yearling steers		
Private	29	77
Federal	12	0
Long yearling heifers		
Private	26	48
Federal	0	0
Limiting resource	Spring range	Spring range
Operating capital requirement	$13,762	$26,691
Net ranch income	$ 1,925	$ 1,863

[a]Graze private summer range.

[b]Graze federal summer range.

significantly higher costs on the 300RANCH than on the 150RANCH, while costs and returns from yearlings were the same for both ranch sizes.

The Optimum Strategies

The optimum livestock production and marketing strategies were developed from the linear programming optimization of the complete models. The ideal situation would be to change ranch organization each year to employ the specific production and marketing strategies maximizing net ranch income for the given year. This would maximize net ranch income over any time period. However, because of the inability to accurately predict future prices in time to make the needed decisions and the difficult and unrealistic requirement of constantly changing ranch organization, the optimum strategy developed from the average price data is the most realistic approach to maximizing long term net ranch income.

150RANCH

The income maximizing ranch organization was a combination of the cow-calf and long yearling options. The sale of heifer calves at weaning and the retention of all steer calves for sale as long yearlings resulted in a net ranch income of $2,268, approximately 6 percent over the baseline cow-calf operation, while the capital requirement decreased $483. A herd of 120 brood cows, all grazed on federal summer range, supplied the calves for the operation and no additional weaner calves or short yearlings were purchased. Private summer range was first allocated to long

yearlings and then to a portion of the replacement heifers. The remaining replacement heifers grazed federal summer range. Spring range was the resource limiting the optimum strategy.

This optimum combination of the cow-calf and long yearling programs allocated forage between brood cows and yearling steers. Heifer calves, which were not as profitable as steers for retention, were sold at weaning thereby requiring no additional feed and thus allowing the addition of 17 more brood cows than in a fixed long yearling option. These 17 cows contributed 7 additional steers for retention as long yearlings. It is this optimization of resource use which make the results of this study considerably different than budgeting studies comparing "all or nothing" strategies like those presented above in the fixed retention options. The optimum production and marketing strategies for both ranch sizes are presented in Table 10.

Sensitivity analysis of the optimum indicated that the 150RANCH solution was very sensitive to a drop in the price received for long yearling steers. If the gross return for these yearlings is lowered from $263.22 to $262.16 the baseline cow-calf operation and the above solution become essentially identical in terms of net ranch income (assuming all other factors remain constant). This is reflected very clearly in both solutions as there is only a $120 difference in net ranch income between the baseline cow-calf and optimal solutions. This may indicate that the choice between a cow-calf or the prescribed cow-calf-long yearling operation is a matter of operator preference. However, lower prices for yearlings

Table 10. Organization of the optimum ranch operation for both ranch sizes.

Item	150RANCH	300RANCH
Cows		
Private[a]	0	89
Federal[b]	120	133
Bulls		
Private	0	4
Federal	5	7
Replacement heifers		
Private	6	33
Federal	12	0
Livestock marketed		
Cull cows	18	33
Heifer calves	30	55
Long yearling steers		
Private	48	89
Federal	0	0
Limiting resource	Spring range	Spring range
Operating capital requirement	$13,937	$27,334
Net ranch income	$ 2,268	$ 2,049

[a] Graze private summer range.

[b] Graze federal summer range.

may be accompanied by proportionately lower calf prices and the long yearling option may remain optimal. The 6 years of price data used in this study seem to indicate weaner calf prices being much more volatile than yearling prices and this needs consideration in the decision making process. The sensitivity analysis does not test the situation of two or more variables changing simultaneously.

300RANCH

The optimum strategy for maximization of net ranch income for the 300RANCH was the same as the 150RANCH above. Sale of all heifer calves at weaning, and retention of all steer calves for sale as long yearlings, increased net income by $1,200 to $2,049, more than twice the net ranch income for the cow-calf operation. Operating capital decreased $1,545. The 222 head of brood cows provided all calves for retention and no calves or short yearlings were purchased. Spring range was the resource which limited the optimum solution.

For the 300RANCH as with the 150RANCH, optimization involved allocation of forage between brood cows and long yearling steers. Selling heifer calves at weaning allowed a breeding herd with 30 more cows than in the fixed long yearling option which required the retention of heifers in addition to steers. These 30 additional cows contributed an additional 12 steer calves for retention and 7 heifer calves for sale at weaning. The other 5 heifer calves were retained as replacements.

