ADAPTIVE PLANNING OVER THE CATTLE PRICE CYCLE

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INTRODUCTION

Cycles in beef cattle inventories and prices have been documented as far back as 1880 (Breimyer). The inability to identify optimal herd management strategies in response to fluctuating cattle prices is frequently blamed for the low historical returns received by cattle producers (Farris and Mallett). Cattle producers typically react to rising prices by increasing the size of their breeding herd and liquidating a portion of the herd when prices decline. Long lags between the time a cow is bred and the time her calf is weaned and ready for market make it difficult for cow-calf operators to make optimal long-run production plans. And because a cow has a long productive life, several years are required to evaluate the decision to invest in a larger breeding herd by adding more heifers. During this period, prices may fluctuate drastically, so that with hindsight, the decision to increase the investment in the herd may have been a poor choice. The same problem occurs when the herd is liquidated because of dim prospects of earning an immediate profit from the intact herd. The use of other resources probably does not fluctuate much over the cattle cycle. Bebout discovered that land committed to calf production remains fairly constant even in periods of low profits.

Previous studies dealing with replacement and culling policies have used constant factor and product prices (Bentley et al.; Rogers) and a fixed set of resources devoted to calf production (King). This paper describes and applies a model for adaptive decision making that incorporates alternative assumptions about future product prices. The decision-making process is tempered by a dynamic variable-cost function that responds to a changing mixture of inputs as the herd expands or contracts. The model is used to examine the operation of a cow-calf firm as it attempts to maximize profits over time. Optimal replacement and culling decisions are derived by using both a planning horizon with a fixed terminal date and a rolling planning horizon covering the same period of time.

A DYNAMIC PLANNING MODEL

The profit-maximizing organization of a firm over a fixed time horizon is described by the following model (Hicks):

$$(1)\quad \pi^* = \max \pi \sum_{t=1}^{T} \sum_{j=1}^{J} P_{jt}y_{jt}\beta^t - \sum_{t=1}^{T} \sum_{i=1}^{I} r_{it}x_{it}\beta^t$$

where x_{it} represents the quantity of the ith factor of production used in the t th period. The quantity of the jth product sold in the t th period is y_{jt}. Factor and product prices are r_{it} and p_{jt}, respectively. Since revenues and costs occur over time, a discounting factor must be employed. Let $\beta = 1/(1+d)$ where d is the appropriate discount rate. The objective of the firm is to maximize the present value of profits over time, π^*. Writing the production function in its implicit form, $F(Y, X) = 0$, (for i=1, ... I; j=1, ..., J; and t=1, ..., T), the model is solved as a constrained profit maximization problem, using the Lagrangean function:

$$(2)\quad L = \sum_{t=1}^{T} \sum_{j=1}^{J} p_{jt}y_{jt}\beta^t - \sum_{t=1}^{T} \sum_{i=1}^{I} r_{it}x_{it}\beta^t - \lambda[F(Y, X)]$$

where Y and X are vectors of y_{jt} and x_{it}, respectively. The equilibrium conditions under perfect competition for this "dynamic" system are given by the following partial derivatives from equation (2):

$$(3)\quad \frac{p_{jt}\beta^t}{p_{\varphi\tau}\beta^\tau} = -\frac{\partial y_{\varphi\tau}}{\partial y_{jt}}$$

$$(4)\quad p_{jt}\beta^t \frac{\partial y_{jt}}{\partial x_{i\tau}} = r_{i\tau}\beta^\tau$$

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$$(5) \quad \frac{r_{it}\beta^t}{r_{k\tau}\beta^\tau} = -\frac{\partial x_{k\tau}}{\partial x_{it}}$$

