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CALF RETENTION AND MARKETING IN A STOCHASTIC ENVIRONMENT

Ted C. Schroeder and Allen M. Featherstone*

The cattle industry has long been characterized by volatile markets. Cow-calf producers are especially vulnerable to these market swings, because of their position in the beef production chain. Due to the large capital investment and asset fixity in breeding herds, cow-calf producers generally do not significantly modify production decisions in the short run. However, cow-calf producers do have considerable discretion in the timing and form of which to sell their calf crop. That is, they can sell the calves at weaning, retain them through a backgrounding phase, or maintain ownership of the calves through finishing. The choice of marketing and retention activities can greatly influence the financial risks and returns the cow-calf producer may realize. The objective of this study is to examine optimal calf retention and marketing strategies for cow-calf producers.

Cow-calf producers have typically marketed the majority of their calf crop at weaning. Gilliam reports that in 1980, 64% of the U.S. calf crop marketed was sold by the calf producer shortly after weaning, 36% was sold as yearlings, and virtually none of the calves were retained through finishing. However, several studies have shown that retaining calves well beyond weaning has been more profitable than selling the calves at weaning (Watt, Little, and Petry; Lambert and Sands). Ford, Clanton, and England concluded that retained ownership through the feedlot finishing phase resulted in the highest profits of the retention strategies studied. However, the decision of whether or not to retain ownership of calves is not an all or none situation. That is, the cow-calf producer may be well advised at certain times to retain only a portion of the calf crop. For example, Gebremeskel and Shumway concluded that depending upon forage conditions and calf prices at weaning, from 15% to 100% of the calf crop should be retained through the yearling and/or finishing phases.

These previous studies provide useful insights regarding the potential profit enhancements and risk reductions that calf retention offers cow-calf producers relative to always selling their calves at weaning. However, these studies have generally been subject to two limitations. First, most previous studies have assumed a static decision process. However, marketing and retention activities are adaptive processes, with the decisions at each stage dependent upon the previous decisions and a revised set of information. For example, the decision of how many yearlings to retain will be conditional on how many calves were retained and on expectations regarding future fed cattle prices. Incorporation of this dynamic decision process and the intertemporal dependencies requires a sequential empirical analyses.

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A second limitation to previous analyses has been the lack of consideration of general marketing alternatives available to cow-calf producers. That is, previous analyses have considered cow-calf producer risk management via only retention activities in a cash market. They have not considered the marketing risk management alternatives available such as hedging and options on calves retained through backgrounding as well as yearlings retained through finishing. Given the volatile nature of feeder and finished cattle prices there is considerable uncertainty regarding future revenues. In order to reduce the risks of adverse price changes during retention the producers should consider using alternative pricing strategies. For example, Bobst, Grunewald, and Davis used portfolio analysis to conclude that efficient frontiers for calf backgrounding operations included hedging as much as 100% of the calves purchased and backgrounded.