Sensitivity analysis of the optimum solution for the 300RANCH indicates that this optimum is more stable in the event of lower

prices for yearlings than the 150RANCH solution. The gross return for long yearling steers must drop from $263.22 down to $249.68 before any change in the solution occurs, assuming that all other factors remain constant. This stability is also reflected in the large difference in net ranch income between the optimal solution and the baseline cow-calf operation.

Analysis at 1973 Prices

This analysis is included for comparison with the average price situation and to provide examples of the effects market fluctuations have on ranch income. Prices paid for cattle in Utah during 1973 were quite different than the 1970-75 average. Prices paid for all classes of livestock were higher than average, but lightweight weaner calves received exceptionally high prices. This price situation changed the optimum ranch organization.

150RANCH

The optimum ranch organization in terms of maximizing net ranch income became the baseline cow-calf operation. The net ranch income of $9,340 was 19 percent higher than the net ranch income of $7,855 which would result if the original optimum strategy based on 1970-75 average prices were employed at 1973 prices.

300RANCH

Optimum ranch organization was essentially the baseline cow-calf operation. However, this ranch size had a slight excess of winter feed and 5 short yearling steers were retained. April

prices for short yearlings (470 pounds) were very high in 1973 making retention profitable if feed resources permitted. The net ranch income of $14,076 was 14 percent greater than the net ranch income of $12,306 which would have been generated at these prices using the original optimum strategy.

Analysis at 1975 Prices

Prices paid for cattle in Utah in 1975 exhibited a very rare phenomena. Calf prices were considerably below average while 700-800 pound yearlings were slightly above average and bringing more per pound than the lightweight feeder calves.

150RANCH

With this price relationship the retention of heifers became profitable and 26 yearling heifers displaced 17 cows reducing the breeding herd to 103 cows. As in the original optimum strategy, all steers were retained as long yearlings. Net ranch income was $2,105. In this situation, the baseline cow-calf operation would have suffered a loss of approximately $1,450. Calf prices in 1975 were too low to pay all of the costs incurred in production.

300RANCH

A similar case existed on the 300RANCH. All 48 heifer calves not needed for cow herd replacement displaced 30 cows from the original average price optimum leaving a herd of 192 cows. This organization is the same as the fixed long yearling option retaining all calves for sale as long yearlings. Net return

was $2,108 while the baseline cow-calf operation would have lost approximately $5,600.

The Required Decrease in the Breeding Herd to Accommodate Retained Yearlings

As a result of retaining weaner calves for sale the following fall as long yearlings, the size of the breeding herd was reduced to provide the needed feed resource. On both ranch sizes the herd reduction resulting from optimization and retention of yearlings was 24.5 percent of the baseline. The cow herd was reduced from 159 to 120 brood cows on the 150RANCH and from 294 to 222 brood cows on the 300RANCH. In addition, this means that at an 80 percent calf crop approximately 32 less calves are weaned on the 150RANCH and 58 less are weaned on the 300RANCH.

First Year Cash Flow

During the first year in which an operation switches from the baseline cow-calf operation to the cow-calf long yearling strategy, there is concern over the possible decrease in cash flow from retaining and not selling some of the steer calves. On the 150RANCH, 39 additional cows must be culled to provide the feed for the 48 steer calves which are not sold. Based on $187.60 per head for 39 cull cows sold and $170.60 per head for 48 steer calves not sold, there is an $872 decrease in annual cash flow. However, this will be offset somewhat during the ensuing production year as the operating capital requirement decreases $483. On the 300RANCH,

72 additional cows are culled and 89 steer calves are not sent to sale. This results in a $1,676 decrease in cash flow which is nearly entirely offset by a $1,545 decrease in the amount of operating capital required during the next year. Additionally, the extremely heavy culling of the cow herd in the first year may well result in an improved calf crop percentage the following fall and a rapid improvement in cow herd quality.

The Effects on Beef Production and Price

A 25 percent decrease in the size of the breeding herd to accommodate retained yearlings would result in a reduction in the number of feeder livestock marketed in Utah and the region as indicated in Table 11. Table 12 summarizes the reduction in pounds of beef produced which would result from a reduction in feeder livestock numbers. The portion of total U. S. beef production coming from Utah is only 0.7 percent (Abdalla, 1976) and even at the 100 percent adoption level the reduction in total U. S. beef production is insignificant. For this reason, the regional reduction in beef production, due to rancher adoption of the optimum strategy throughout the 11 western states, was used to calculate the change in the price of beef in the U. S. which would result.