where

t and τ = 1, ..., T
i = 1, ..., k, ..., I
j = 1, ..., φ, ..., J

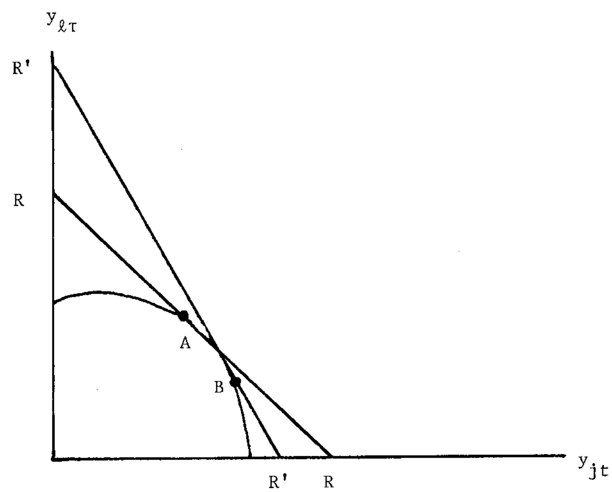
Equation (3) shows that a firm will produce two goods such that their intertemporal rate of product transformation is equal to their discounted price ratios. For example, y_φ and y_j could represent the production of light and heavy calves, respectively, given the farm's resources. In a single-period time frame, that is, $t = \tau$, equilibrium mix would be at point A in Figure 1, panel A. When $t \neq \tau$, the slope of the isorevenue line changes by the ratio of β^t/β^τ, and the intertemporal equilibrium position of the firm is at point B. For simplicity only, a single product transformation curve is used to depict both the intra- and interperiod cases. In general, there would be a different production transformation curve for each pair of factor-product-time relations.

Equation (4) shows that the perfectly competitive firm is in equilibrium when the discounted value of the marginal product from the ith input used in period t is equal to its discounted value in period τ. Equation (5) shows that in a multiperiod production problem, equilibrium is attained when the ratio of factor costs, each discounted from the time they were used, is equal to the intertemporal rate of substitution between the two factors. For example, a weaned calf may be raised to a particular weight either by feeding it intensively in the current period or by spreading the feeding out over two or more periods. The effect of adding this time dimension is illustrated in Figure 1, panel B. In this panel, the inputs are x_{it} and $x_{k\tau}$, and y is the isoproduct curve, say a particular weight and grade calf. CC and C'C' are isocost lines associated with using both inputs in the same period ($t=\tau$) or over two or more periods ($t<\tau$). For simplicity, only a single isoquant is shown for both the intra- and interperiod cases.

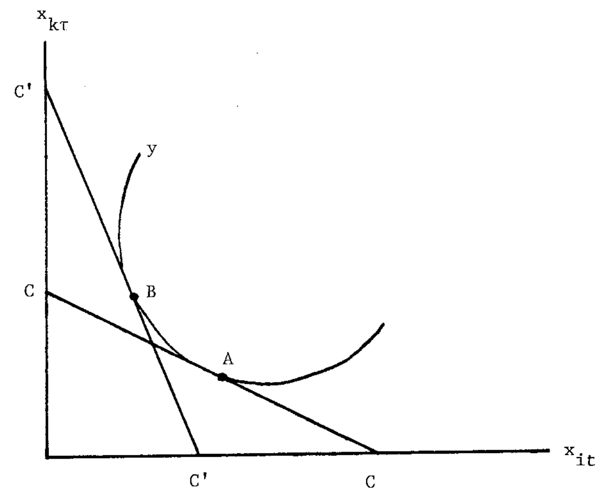
The multiperiod theory of the firm presented above produces a deterministic set of policies to be followed by the firm over a finite period of time. These policies are completely determined in the initial period of the firm's planning horizon and are based on the manager's knowledge of the interrelationships of various production components, present and future market conditions, and the time and manner in which the firm is to cease production. This latter point includes such terminal events as the sale or liquidation of the firm at a specified future date or its bequest to an heir when the owner dies. Given the needed information at the beginning of the planning horizon, the theory of the firm yields an optimal set of policies to be followed over the life of the firm with respect to each variable x_{it}. No further decisions need to be made after the initial period.

The model described in equation (1) produces a set of open-loop controls without feedback (Rausser). However, since the length of time the firm is to be operated, and thus the manner and date of its final disposition, are unknown, some

FIGURE 1. Intertemporal Product Transformation and Isoquant Curves.



Panel A. Rate of production transformation curve and isorevenue curve for two points in time. RR depicts the isorevenue line when income is received in the same period for both products, $t=\tau$. Its slope is $-P_{jt}/P_{\varphi\tau}$. R'R' is the isorevenue curve when income is received in different periods and $t<\tau$. The slope of R'R is $-P_{jt}\beta^t/P_{\varphi\tau}\beta^\tau = P_{jt}(1+d)^t/P_{\varphi\tau}(1+d)^\tau$.