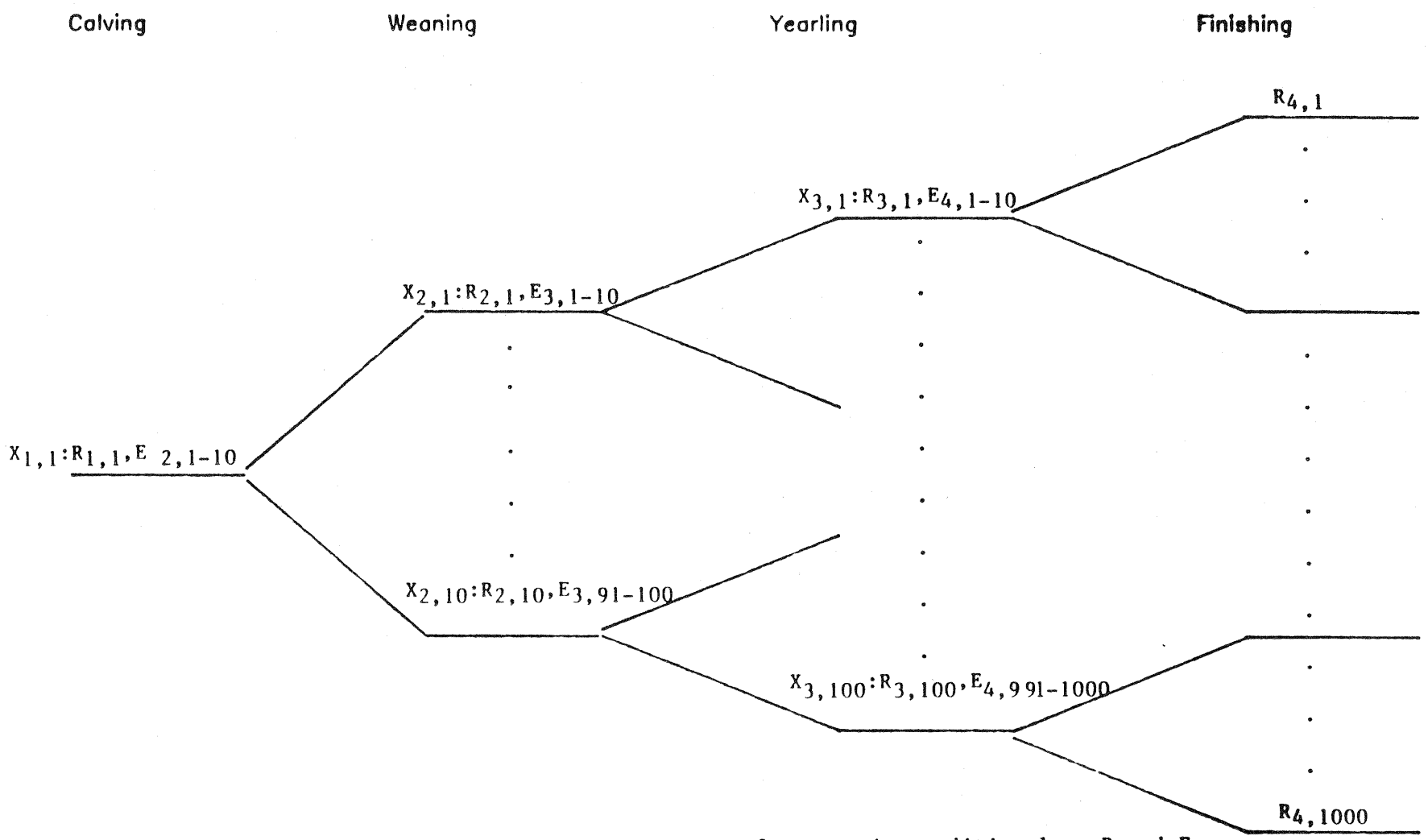
Additionally, with the exception of Gebremeskel and Shumway, none of the aforementioned studies considered continuous choices of calf retention and/or marketing alternatives. An interdependency exists between retention decisions and marketing alternatives available to the calf producer. In the presence of forward markets a risk averse cow-calf producer would be expected to be less apprehensive to retain at least a portion of his calf crop if he could reduce price risk.

In order to adequately capture the intertemporal dependencies among the expected payoffs in calf retention activities it is necessary to use a dynamic model to examine the optimal solution. In addition, given the uncertainty regarding future prices of calves that are retained, the model needs to be able to incorporate the stochastic distribution of expected future prices that a calf producer perceives when making these decisions.

In the next section of this paper the model is outlined. Next, the marketing alternatives examined in this analyses are discussed. The following section reports the empirical findings of the model. The paper concludes with a summary of and the implications of this research.

The Model

A discrete stochastic programming (DSP) model was formulated to determine optimal retention and marketing decisions for a cow-calf producer. Anderson, Dillon, and Hardaker illustrate the use of DSP in a similar problem. DSP is a dynamic model that can be used to model sequential decision making where new information is incorporated at discrete points in the production and marketing phases (Cocks, Rae 1971b). A schematic representation of the calf retention and marketing DSP model is shown in figure 1. The first stage represents the calving and calf raising phase of production. All calves are assumed to be born in the spring (February-April) and raised to fall weaning (August-October). At weaning, a set of decisions regarding retention and marketing activities are made, conditional upon current calf prices and expected distributions of yearling and finished cattle prices. At weaning, the cow-calf producer decides the number of calves to retain and the pricing of the calves retained through the yearling phase using cash, futures, and/or put options. Realizations occur during the spring (February-April) for the calves retained through the yearling phase and a revised set of information regarding future live cattle price expectations are used to determine the retention of yearlings and the pricing of the yearlings. At the end of the finishing phase, approximately 16 months after calving, the yearlings that were retained are marketed as finished cattle.



$X_{t,i}$ denotes the decision made at stage t in state of nature i, conditional on R and E.

$R_{t,i}$ denotes the realization of a random price variable at stage t in state of nature i.

$E_{t,j}$ denotes the set of expectations of a random price variable in stage t conditional on the previous state.

Figure 1. Calf Retention and Marketing Discrete Stochastic Programming Schematic.