Total liveweight beef production in the U. S. for 1975 was 40,680,069,000 pounds (Abdalla, 1976). At 25, 50, 75, and 100 percent adoption at the regional level, total U. S. beef production would be reduced approximately 0.94, 1.88, 2.82, and 3.76 percent, respectively. Based on the elasticity coefficient of -1.49, if 25

Table 11. The reduction in the number of beef calves marketed in Utah and the region which would result from 25, 50, 75, and 100 percent of the ranches adopting the optimum strategy.

Adoption level (percent)	Reduction in beef calves marketed (head)	
	Utah	Region
25	15,619	347,863
50	31,238	695,726
75	46,857	1,043,589
100	62,476	1,391,452

Table 12. The reduction in the pounds (liveweight) of beef produced in Utah and the region which would result from 25, 50, 75, and 100 percent of the ranches adopting the optimum strategy (it was assumed that all calves and yearlings would be fed to 1,100 pounds).

Adoption level (percent)	Reduction in beef production (pounds)	
	Utah	Region
25	17,180,900	382,649,300
50	34,361,800	765,298,600
75	51,541,600	1,147,947,900
100	68,722,500	1,530,597,200

percent of the ranchers in the region adopted the optimum strategy the price of beef would increase 1.4 percent, 50 percent adoption would cause a 2.8 percent increase, 75 percent adoption would cause a 4.2 percent increase, and 100 percent adoption would cause an increase of 5.6 percent in the price of beef in the U.S. For example, if the price of beef in the U. S. was $.35 per pound, and 50 percent of the ranchers in the 11 western states adopted the optimum strategy reducing total U. S. beef production by 1.88 percent, the price of beef would go up 2.8 percent to $.36 per pound. If 100 percent of the ranchers changed, the price of beef would go from $.35 per pound to $.37 per pound.

Due to the inelastic demand for beef in the U. S. a reduction in beef production (resulting from decreased herd size to accommodate yearlings to achieve optimization) would cause an increase in the price of beef which more than offsets any loss in revenue from selling a smaller quantity (Workman, King, and Hooper, 1972). Price increases which may be a secondary effect of optimization could lead to a secondary increase in income.

SUMMARY AND CONCLUSIONS

The 150RANCH and 300RANCH models led to baseline cow-calf solutions which were realistic and consistent with input data. The base herd size for the 150RANCH and 300RANCH models were 159 and 294 cows, respectively. Spring range was the limiting resource on both ranch sizes for the baseline cow-calf operation, the long yearling options, and the optimum cow-calf-long yearling operation. Winter feed was limiting for the short yearling options.

Optimal livestock production and marketing strategies developed by solving the linear programming problems using all production activities were the same for both ranch sizes. The strategies were a combination of the cow-calf and long yearling options. Heifer calves were sold at weaning and the cow herd was reduced approximately 25 percent to accommodate the retention of all steer calves. These calves were wintered on hay, grain, protein supplement, and range forage, summered on grass, and then sold weighing 740 pounds 11 months after weaning. No calves or yearlings were purchased by the models for any of the retention options.

The "all or nothing" short yearling retention options were very inferior to the other options in terms of net ranch income. Net ranch income from the retention of all calves for sale as long yearlings was slightly less than net ranch income either from the baseline cow-calf operation or the optimal strategy for the 150RANCH.

On the 300RANCH the retention of all calves for sale as long yearlings increased net ranch income over the baseline cow-calf operation but was not optimal.

Although net ranch income from the optimal strategies was higher for the 150RANCH than the 300RANCH, the increase in net ranch income over the baseline cow-calf operation was greater on the 300RANCH than the 150RANCH. This was due to higher cow costs incurred by the 300RANCH leading to higher savings by replacing cows with yearlings. Consequently, the amount of capital needed for production using the optimal strategies was less than required by the baseline cow-calf solutions on both ranch sizes.

The fact that net ranch income from the 150RANCH was higher than from the 300RANCH should not be construed as indicating the need for a 50 percent reduction in the size of the large ranch. The lower net ranch income from the 300RANCH was mainly the result of a more than proportionate increase in purchased feeds, which increased production costs considerably on the ranches from which the data was taken. Slightly higher bull costs were also incurred. Management to increase ranch efficiency and eliminate the need for the more than proportionate quantities of purchased feed should allow the 300RANCH a rate of return at least equal to that of the 150RANCH. Then net ranch income would be approximately twice that of the small ranch.