Panel B. Isoquant and isocost curves for two points in time. CC depicts the isocost line when both inputs are used in the same period, $t=\tau$. Its slope is $-r_{it}/r_{k\tau}$ C'C' is the isocost line when the inputs are used in different periods, $t<\tau$. Its slope is $-r_{it}\beta^t/r_{k\tau}\beta^\tau = -r_{it}(1+d)^t/r_{k\tau}(1+d)^\tau$.

arbitrary terminal date must be assumed in order to obtain a set of operating policies from this model. This model can be transformed into a more realistic, passive adaptive open-loop, feedback model, if it is solved sequentially for a rolling planning horizon of standard length. In this case, only the decisions for the first year of each planning horizon are actually implemented, and the rolling planning horizon reflects an intention of remaining in business in perpetuity. At the beginning of the following year, a new set of decisions for a planning horizon of T years is found, and again the first year's decisions are implemented. The long-run operation of the firm is determined by the set of first-period solutions to an open-loop policy with planning horizons of (0,T), (1,T+1), ... (T,2T), that is, a rolling planning horizon.

SIMULATION AND ADAPTIVE CONTROLS

The analysis presented in this paper examines the effects of adaptive planning when different types of price information are used in the model. The following section describes the model and solution techniques used to estimate optimal values of the control variables.

The Simulation Model

The basis for this analysis is a simulated East Texas cattle farm. Operating characteristics of the cattle farm are based upon several sources (Boykin et al; Butler, 1972, 1974). Conceptually, the simulation model consists of four parts: a cow-calf herd, forage production, a complement of machinery and equipment, and a financial component. The model operates on a monthly basis for as long as fifteen years.

Cow-calf herd. The model initially contains 425 cows on 500 acres of land. Cows are placed in annual age groups. A Markovian transition matrix is used to simulate conception, calving, and weaning of calves by cows in each age group. Calves are sold at weaning unless retained as replacements. Any cow that fails to conceive or to wean a calf is culled from the herd when the calves are sold. Feed requirements for the cows and calves are calculated on a monthly basis according to the weight, rate of gain, and sex of each animal.

Forage production unit. Coastal bermudagrass and Coastal bermudagrass with crimson clover are the principal forages in this model. Forage production is calculated on a monthly basis. Excess forage produced in any month is carried to the following month as deferred grazing when needed; otherwise, it is harvested as hay. Forage is assumed to lose 15 percent of its utilizable energy content per month when it is carried over for deferred grazing. Ten percent of the energy content of fresh forage is lost whenever hay is made. Hay is stockpiled to meet estimated nutritional needs for the next 12 months: excess hay is sold. Hay and supplements are purchased whenever growth of the cow herd exhausts available forages. Additional land can be purchased in 10-acre increments whenever annual forage requirements exceed expected forage production. Once purchased, land cannot be sold.

Machinery and equipment. The simulation model initially has sufficient machinery and equipment for 425 cows and 500 acres of land. Each item of machinery and equipment is accounted for individually. When equipment reaches the end of its useful life, it is sold for salvage value. A replacement is purchased, unless there is sufficient capacity from the remaining pieces of machinery and equipment to meet the needs of the current cow herd. The capacity of the current complement of machinery and equipment is checked each time additional replacements are added to the herd or land is purchased. Thus, the complement of machinery and equipment and the number of cows can increase or decrease over time while the amount of land in the farm can remain unchanged or increase.

Financial component. The financial component calculates annual net farm income, cash flow, and net worth. A linear consumption function, based upon the work of Martin and Plaxico, is used to determine cash withdrawals from the firm before calculating annual net cash flow. Credit is rationed within the firm whenever there is insufficient cash to finance production or consumption expenditures.

The financial component also estimates the opportunity cost of retaining each age cow for another year and culls a cow whenever her current value as a cull exceeds the present value of her next calf and her cull value in the following year. A discount rate of 7 percent is used in the following analysis to evaluate the opportunity cost of capital invested in the cow-calf enterprise.