Once the decision variables and constraints are determined, a DSP uses information on the realizations in the states of nature and their probabilities to choose the optimal decisions in each state. The decisions in each stage affect the decisions in subsequent stage(s). The realizations can be evaluated using standard risk analysis measures such as expected wealth or expected utility (Rae 1971a). A DSP model may be viewed as finite horizon dynamic programming problem with discrete random events and continuous choice variables (Featherstone, Preckel, and Baker).

Marketing Alternatives

Cow-calf producers considering retaining calves have several marketing and pricing alternatives they can consider. In this study the marketing alternatives that were examined included cash, futures, and options markets. At weaning calves could be sold in the cash market or they could be retained through the yearling phase. The calves retained to the yearling stage could be priced via any combination of a short feeder cattle hedge or the purchase of a put option (any of five strike prices considered $2/cwt. and $4/cwt. in- and out-of-the money and an at-the-money) placed at the start of the backgrounding phase. Calves retained that were not covered with a hedge or put option were subject to the cash market. Calves that were priced using a hedge or option were not necessarily sold as yearlings though the hedges and options were either closed or rolled forward into the fed cattle futures market. Yearlings that were retained through the finishing phase were priced via any combination of hedges or put option purchases on fed cattle futures. At the end of the finishing stage, all remaining cattle were sold in the cash market and all futures positions were liquidated.

The Mathematical Model

The notation for the mathematical model is defined below. Decision variables are in upper case and parameters are in lower case. Throughout the modeling section the first subscript indicates the production phase and the second subscript indicates the state. Let: t = the stage in which a decision is made, t = 1, 2, 3, 4, where 1 is the initialization stage, 2 is the weaning stage, 3 is the yearling stage, and 4 is the finished cattle stage; i = the number of the state at time t, (i = 1 to I_t); j = the number of the state at time t-1, (j = 1 ....I_{t-1},).

It is assumed that the cow-calf producer maximizes expected utility. The mathematical representation of utility is assumed to be a negative exponential function of terminal wealth. Featherstone, Preckel, and Baker discuss some alternative choices for utility functions and conclude that the negative exponential is an appropriate objective for use in a DSP. Formally, the objective is:

$$\text{Maximize} \quad Z = -\sum_{i=1}^{T} p_i e^{-\lambda OE_{4i}}$$

where T is the number of terminal states, p_i is the probability of terminal state i, k is the Pratt-Arrow coefficient of absolute risk aversion, and OE_{4i} is the owner's equity at the end of stage 4 in state i.

Expected utility is maximized subject to the following set of constraints.

Steer and Heifer Marketing Constraints

The steer and heifer marketing constraints limit the amount of steers and heifers that can be hedged or optioned to less than or equal to those retained.

$$FCS_{ti} + OS1_{ti} + OS2_{ti} + OS3_{ti} + OS4_{ti} + OS5_{ti} - CCS_{ti} \leq 0$$

$$FCH_{ti} + OH1_{ti} + OH2_{ti} + OH3_{ti} + OH4_{ti} + OH5_{ti} - CCH_{ti} \leq 0$$

$$\text{for } t = 2, 3 \text{ and } i = 1,2, \ldots, I_t$$

where CCS_{ti} is the number of steers retained in stage t in state i, CCH is the number of heifers retained, FCS is the number of steers hedged, FCH is the number of heifers hedged. OSx and OHx are the number of steers and heifers respectively marketed using a put option (x=1,2,3,4,5 for \$4/cwt out of the money, \$2/cwt out of the money, at the money, \$2/cwt in the money, and \$4/cwt in the money, respectively).

Steer and Heifer Accounting Constraints

Accounting constraints are used to transfer steers and heifers from one period into the next. In period 4, these constraints force the sale of all remaining calves.

$$SCS_{ti} + a_t\ CCS_{ti} - (1 - dlfs_t)CCS_{t-i,j} = 0$$

$$SCH_{ti} + a_t\ CCH_{ti} - (1 - dlfh_t)CCH_{t-1,j} = 0$$

$$\text{for } t = 2, 3, 4 \text{ and } j = 1,2,\ldots,I_{t-1}$$
$$\text{given } j, \text{ i goes from } (j-1) * I_t/I_{t-1} + 1 \text{ to } j * I_t/I_{t-1}$$

where $a_t = 1$ if t = 2 or 3 and zero otherwise, SCS and SCH are the number of steers and heifers sold respectively, dlfs is the steer death loss, dlfh is the heifer death loss.