Analysis at 1973 and 1975 price levels resulted in solutions different than those for the average price situation and demonstrated the effects of extreme price fluctuation. Weaner calves were

exceptionally profitable during 1973 and optimization of the models resulted in a straight cow-calf operation for both ranch sizes. Net ranch income was several times higher than the net ranch income from the average prices. However, in 1975 cattle prices were lower than the average, long yearlings were worth more per pound than weaner calves, and optimization resulted in retention of all calves for sale as long yearlings. Straight cow-calf operations for both ranch sizes would have suffered losses in 1975.

The ideal situation for maximizing net ranch income would be to annually determine the type of ranch organization to maximize returns in that year which would enable returns to be maximized over any time period. However, because of the inability to accurately predict future prices and the unrealistic assumption of being able to change ranch organization each year, the optimum livestock production and marketing strategies developed from the average prices is the only practical means of maximizing long term average income.

Application of the models in planning a single ranching operation would be very useful. Coefficients representing the exact, and perhaps, unique situation of the particular operation being studied could be specified without relying on generalization based on typical operations. Models could be taylored to fit the precise needs of the situation being examined.

The optimum production and marketing strategy developed from the models may result in a small (1-4 percent) reduction in the quantity of beef annually produced in the U. S. if all 11 western state ranchers would to adopt the strategy. This possible reduction

in beef production would result in an increase of 1 to 6 percent in the price of beef paid by consumers. However, these estimates are somewhat higher than would be likely to occur due to two assumptions which were necessary to make the calculations. First, that all ranches in the region are presently traditional cow-calf operations marketing only weaner calves, and the second, that all calves and yearlings marketed from these ranches are fed to 1,100 pounds. The above estimates should be viewed as the maximum possible effects on price and beef production that may occur due to shifts in ranch organization.

The range livestock industry would benefit from shifting to the optimum production and marketing strategy in two ways. First, because marketing steer calves as yearlings increased net ranch income in this study over that produced by a traditional cow-calf operation at current prices, and secondly, because of the inelastic demand for beef in the U. S., a reduction in beef production (resulting from decreased herd size to accommodate yearlings) would cause an increase in the price of beef which more than offsets any loss in revenue from selling a smaller quantity (Workman, King, and Hooper, 1972). Thus, reducing the cow herd and selling yearlings instead of calves increased net ranch income and may result in price increases which could lead to a secondary increase in net ranch income.

As is true with any modeling process, the results are only as good as the data. The major objectives of this study were aimed at state, regional, and national levels. The data came from

studies done in Utah and surrounding states and were considered as representative of "typical" operations. It is acknowledged that "typical" operations are scarce and that most ranches are unique in some small way. However, it is felt that the results of this study are representative of Utah ranches and that the implications are valid.

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APPENDIXES

Appendix A

Matrix of 150RANCH Model

Appendix A

Matrix of 15ORANCH Model

C	B	A01 -102.89	A02 -108.54	A03 136.42	A04 170.60	A05 -19.34	A06 -24.98	A07 187.60	A08 -146.74	A09 -155.11	A10 -44.52	A11 212.37	A12 -177.99	A13 -31.34	A14 -36.99	A15 263.22	A16 -221.39	A17 -.04	A18 -.08	A19 0	A20 -44.52	A21 178.60	A22 -31.34	A23 -36.99	A24 214.74
R01	282,000	1,200	1,200			900	900		4,725	4,725	900			200	200								200	200	
R02	23,460	120	120			120	120		240	240	150														
R03	93	.403	.403			.235	.235		1.25	1.25															
R04	780	4.455	4.455			2.687	2.687				1.905												2.167	2.167	
R05	417	2.167	2.167			2.167	2.167		3.225	3.225				2.167	2.167								2.263		
R06	130	4.021				2.37			4.166					2.433										3.333	
R07	530		3.333				3.333			5					3.333										
R08		-.4	-.4	1		1	1														1				
R09		-.4	-.4		1						1		-1												
R10		.15	.15			-1	-1																		
R11		-.15	-.15					1																	
R12		.04							-1																
R13			.04							-1															
R14											-1	1		1	1		-1								
R15														-1	-1	1									
R16																	221.39	-1							
R17													177.99						-1						
R18		84.51	89.94			5.99	11.42		2.63	10.78	38.76		177.99	23.12	28.55		221.39			-1	38.76		23.12	28.55	
R19	75	1	1																						
R20																					-1	1	1	1	
R21																							-1	-1	1