The financial component also estimates the opportunity cost of retaining a cow in the herd for another year. The opportunity cost is determined as a function of the cow's age, current cattle prices, and expected cattle prices in the next calving period. Cows are likely to be culled from the herd whenever cattle prices are expected to decline sharply in the near future. The opportunity cost of retaining a cow would increase with the discount rate.

The simulation model can be run alone with data provided by the user to evaluate various decisions and the effects of different parameters. Or, it may be run under the control of an optimizing algorithm to determine optimal values for various decision variables. In this analysis, annual replacement and culling rates are decision variables under the control of an optimizing algorithm.

Price Information

Many attempts have been made to discover the empirical basis of fluctuations in cattle prices. There is evidence that cattle producers react to recent prices when making current decisions about future production levels (Franzman). That such behavior perpetuates the cyclical tendency of cattle prices was demonstrated by Hertzler and Cothern. Franzman has shown that the resulting cycles can be modeled with enough accuracy to forecast future trends and turning points. Thus, simple price-forecasting models might help managers to make more effective long-run decisions.

Three kinds of price information are used in this analysis to derive long-run adaptive controls. Controls are first obtained using the actual price series, as though they were known in advance, for slaughter cows, good and choice heifers, and good and choice steers (USDA). These controls provide a baseline for comparing controls based on forecasts that either are derived by using a cyclical forecasting price equation of historical prices or by assuming that current prices will prevail in each of the subsequent ten years.

To investigate the effect of planning that recognizes historical cyclical prices, adaptive controls are obtained by the use of a cyclical forecasting equation for each of the three price series. The forecasting equations are of the general form (Talpaz).

$$(6) \quad P_{jt} = a_j + b_j \sin(wt) + c_j \cos(wt)$$

where P_{jt} is the price of the jth class of cattle in period t, w determines the length, and b and c measure the amplitude of the price cycle. The forecasting equations are reestimated annually by adding the latest twelve months of price observations to the time series.

The final set of adaptive controls is obtained under the assumption that prices received during the first year of each planning horizon will remain constant over the complete planning horizon.

The Objective Function

Many objective functions have been used to analyze the performance of a firm over time (Martin and Plaxico). A commonly used objective is to maximize terminal net worth of the firm, because terminal net worth is simultaneously the sum of retained earnings and, in a competitive market at equilibrium, also an estimate of the present value of future earnings of the firm. While the calf industry is composed of perfectly competitive firms, it probably seldom achieves a point of stable equilibrium. Cattle prices fluctuate daily in response to changing market conditions. Thus, terminal net worth, which contains a sizable value for breeding cows, does not appear to be a suitable objective for the value of the breeding herd is continually changing.

The objective function used in this analysis comprises two parts. First, a direct accounting is made of net revenue expected to be earned over the planning horizon. To this is added an estimate of the future profitability of the firm in the form of an annuity. The annuity is determined by the number of cows in the herd at the end of the planning horizon. Thus, the objective function is the sum of the present value of expected net revenue over the planning horizon and the present value of an annuity of earnings beyond the planning horizon. The objective function is maximized by attaching an optimizing algorithm to the simulation model (Richardson, et al.).

Year-to-year changes in net worth reflect changing asset values and annual net revenue. But, annual net revenue is reduced by a withdrawal for consumption by using a linear consumption function before being included in year-end net worth. For this reason, net worth usually increases by a larger amount when heifers are retained than when they are sold, and a portion of the resulting revenue is withdrawn for consumption.

Adaptive Controls

An optimal set of replacement and culling rates is found for each planning horizon. A standard ten-year planning horizon is used because it closely approximates the average length of the price cycle and is at least as long as the typical productive life of a replacement heifer. The results from the first standard planning horizon, covering the period 1958 to 1967, are equivalent to the model in equation (1) with the addition of an annuity representing expected income beyond the terminal year T. The decisions are optimal with regard to the information that is available at the beginning of the planning horizon, that is, a forecast price series and a terminal date, T=10 years.

But, after operating the firm for the first year, the decision maker revises his long-run plans in the face of new information—a revised price forecast and a new terminal date. The set of first-year decisions from a series of optimal plans over a rolling planning horizon comprises long-run adaptive controls.