Owner's Equity Constraints

The owner's equity constraints sum the income from sales plus the incremental income from marketing activities such as hedging and options.

$$OE_{1i} - OE_{2i} + s_{2i}\ SCS_{2i} + h_2\ SCH_{2i} = fc_2$$

$$\text{for } i = 1 \text{ to } I_t$$

$$OE_{t-1,j} - OE_{ti} + s_{ti}\ SCS_{ti} + h_{ti}\ SCH_{ti} + fs_{ti}\ FCS_{t-1,j} + fh_{ti}\ FCH_{t-1,j}$$

$$+ osl_{ti}\ OS1_{t-1,j} + ohl_{ti}\ OH1_{t-1,j} + os2_{ti}\ OS2_{t-1,j} + oh2_{ti}\ OH2_{t-1,j}$$

$$+ os3_{ti}\ OS3_{t-1,j} + oh3_{ti}\ OH3_{t-1,j} + os4_{ti}\ OS4_{t-1,j} + oh4_{ti}\ OH4_{t-1,j}$$

$$+ os5_{ti}\ OS5_{t-i,j} + oh5_{ti}\ OH5_{t-1,j} = fc_t$$

$$\text{for } t = 3, 4 \text{ and } j = 1, \ldots, I_{t-1}$$
$$\text{given } j, \text{ i goes from } (j - 1)* I_t/I_{t-1} + 1 \text{ to } j * I_t/I_{t-1}$$

where OE_{ti} is the owner's equity at stage t in state i, osx and ohx (x=1,2,3,4,5 for \$4/cwt out of the money, \$2/cwt out of the money, at the

money, $2/cwt in the money, and $4/cwt in the money, respectively) are the incremental steer and heifer put option profits, s is the steer contribution to fixed costs, h is the heifer contribution to fixed costs, fs is the incremental steer profit from hedging, fh is the incremental heifer profit from hedging, and fc_t is the fixed costs of cow-calf producers, $fc_t = 0$, if t = 1, 2, or 3.

Initialization Constraints

$$OE_{11} = ie$$

$$CCS_{11} = is$$

$$CCH_{11} = ih$$

Initialization constraints specify the initial owners equity (ie), initial number of steer calves (is), and initial number of heifer calves (ih) in stage 1 and state 1.

Stochastic Environment

A cow-calf producer faces many uncertain variables including output prices, production costs, and environmental factors. This section describes the procedures used to define the stochastic environment. The size of a DSP model increases exponentially as the number of stages or states modeled increase. In calf retention decisions, the most natural time periods in which to make retention and marketing decisions seem to be at points where the production management of the animals change. Thus, three stages were used representing the intialization stage (calving), weaning stage, and the yearling stage.[1]

Random variable realizations for each state of nature and the probability of each state must be defined for each stage. These states and probabilities define the stochastic process underlying the random variables. Because of limited computer capacity, it is not possible to model all of the random variables that the decision maker faces nor all outcomes of the random variables chosen. Ten states of nature were chosen for each stage in this study. Featherstone, Preckel, and Baker discuss methods for limiting the number of random variables while capturing both the essential stochastic and nonstochastic relationships.

Prices of calves, yearlings, and finished cattle are the most critical and volatile variables facing a cow-calf producer retaining calves. Thus, heifer and steer prices, and basis relationships were the stochastic variables modeled. Feed prices and operating expenses were assumed to be nonstochastic.

The method used to approximate the distribution of expected prices at each stage and for each state was to partition the probability distribution of prices into ten regions, calculate the probability of each region using numerical integration, and calculate the conditional mean price in the region. The conditional means were then used as the realizations.

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[1] A closedown stage is needed to sell the finished cattle, to close out futures positions, and to calculate profits. In the terminology of DSP, this is not usually referred to as a stage, but rather the terminal conditions or the closedown.

Price Distributions

This section describes the modeling of the stochastic price distributions. A description of the determination of the futures prices and option premiums is also included in this section. Finally, the distributions of cash profits, hedging profits, and option profits are discussed.

The 4/500 pound steer price distribution was calculated based the following process:

$$SP1_i = SP1 + e_i \qquad \text{for } i=1,2,\ldots 10$$

where $SP1_i$ is the price of 4/500 pound steers in state i, SP1 is the average 4/500 pound steer price during August through October, and e is a random component; it is assumed to be distributed normally with a zero mean and standard deviation of $13.20/cwt based on 1981 through 1986 data.

Yearling steer price distributions are estimated from each calf price based on the following relation:

$$SP2_t = \underset{(8.26)}{24.31} + \underset{(0.123)}{0.587}SP1_{t-1} + a_t$$

$$R^2 = 0.72, \text{ RMSE} = 7.46, \text{ Durbin-Watson} = 2.23$$

where $SP2_t$ is the 7/800 pound steer price ($/cwt) in year t during February through April, $SP1_{t-1}$ is the previous year's average August through October 4/500 pound steer price ($/cwt), standard errors are in parentheses, and a is a normally distributed deviate with zero mean and standard deviation of $5.02/cwt. The relationship was initially estimated (via OLS) using prices through 1981 and updated annually through 1986. The standard deviation of the deviates was estimated using the errors from out-of-sample forecasts of this model during the 1981 through 1986 period. In estimating the forecast error the model was re-estimated annually incorporating the most recent year's prices.