Appendix B

Prices Paid for Cattle in Utah 1970-75

Table 13. Average price per hundredweight paid for cattle in Utah 1970-1975, North Salt Lake Stockyards.[a]

Year	300-400 lbs. November 1		400-500 lbs. April 1		600-700 lbs. October 1	700-800 lbs. October 1
	Steers	Heifers	Steers	Heifers	Heifers	Steers
1970	$34.78	$31.52	$39.50	$34.96	$22.85	$30.06
1971	40.66	36.17	36.37	32.75	30.95	33.59
1972	54.00	45.90	40.38	37.77	38.67	39.96
1973	61.38	52.00	60.75	52.16	40.25	46.19
1974	30.76	25.56	52.41	46.81	24.69	27.73
1975	34.30	24.26	30.63	23.60	32.06	35.88
Average	$42.65	$35.90	$43.34	$38.00	$31.58	$35.57

[a] Averages are based on price information from weekly issues of Market News, published in Ogden, Utah by the Livestock Division of the Agricultural Marketing Service, U. S. Department of Agriculture.

Appendix C

Organization of the Various Solutions to Both Ranch Models

Table 14. Organization of all options for 150RANCH.

Item	Options			
	Cow-calf	Short yearling	Long yearling	Optimum
Cows				
Private[a]	17	20	0	0
Federal[b]	142	108	103	120
Bulls				
Private	1	1	0	0
Federal	6	4	4	5
Replacement heifers				
Private	24	19	0	6
Federal	0	0	16	12
Livestock marketed				
Cull cows	24	19	16	18
Steer calves	64	--	--	0
Heifer calves	40	--	--	30
Short yearling steers	--	51	--	0
Short yearling heifers	--	32	--	0
Long yearling steers				
Private	--	--	29	48
Federal	--	--	12	0
Long yearling heifers				
Private	--	--	26	0
Federal	--	--	0	0
Limiting resource	Spring range	Winter feed	Spring range	Spring range
Operating capital requirement	$14,420	$14,766	$13,762	$13,937
Net ranch income	$ 2,148	$ 1,546	$ 1,925	$ 2,268

[a] Graze on private summer range.

[b] Graze on federal summer range.

Table 15. Organization of all options for 300RANCH.

Item	Options			
	Cow-calf	Short yearling	Long yearling	Optimum
Cows				
Private[a]	134	137	73	89
Federal[b]	160	120	119	133
Bulls				
Private	7	7	4	4
Federal	8	6	6	7
Replacement heifers				
Private	44	39	29	33
Federal	0	0	0	0
Livestock marketed				
Cull cows	44	39	29	33
Steer calves	118	--	--	0
Heifer calves	73	--	--	55
Short yearling steers	--	103	--	0
Short yearling heifers	--	64	--	0
Long yearling steers				
Private	--	--	77	89
Federal	--	--	0	0
Long yearling heifers				
Private	--	--	48	0
Federal	--	--	0	0
Limiting resource	Spring range	Winter feed	Spring range	Spring range
Operating capital requirement	$28,879	$31,562	$26,691	$27,334
Net ranch income	$ 849	$ 601	$ 1,863	$ 2,049

[a] Graze on private summer range.

[b] Graze on federal summer range.

VITA

David B. Hewlett

Candidate for the Degree of

Master of Science

Thesis: An Economic Analysis of Management Alternatives for Utah Cattle Ranches and Potential Effects on Beef Production

Major Field: Range Science

Biographical Information:

Personal Data: Born at Twin Falls, Idaho, August 6, 1953, son of Lowell C. and Eleanor Hewlett; married Jill Braegger September 14, 1973; no children.

Education: Attended elementary school in Burley, Idaho; graduated from Burley High School in 1971; attended Idaho State University for two years 1971-73; received Bachelor of Science degree from Utah State University in 1975, with a major in Range Science; completed requirements for the Master of Science degree from Utah State University in 1976, specializing in range resource economics.

Professional Experience: Fire control aid for Bureau of Land Management at Burley, Idaho, summers of 1972 and 1973; range aid for Bureau of Land Management at Burley, Idaho, summer, 1974; worked on Tintic research pastures during summers of 1975 and 1976 while a research assistant at Utah State University; served as a teaching assistant for three hour course entitled "Principles of Range Management", spring quarter, 1976.

Professional Organizations: Member of the Society for Range Management, Xi Sigma Pi (national natural resources honarary society), and Phi Kappa Phi National Honor Society.