Adaptive controls are obtained for the period 1958 to 1967 (the adaptive controls for the standard planning horizon beginning in 1967 are based on the 1967 to 1976 price series). Two results are obtained with this analysis: (1) the set of controls that are typical of analysis using fixed planning horizons with specified terminal dates, and (2) a set of adaptive controls over a rolling planning horizon, covering the same period that models the behavior of the firm as it attempts to adjust the use of resources in a most profitable manner as new price information becomes available, and as the planning horizon is extended further in time.

RESULTS

The following discussion compares the results of the optimal plan for a single fixed planning horizon (assuming that actual historic prices are known in advance) with the results of adaptive plans (when decisions are made on the basis of different price forecasts). The optimal plan is compared with the adaptive plans on the basis of present value of net revenue that would have been realized from these alternative decisions over the same ten-year period, given the prices that actually prevailed.

Fixed Planning Horizon With Terminal Date

The optimal number of heifers to retain each year in the fixed ten-year planning horizon is highly variable (Table 1). However, the objective function value is not particularly sensitive to other replacement policies, as demonstrated by the ranges in the number of heifers retained in several near-optimal plans. The objective function values of each of these near-optimal plans are within 1.5 percent of the value of the optimal policy. No early culling of cows is specified by the optimal plan.

The present value of net revenue earned with the objective function is $178,126. After 10 years, the herd contains 430 cows on 510 acres of land. Because there is little new investment during this period, retained earnings are held as cash and account for almost a quarter of the firm's total assets after 10 years.

Adaptive Plans

The adaptive policies based on perfect knowledge of future cattle prices are shown in Table 1. Annual placements of heifers are less variable

TABLE 1. Operating Characteristics of the Optimal Plan for Fixed Planning Horizon and Adaptive Plans for the Same Time Period, Using Actual Price Series

	Fixed Planning Horizon				Adaptive Plan With Actual Prices		
Year	Number of Heifers Retained	Range in Alternative Replacement Policies [a]	Net Revenue	Cash Withdrawn for Consumption	Number of Heifers Retained	Net Revenue	Cash Withdrawn for Consumption
1958	95.9	96.9-98.9	$28,694	$11,696	95.9	$28,694	$11,696
1959	81.2	71.3-95.0	33,267	12,839	79.8	33,597	12,922
1960	97.3	96.6-110.2	18,355	9,111	101.2	17,605	8,924
1961	100.0	79.2-115.8	17,250	8,835	97.9	17,408	8,874
1962	42.5	0-69.6	29,085	11,794	75.9	23,410	10,375
1963	111.1	70.2-111.1	15,323	8,353	101.2	13,865	7,989
1964	62.3	0-64.1	5,060	6,030	95.8	-524	6,030
1965	32.8	0-34.4	17,998	9,022	85.6	6,348	6,110
1966	5.4	0-24.2	38,130	14,055	91.2	21,713	9,951
1967	9.3	2.8-19.5	33,723	12,953	78.7	23,318	10,352
Present Value of Net Revenue:			$178,126			$146,350	
Terminal Net Worth:			$458,980			$466,710	

[a] Extreme values of replacement policies with objective functions that are within 1.5 percent of the maximum objective function value.

than is called for with a fixed planning horizon. The adaptive plan has a present value of net revenue of $146,350. Profits are reinvested in productive assets (Table 2), so that after 10 years the firm has 515 cows and contains 560 acres. Net worth is $466,710.

Only slightly different results are obtained when prices are expected to remain constant over the planning horizon (Tables 2 and 3). The present value of the plan, evaluated *ex post* with actual prices, is $146,518.

The largest discounted stream of net revenue is obtained from the adaptive policies derived using cyclical price expectations. Total net revenue realized over 10 years is less than that realized under the other adaptive plans, but because of the pattern of receipts, discounted net revenue is larger. This is the only plan analyzed that calls for the early culling of a portion of the cow herd. This decision is in response to the expectation that cattle prices will decline sharply for several years. By the end of the simulation, the herd contains 461 cows on the initial 500 acres. The firm's net worth increases to $439,903. Because of the slower rate of growth, a larger portion of the firm's assets are held as cash than in the other adaptive plans.

Constant Rates of Growth

The present values of net revenue obtained by adaptive planning is always less than the present value of net revenue from the optimal plan for the fixed planning horizon covering the same period of time. These differences suggest that additional costs are incurred in the process of periodically adjusting management tactics over a rolling planning horizon. To test this possibility, the model is analyzed by allowing the number of heifers retained to increase by a constant percentage each year.