The finished steer price distributions during June through August are estimated in a similar fashion using the February through April yearling prices in the following manner:

$$SP3_t = \underset{(7.11)}{23.521} + \underset{(0.116)}{0.589}SP2_t + r_t$$

$$R^2 = 0.72, \text{ RMSE} = 6.05, \text{ Durbin-Watson} = 1.88$$

where $SP3_t$ is the average June through August finished steer price ($/cwt) in year t, and SP2 is as defined above. The random component, r, is estimated in the same fashion as the yearling calf deviates, using a normal distribution with mean zero and standard deviation of $5.38/cwt.

Commercial heifer prices generally follow steer prices fairly closely with some random deviation. Thus, heifer prices were assumed to be a linear function of the prices of similar weight steers with random normal deviations based upon the standard error of this relationship during 1981 through 1986. All price relationships were estimated using 3-month averages of the weekly Dodge City, Kansas feeder cattle auction prices for medium framed steers and heifers for weights of 4/500 lbs., 7/800 lbs., and finished weights of 1100 lbs. for steers and 1050 lbs. for heifers. The means and standard deviations of the steer an heifer prices used in the DSP model are reported in table 1.

It was assumed that the futures price, at the time a hedge or option was being considered, equaled the expected cash price near the futures maturity date of feeder or finished cattle adjusted for the expected basis. The expected basis was estimated using feeder cattle and fed cattle cash and nearby futures prices over the 1981 through 1986 period during the relevant seasons.[2] Thus, for each expected cash price distribution, the deferred futures price distribution was similar except for the constant basis adjustment. At the time the hedge or option was lifted, the futures price was assumed to equal the relevant cash price adjusted for basis plus a normal random deviate reflecting basis risk that was present during the 1981 through 1986 period.

Option premiums were calculated using Black and Scholes option pricing model. A sensitive variable in the option pricing model is the futures price volatility. Little published research has been done estimating recent cattle futures price implied volatilities. For 5 month to maturity options, Firch and Dahlgran estimated live cattle futures price implied volatilities ranging from 14.9 to 15.5 for the June 1985 contract. Gordon found that over various months to maturity and contract months in 1985, live cattle futures price implied volatilities ranged from 14.5% to 26.6%, with most being around 20%. Thus, in this study option premiums were approximated using futures price volatilities of 20% and this is compared with results using a futures price volatility of 15%. At option expiration, options were sold if their value exceeded the commission costs otherwise they were left to expire.

The representative cow-calf producer modeled is assumed to retain 18% of his total calf crop for replacement heifers in the breeding herd, of the remaining calves, all of which he sells (after death losses), 62% are assumed to be steers and 38% are assumed to be heifers. It is assumed that the cow-calf producer does not have the fixed facilities for finishing cattle and any yearlings retained are placed in a custom feedlot. Because of the performance and price differences that have been present in recent years between steers and heifers, steer and heifer retention and marketing decisions were considered separately. The costs of maintaining the cow-calf herd, drylot backgrounding of the calves, and finishing yearlings in a custom feedlot were taken from 1986 Kansas Farm Management Guides developed by Kansas State University Extension Specialists.

The means and standard deviations of the returns above variable costs for cash marketing, hedging, and options are reported in table 2. The large differences between mean steer and heifer cash profits reflect the relative steer-heifer price differentials and differences in production efficiency. On average the cow-calf producer was generally not covering variable costs, however, his chances of being profitable increased when cattle were retained through the finishing phase.

Results and Discussion

Steer and heifer calf retention and marketing activities are examined for a representative midwestern cow-calf producer. The effects of the level of risk aversion on marketing and retention activities are examined. The decisions to retain calves and/or place futures positions depend upon the realized calf price, the expected distribution of future prices, and the level

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[2] Due to the changes which occurred in the feeder cattle futures contract specifications in 1986, changing basis significantly, the Cattle-Fax USFSP price was used as a proxy for the feeder cattle futures price in estimating the expected feeder cattle basis.

