VERTICAL INTEGRATION FOR RISK MANAGEMENT: AN APPLICATION TO A CATTLE RANCH*

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Substantial variations in equity and income of cattle producers and feeders in highly leveraged operations have occurred during the early 1970s as the result of wide variations in prices of cattle and purchased feed. Moreover, severe losses in many commercial feedlots have resulted in greater forage inputs in beef production, with feeder cattle placed in feedlots at heavier weights and for shorter periods of time. The large price uncertainty, together with possible changes in the livestock production system, make cattle producers' search for effective methods of risk management more urgent.

The search is hampered, however, by a limited scope of choices in risk management. Forward price commitments in cattle production have received limited use at the producer level. Public programs of price support and supply management have never been available. Insurance choices are few, as are alternatives for diversifying use of grazing lands and other resources specialized to cattle production. Often, producers' primary methods of risk-bearing are reliance on financial reserves, including unused borrowing capacity, emergency loans provided by public programs and outside sources of income. However, effective opportunities for reduction of income variability may be offered by vertical integration expressed as retention of calf ownership through finishing stages either on pasture or by custom feeding in commercial feedlots.

The purpose of this paper is to develop a procedure for evaluating risk-return effects of selling produced calves, or holding them through subsequent stages of the production process. Multiperiod risk programming is used to model the vertical sequence of decision choices and to evaluate risk and returns in a value-added sense as suggested by Logan [5]. Following sections describe the model's specification and its application to a representative ranch firm in the Rolling Plains of Texas.

MODELING VERTICAL INTEGRATION IN CATTLE PRODUCTION

Multiperiod quadratic programming is used to model a representative ranch firm and to derive a set of E-V efficient growth plans.[1] Financial components, linear structure and other basic features of this model are generally similar to those used in other studies [1, 2].

However, a key distinction is availability of vertically sequenced production and marketing choices in the firm's inventory of portfolio choices. The linear portion of the firm's objective for each period reflects time discounted expected values on gross margins for the vertically sequenced choices specified over all periods in the model's horizon. And, the nonlinear portion for each period reflects time discounted variances and covariances on gross margins for vertically sequenced choices. Hence, each growth plan in the E-V efficient set indicates the optimal combination of investment and vertical production alternatives in each year of the planning horizon that

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[1] E-V efficient growth plans refer to identification of a set of production strategies which produce a given expected income (E) with minimum variance (V) of that expected income.

will minimize expected variance for the specified net present value of income.

The sequential flow of choices in cattle production and marketing is broadly outlined in Figure 1 and modeled mathematically for one time period in Table 1.[2] The sequence begins with calf production in the weaned calf stage. This phase is terminated by sale of the animal or by transferring it to the stocker phase for grazing on wheat pasture. Alternatively the weaned calf could be placed directly into the feedlot phase on a custom feeding basis, bypassing the stocker phase. The stocker phase is terminated by sale of the stocker animal or by placement in a feedlot for custom feeding. The feedlot phase is terminated by sale of the fed animal for slaughter. Options to purchase steers for grazing and custom feeding are also provided.

The extent of vertical integration in each E-V solution depends jointly on the target level of income in the growth plan and the combination of activities needed to minimize variance. The contribution of

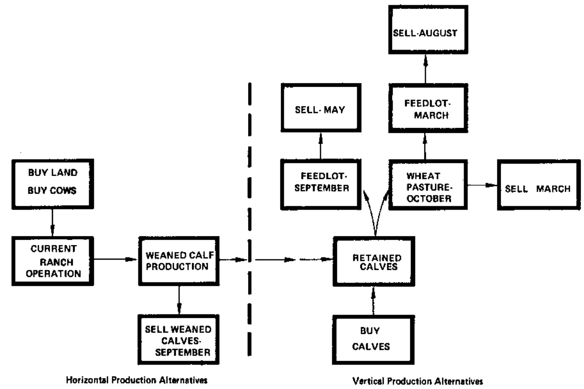

FIGURE 1. ANNUAL PRODUCTION CHOICES TO EXPAND NET RANCH INCOME, TEXAS ROLLING PLAINS

return and risk associated with choices in vertical sequence is expressed as value-added to the objective by the respective stages. Selling a weaned calf

TABLE 1. OUTLINE OF THE QUADRATIC PROGRAMMING MODEL TO CONSIDER INTEGRATION FOR RISK MANAGEMENT

Constraint	Livestock Production Activities: Produce weaned calves	Vertical alternatives[a]: Feedlot	Vertical alternatives[a]: Wheat pasture	Vertical alternatives[a]: Wheat feedlot	Cash, Credit, Investment, Consumption, Taxes	Row relationship	RHS	Variance Specifications: Level of[b] vertical integration	Variance Specifications: Total variance per given level of vertical integration
Objective[c]	$\frac{C_n}{(1+i)^n}$	$\frac{C_n}{(1+i)^n}$	$\frac{C_n}{(1+i)^n}$	$\frac{C_n}{(1+i)^n}$	$\pm \frac{C_n}{(1+i)^n}$	N	MAX		
Period n									
Rangeland	A				-A	L	Ac		
Cows	A				-A	L	Hd		
Calf transfer	-1	1	1			L	0		
Wheat calf transfer			-1	1		L	0		
Cash m^d	±A	±A	±A	±A	±A	L	$		
Borrowing m^d	±A	±A	±A	±A	±A	L	$		
Variance-covariance[e]									
Period n									
Produce calves	W							1	W
Feedlot	WX	X						2	W+X+WX
Wheat pasture	WY	XY	Y					3	W+Y+WY
Wheat/feedlot	WZ	XZ	YX Q	Z				4	W+Y+Z+WY+WZ+YZ

[a]Vertical alternatives represent placement of weaned (retained or purchased) calves in feedlots or on wheat pasture followed by the choice of further fattening in a feedlot.