The results from maintaining a nearly constant herd size—no increase in the number of heifers retained—over the 10-year period are shown in Table 4. Sufficient heifers are retained each year to replace cows that die or are culled for disease or fertility problems. Over the 10-year period, 750 heifers are retained from sales and are added to the breeding herd. Additional simulations were conducted, in which the number of heifers retained increased by 1, 2, 3, 4, and 5 percent each year. In general, as the proportion of heifers retained (not sold) increases, realized net revenue declines for the 10-year period and net worth increases, principally due to the increase in the number of cows added to the breeding herd (Tables 4 and 5).

The present value of net revenue under the no-growth plan is less than the amount earned under the optimal plan for the fixed planning horizon using actual prices. The same result is found when the number of heifers placed into the herd increases by 1 to 5 percent annually. Net worth after ten years of growth is slightly greater under the two highest heifer retention rates than terminal net worth under the optimal plan with perfect price forecasts for the fixed planning horizon. However, the present value of net revenue is considerably lower.

TABLE 2. Relative Composition of Firm Assets Under Various Plans

Plans	Cash on Hand	Value of Herd	Machinery and Equipment	Value of Land
	percent			
Initial Composition, all Plans	2.5	38.2	9.6	49.8
Fixed Planning Horizon, After Ten Years	23.4	27.1	6.8	42.7
Rolling Planning Horizon (Adaptive Controls)				
Actual Prices	9.3	37.5	7.7	45.5
Constant Prices	10.4	37.7	7.6	44.2
Cyclical Prices	13.3	36.0	7.6	43.1
Constant Growth Rate				
No Growth	16.6	33.0	7.8	42.6
1 Percent Per Year	15.9	34.4	7.7	42.0
2 Percent Per Year	9.3	37.6	7.8	45.2
5 Percent Per Year	0.0	41.5	9.0	49.5

TABLE 3. Operating Characteristics of Adaptive Plans Based Upon Constant and Cyclical Price Forecasts

	Constant Prices			Cyclical Prices		
Year	Number of Heifers Retained	Net Revenue	Cash Withdrawn for Consumption	Number of Heifers Retained	Net Revenue	Cash Withdrawn for Consumption
1958	100.0	$27,750	$11,460	81.5	$32,008	$12,525
1959	90.0	31,072	12,291	95.9	30,187	12,069
1960	86.6	20,621	9,678	55.3	25,100	10,798
1961	95.7	19,661	9,438	78.3	63,576	20,417
1962	102.2	18,462	9,138	73.5	14,070	8,040
1963	103.9	10,806	7,224	77.0	-1,287	6,030
1964	49.0	4,668	6,030	86.3	-9,880	6,030
1965	110.1	9,406	6,874	95.4	-4,120	6,030
1966	63.5	25,625	10,929	95.2	9,197	6,822
1967	116.1	18,382	9,118	74.9	21,002	9,773
Present Value of Net Revenue:		$146,518			$151,484	
Terminal Net Worth:		$470,541			$439,903	

Slow rates of growth (0–1 percent) in the number of heifers retained annually produces a larger present value of net revenue than any of the adaptive plans tested. Discounted net revenue obtained with a 2-percent rate of growth is slightly less than the discounted net revenue obtained with the adaptive plan based upon cyclical price forecasts. At higher rates of growth, discounted net revenue is consistently less than that earned with any of the adaptive plans.

CONCLUSIONS

In terms of discounted net revenue, the most profitable plan was obtained when it was assumed that the firm would cease operations after a fixed period of time, and that it had perfect price information over its planning horizon. Higher operating profits increased the amount of capital withdrawn from the firm for consumption. No land was added to the initial resources, and the cow herd grew very little over ten years. Retained earnings appear in the final net worth as cash on hand.

Decisions based upon the fixed planning horizon overestimated the profitability of a firm using adaptive controls that adjust to new price information over a rolling planning horizon.

The net worth after ten years of adaptive planning was always larger than the terminal net worth from the fixed ten-year plan. And, the composition of the firm's total assets reflected a larger investment in productive resources, suggesting that the firm would be in a better position to continue production in the future.