Table 1. Means and Standard Deviations of Steer and Heifer Cash Prices Used in the DSI

	Mean[a]	Standard Deviation[a]	Minimum Value	Maximum Value
Calves:[b]		$/cwt		
Steer Price	70.59	13.05	39.12	102.06
Heifer Price	60.31	11.06	33.45	86.91
Yearlings:[c]				
Steer Price	65.57	9.12	35.18	95.97
Heifer Price	62.54	9.16	33.18	92.29
Slaughter:[d]				
Steer Price	62.14	7.54	31.46	92.83
Heifer Price	60.23	7.43	29.62	90.52

a Probability weighted.
b Steer calf weight of 450 pounds and heifer calf weight of 425 pounds.
c Yearling steer weight of 750 pounds and yearling heifer weight of 725 pounds.
d Slaughter steer weight of 1150 pounds and slaughter heifer weight of 1050 pounds.

Table 2. Means and Standard Deviations of Returns Above Variable Costs.

	Mean[a]	Standard Deviation	Minimum Value	Maximum Value
Calves:		$/head		
Steer Cash	- 2.57	60.28	-147.97	142.84
Heifer Cash	-65.53	39.26	-182.74	50.54
Yearlings:				
Steer Cash	- 4.64	66.51	-226.38	217.10
Steer Hedge	- 5.98	57.21	-151.09	133.80
Steer Option (20%)[b]	-16.46	57.51	-169.14	180.49
Steer Option (15%)[c]	- 9.91	58.21	-167.47	188.94
Heifer Cash	-40.45	64.63	-247.55	169.37
Heifer Hedge	-41.75	56.02	-177.12	104.54
Heifer Option (20%)	-51.87	56.02	-186.68	133.98
Heifer Option (15%)	-45.54	56.67	-182.17	142.15
Slaughter:				
Steer Cash	4.05	79.67	-319.95	328.04
Steer Hedge	2.19	57.68	-199.01	225.81
Steer Option (20%)	- 3.71	63.44	-212.03	288.74
Steer Option (15%)	4.05	64.00	-206.52	298.76
Heifer Cash	-30.16	74.91	-338.72	275.16
Heifer Hedge	-31.93	54.44	-217.58	179.52
Heifer Option (20%)	-37.56	59.68	-236.05	237.64
Heifer Option (15%)	-30.16	60.24	-230.79	247.21

a Probability weighted.
b At-the-money put option with an assumed futures price volatility of 20%.
c At-the-money put option with an assumed futures price volatility of 15%.

of producer risk aversion. To more closely examine the results they were summarized in three separate cash profit categories. For calves, the 10 cash profit realizations were split into the 3 lowest, 4 middle, and 3 highest cash profit levels. Since the cash profits do not have equal probabilities of occurring (i.e., a normal distribution was assumed rather than a uniform one) the lowest 3 profits included roughly 25% of the profit probability distribution, the middle profits covered 50% of the probability distribution, and the highest 3 profits covered 25% of the distribution. For yearlings, the 100 cash profit realizations were split into the 30 lowest, 40 middle, and 30 highest yearling cash profits.

The average steer and heifer retention in each profit category is reported in table 3. When calf cash profits were in the lower 25% probability category the model retained 100% of heifers and steers regardless of the producers aversion to risk. On the other extreme, when calf profits were at their highest levels, the optimal solution was not to retain any of the steer calves but still retain all heifer calves. The price discounts that heifer calves received during the 1976 through 1986 period resulted in heifer retention having a higher incremental profit relative to steer retention. The liquidation of the beef herd which took place during the 1976 to 1986 period, with a reduction in herd size in excess of 20% (USDA), likely contributed to the heifer price discounts observed. During rebuilding phases of the beef herd this result may change. As the producer became more risk averse, the general tendency was to retain less calves and yearlings when cash profits were in the middle 40% ranges. However, in the lower profit ranges the optimal solution was to maintain 100% ownership through the finishing phase for both steers and heifers regardless of producer risk aversion. During times of high profits the cow-calf producer is better off selling steer calves and taking the profits, but there is still an incentive to maintain ownership of heifers as their price relative to steers is expected to increase. During times of low profits (large losses) the producer is better off retaining all calves and yearlings through the finishing phase. The futures price volatility had very little impact on retention decisions. A reduction in the volatility from 20% to 15% increased average retention slightly for the more risk averse producers.

The retention decisions are interdependent upon the hedging and put option marketing decisions made by the producer. The mean hedging and put option purchasing decisions under the three categories of cash profit realizations are reported in tables 4 and 5, respectively. The futures price volatility did not have a large impact upon calf hedging and put option activities. However, volatility had a pronounced impact on hedging and options usage for yearlings being retained through the finishing phase. For the more risk averse producers, option usage was very limited with 20% futures price volatility but put option purchases increased with 15% volatility. The increased use of options with 15% volatility was combined with a reduction in hedging though the increased option usage more than offset the decline in hedging activity.