Adaptive planning based on cyclical price forecasts resulted in a larger present value of net revenue than did the adaptive plans based upon other kinds of price forecasts. Higher capital withdrawals for consumption and smaller herds in the final year resulted in a smaller final net worth than was obtained with the other adaptive plans.

With the exception of heavy culling of cows in the cyclical price model, no cyclical patterns

TABLE 4. Operating Characteristics of Plans With Constant Rates of Growth in Number of Replacement Heifers

	No Increase in Number of Heifers Retained Each Year			One Percent Per Annum Increase in Number of Heifers		
Year	Number of Heifers Retained	Net Revenue	Cash Withdrawn for Consumption	Number of Heifers Retained	Net Revenue	Cash Withdrawn for Consumption
1958	75	$33,504	$12,899	75.8	$33,320	$12,852
1959	75	35,315	13,351	76.5	34,933	13,256
1960	75	21,180	9,818	77.3	20,726	9,704
1961	75	20,816	9,726	78.0	20,325	9,604
1962	75	19,304	9,348	78.8	18,820	9,227
1963	75	15,341	8,358	79.6	14,894	8,246
1964	75	2,499	6,030	80.4	2,005	6,030
1965	75	8,055	6,536	81.2	7,716	6,451
1966	75	19,314	9,351	82.0	19,368	9,365
1967	75	18,408	9,125	82.8	18,681	9,193
Present Value of Net Revenue:		$155,601			$153,212	
Terminal Net Worth:		$447,037			$452,357	

were discernible in heifer placements, herd size, or culling decisions. This is in contrast to plans calling for cyclical culling policies (King). Cows were generally culled after weaning ten calves. Earlier studies based upon constant factor-product price relations cite a constant profit-maximizing culling age of between eight and twelve years (Bentley et al.; Rogers).

An alternative to adaptive decision making was examined by allowing the herd to increase at a constant rate over time. A slow rate of growth in the number of heifers added to the herd each year (0 to 2 percent) provided a higher present value of discounted net revenue than the adaptive plans. The increase in terminal net worth was smaller due to greater withdrawal for consumption and smaller inventory of cows in the final year.

In practical terms, these results imply that cyclical culling and replacement strategies that attempt to "beat the cattle cycle" may be inefficient. The introduction of a large portion of heifers to a cow herd reduces net farm income for several years while they continue to grow and produce light calves. The high degree of variability in cattle prices over the cattle cycle makes it difficult to predict accurately the opportune time to introduce large numbers of heifers into a cow herd. Furthermore, the exact effect of a particular discount rate or set of expected prices on a firm's profitability can be determined only by examining individual firm situations (the model used in this analysis can be used to simulate a wide range of cow-calf farms).

Given that the resources available to the cow-calf operator have few alternative uses, the best long-run strategy appears to be one of slow sustained growth of the herd. This policy would be interrupted only when a combination of a high discount rate and rapidly declining cattle prices calls for the immediate sale of a larger than average proportion of the breeding herd.

TABLE 5. Operating Characteristics of Plans With Constant Rates of Growth in Number of Replacement Heifers

	Three Percent Per Annum Increase in Number of Heifers			Five Percent Per Annum Increase in Number of Heifers		
Year	Number of Heifers Retained	Net Revenue	Cash Withdrawn for Consumption	Number of Heifers Retained	Net Revenue	Cash Withdrawn for Consumption
1958	77.3	$32,975	$12,766	78.8	$32,630	$12,680
1959	79.6	34,159	13,062	82.7	33,384	12,868
1960	82.0	19,794	9,471	86.8	18,842	9,233
1961	84.4	19,271	9,340	91.2	18,133	9,055
1962	86.9	17,757	8,962	95.7	16,545	8,659
1963	89.6	13,862	7,988	100.5	13,330	7,855
1964	92.2	926	6,030	105.5	(1,575)	6,030
1965	95.0	7,800	6,472	110.8	1,286	6,030
1966	97.9	15,557	8,412	116.3	11,832	7,481
1967	100.8	16,818	8,727	122.2	13,061	7,788
Present Value of Net Revenue:		$145,026			$130,957	
Terminal Net Worth:		$460,042			$461,078	

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