As the producer became more risk averse hedging activity increased, increasing for example, from 48% of calves being hedged in the middle profit range for the least risk averse to almost 100% for the most risk averse producers. In addition, the optimal decision was to hedge less during low cash profits, even though this was a period of high retention activity. Locking in a loss via hedging may not be a comfortable action, nonetheless it was sometimes optimal for the more risk averse producers.

Option usage for yearlings was virtually nonexistent under the 20% volatility assumption but increased significantly with 15% volatility. This result re-emphasizes the importance of implied volatility assumptions in option

Table 3. Average Percentage of Calves and Yearlings Retained Under Three Profit Levels.

Pratt-Arrow Risk Aversion Coefficient	Steers: Average Calves Retained Lower[a] %	Middle[b] %	Upper[c] %	Steers: Average Yearling Retained Lower %	Middle %	Upper %	Heifers: Average Calves Retained Lower %	Middle %	Upper %	Heifers: Average Yearlings Retained Lower %	Middle %	Upper %
FUTURES PRICE VOLATILITY = 20%												
.000001	100	100	0	100	100	0	100	100	100	100	91	32
.000005	100	100	0	100	100	0	100	100	100	100	91	32
.00001	100	100	0	100	98	0	100	100	100	100	91	32
.00005	100	76	0	100	91	0	100	100	100	100	87	25
.0001	100	76	0	100	91	0	100	100	100	100	85	21
.0005	100	50	0	100	87	0	100	100	100	100	80	17
FUTURES PRICE VOLATILITY = 15%												
.000001	100	100	0	100	100	0	100	100	100	100	91	32
.000005	100	100	0	100	100	0	100	100	100	100	91	32
.00001	100	100	0	100	100	0	100	100	100	100	91	32
.00005	100	82	0	100	91	0	100	100	100	100	91	25
.0001	100	76	0	100	91	0	100	100	100	100	87	21
.0005	100	56	0	100	88	0	100	100	100	99	81	17
Probability	0.25	0.50	0.25	0.24	0.52	0.24	0.25	0.50	0.25	0.24	0.52	0.24

[a] Includes the lowest 30% of profit realizations.
[b] Includes the middle 40% of profit realizations.
[c] Includes the highest 30% of profit realizations.

Table 4. Average Percentage of Calves and Yearlings Retained and Hedged in the Futures Market Under Three Profit Levels.

Pratt-Arrow Risk Aversion Coefficient	Steers: Average Calves Hedged			Steers: Average Yearlings Hedged			Heifers: Average Calves Hedged			Heifers: Average Yearlings Hedged		
	Lower[a] %	Middle[b] %	Upper[c] %	Lower %	Middle %	Upper %	Lower %	Middle %	Upper %	Lower %	Middle %	Upper %
					FUTURES PRICE VOLATILITY = 20%							
.000001	0	48	-	35	32	-	0	48	54	29	38	47
.000005	0	48	-	37	35	-	0	48	54	41	45	43
.00001	0	48	-	43	40	-	0	48	54	56	61	43
.00005	41	69	-	74	67	-	42	48	54	74	80	57
.0001	60	92	-	82	73	-	57	45	63	83	88	68
.0005	78	100	-	86	74	-	68	62	82	93	94	80
					FUTURES PRICE VOLATILITY = 15%							
.000001	0	48	-	1	9	0	0	48	54	1	13	4
.000005	0	48	-	0	9	0	0	48	54	0	13	4
.00001	0	48	-	0	9	0	0	48	54	0	16	4
.00005	32	68	-	4	23	0	0	47	54	10	27	18
.0001	41	90	-	16	29	0	23	42	62	36	43	33
.0005	56	100	-	58	55	0	67	58	82	78	73	59
Probability	0.25	0.50	0.25	0.24	0.52	0.24	0.25	0.50	0.25	0.24	0.52	0.24

[a] Includes the lowest 30% of profit realizations.
[b] Includes the middle 40% of profit realizations.
[c] Includes the highest 30% of profit realizations.

Table 5. Average Percentage of Calves and Yearlings Retained That Were Hedged Using Put Options Under Three Profit Levels.

Pratt-Arrow Risk Aversion Coefficient	Steer						Heifers					
	Average Calves Option			Average Yearling Options			Average Calves Option			Average Yearling Options		
	Lower[a] %	Middle[b] %	Upper[c] %	Lower %	Middle %	Upper %	Lower %	Middle %	Upper %	Lower %	Middle %	Upper %
FUTURES PRICE VOLATILITY = 20%												
.000001	0	0	0	3	0	0	0	0	0	5	0	0
.000005	0	0	0	6	0	0	0	0	0	6	0	0
.00001	0	0	0	6	0	0	0	0	0	6	0	0
.00005	0	0	0	7	0	0	0	0	0	6	0	0
.0001	0	0	0	6	0	0	0	0	0	2	0	0
.0005	0	0	0	2	0	0	0	0	0	2	0	0
FUTURES PRICE VOLATILITY = 15%												
.000001	9	0	0	89	55	0	9	0	0	84	60	42
.000005	9	0	0	90	75	0	9	0	0	90	73	42
.00001	9	0	0	90	77	0	9	0	0	95	73	42
.00005	43	0	0	94	66	0	9	0	0	88	67	43
.0001	48	0	0	83	60	0	9	0	0	63	53	43
.0005	30	0	0	41	31	0	1	0	0	21	26	34
Probability	0.25	0.50	0.25	0.24	0.52	0.24	0.25	0.50	0.25	0.24	0.52	0.24

[a] Includes the lowest 30% of profit realizations.
[b] Includes the middle 40% of profit realizations.
[c] Includes the highest 30% of profit realizations.

marketing strategy evaluations and the sensitivity of optimal option hedging decisions to option premiums. Option usage was highest for the less risk averse producers since they were more willing to pay the up front premium for the chance of higher profits. The more risk averse producers substituted the less variable hedges for option purchases. For example, with 15% volatility, for yearlings being retained when cash profits were in the lower range, hedging by less risk averse producers was typically under 10% and option usage averaged above 80%. However, as risk aversion increased, the hedging activity increased to more than 58% on average and option usage reduced to 40% or less. Thus, the more risk averse producers prefer hedging with a sure outcome and lower risk to options. Even with these substitutions, the more risk averse the producer was, the more closely to 100% forward priced (hedging plus options).

When the futures price volatility was 15%, the strike prices chosen by the model for put options purchased depended upon the level of risk aversion of the producer. For the less risk averse producer, about 60% of the options selected on average were out of the money and about 25% were in the money. The less risk averse individuals were more willing to pay a low premium for the chance of higher returns if prices increase, than they were to pay the higher premiums for the in the money options. However, the more risk averse producers preferred the in the money options to the out of the money. For example, for the most risk averse producer, about 70% of the options purchased on average for both steers and heifers were in the money and only about 20% were out of the money. An in the money option will in general be less risky than an out of the money option because when purchasing an in the money put option one is paying a higher premium to guarantee a higher net minimum selling price. The expected price distribution generated by the purchase of an in the money put option will have a lower variance than the price distribution for an out of the money put option. Thus, in the money options are likely to be preferred by more risk averse producers and out of the money options are preferred by the less risk averse.

Conclusions and Implications

Cow-calf producers have traditionally sold their calves at weaning. However, retaining ownership of the calves through backgrounding and/or finishing may result in improved returns. The decision to retain calves is dependent upon the current profit situation, expected future price distributions, and the cow-calf producers aversion to risk. During periods of low cash profits producers are better off retaining calves. During periods of high profits cow-calf producers are better off selling steer calves though still retaining heifer calves, given typical historical discounts for heifer calves relative to steers. The more risk averse the producer, the less calves retained, though average retention declined only a little as risk aversion increased.

Hedging and options were used to price at least a portion of the retained calves most of the time. When current profits were low and the producer was risk averse leaving the calves unhedged was optimal. However, when profits were in the middle and upper categories or as risk aversion increased, hedging and options usage increased to as much as 100% of the retained calves. If put options were trading with premiums reflecting 15% futures price volatility much of the optimal price protection was in the form of purchased put options. However, when premiums were high, reflecting 20% volatility, hedging generally was preferred to put options.

The results of this study rely on historical cattle price distributions and relationships that were present during the 1976 through 1986 period. To the extent that these historical prices provide good proxies for future price distributions the results should be robust. Given the continual cattle herd liquidation which occurred during this eleven year period, heifer price differentials may not be representative of those one might observe during herd rebuilding years. Thus, heifer retention may not be as preferred during periods of herd building as these results may indicate.

Cow-calf producers need to continue to monitor changing market conditions when evaluating calf retention and marketing decisions. Recent tax law changes in the Tax Reform Act of 1986 could make calf retention even more preferred than this study might imply. Historically, a large percentage of cattle feeding has been done by outside investors. Rossi concluded that a decisive factor in whether or not nonfarm investors will continue considering cattle feeding ventures is whether the investor can meet the material participation standards necessary for deduction of losses as regular income for tax purposes. If this standard proves difficult to meet (uncertainty exists as to the degree of active participation required), calf prices could decline relative to finished cattle prices due to the reduction in number of buyers bidding on calves.

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