[b]Level 1 = weaned calves sold.
Level 2 = weaned calves placed into feedlot, then sold.
Level 3 = weaned calves placed on wheat pasture, then sold.
Level 4 = wheat pasture calves placed into a feedlot, then sold.

[c]C = annual gross margin.
i = discount rate.
n = respective annual time period (1..........n).

[d]m = respective subperiod within the n^{th} time period (1.....n).

[e]A single letter on the diagonal represents the variance for a specified activity level while the off-diagonal letter combination represents the covariance relationships for specified levels of activities. These values are appropriately discounted to reflect a given time period.

[2]Additional details and further discussion of the model are available from the senior author.

generates net income equal to its market value less its costs of production. Placing a weaned steer on wheat pasture in the stocker phase will "cost" the wheat pasture activity the market value of the weaned calf plus cash costs associated with using the wheat pasture. If the steer is subsequently placed in a feedlot for custom feeding, it will "cost" the feeding activity its market value at the end of the stocker phase plus other costs incurred in the feedlot. The total value of annual production is the sum of net income over the respective stages.

Similarly, the variance associated with each additional stage of production is considered as value-added to the variance of the preceding stage. Net addition to total annual variance depends on individual variance of the additional stage and on its correlation with preceding stages. Negative correlation between vertically sequenced stages may result in a total variance that is less than the sum of the individual variances [6]. A positive correlation will yield a combined variance exceeding the sum of individual variances on the respective stages. These annual variance-covariance relations are expressed in the variance section of Table 1. Single letters along the main diagonal of the variance-covariance matrix represent the variance for respective activities in vertical sequence. Combinations of letters appearing off the main diagonal represent covariance relationships for respective activities in vertical sequence. The summations of variance for alternative combinations of sequential choices are identified in the lower right-hand corner of Table 1. Thus, a combination of calf production, grazing on wheat pasture with placement in a feedlot and subsequent sale, would yield total variance of (W+Y+Z+WY+WZ+YZ) for the respective year of the model. Hence, alternative levels and combinations of vertically sequenced activities can be evaluated in terms of their effects on the firm's level and variability of expected income.

Vertical choices require a multiperiod formulation within years to reflect the short-run sequence of decision choices, and account for income and variance added by the respective stages. In addition, a multiyear formulation is needed to properly account for investment and credit components and other cash flows that influence firm growth. Investments in land, range improvements and livestock with related financing choices are provided to add resource capabilities in the respective years, thereby increasing income-generating capacity. Sources of risk are expressed solely as expected variability of gross margins on production and marketing choices in the respective years.

Hence, the model combines longer run choices for investment and financing with shorter run decisions on sequences of production and marketing, to yield a set of E-V efficient growth plans. These vertical choices in cattle production offer considerable flexibility to the decision-maker because they do not involve large investments in fixed capital assets. Adding vertical stages to calf production is typically a short-run decision, based on expected market prices and forage conditions, that is largely independent of longer run growth plans. Its main effects on cash flow are to delay receipts from product sales until the end of the vertical sequence and to require somewhat longer terms on operating credit to carry the animal through the vertical stages.

AN EMPIRICAL APPLICATION

A representative ranch in the Rolling Plains of Texas was modeled from use of published data [3, 4, 6] and from consultation with extension personnel, lenders and producers familiar with the area. Ranching in the Rolling Plains represents a major sector of the regional economy; however, cattle production has experienced wide income variations due to changing weather and price conditions. Moreover, relatively heavy stocking rates have depleted the forage resource and have contributed to variability of beef production. Hence, there is serious need for developing production and marketing plans that stabilize ranch incomes in this area.

Investments available to the representative ranch included purchases of additional rangeland and cows. The calf production system specified in the model was characterized by continuous year-long grazing, an average stocking rate of one cow per 14 acres of rangeland, and supplemental feeding of the cows during the winter [8]. Other production choices in the model included the vertical sequences outlined earlier.

Income added by vertical integration was based on expected gross margins for the respective activities in vertical sequence. Expected gross margins (total sales less variable costs of production) were estimated as mean gross margins obtained from each production stage over the 1969-1973 period. Prices and costs were obtained from time series observations for each production activity in each year of the time period. Data on levels and variability of beef production were collected from an experiment station ranch in the study area.

Annual livestock prices [7] and production data were combined to derive annual expected gross margins for 1969-1973. Variances and covariances for annual gross margins of vertically sequenced activities were then derived.[3] The time series of gross margins was limited to five years, due to changes in experimental design of the grazing systems on the experimental ranch in 1969. Therefore, degrees of freedom for the statistical analysis were somewhat limited.

Time series observations on gross margins reflected jointly the effects of variations in prices for calves, stockers, slaughter cattle and variability in forage production. Variability in range forage production was reflected in annual fluctuations in calf crops, weaning weights and stocking rates. Annual variability of wheat pasture forage was reflected by fluctuations in stocking rates of stockers. Annual feed prices were important variables influencing fluctuation in the gross margins of slaughter animals. Thus, price and production variables that were determined to significantly affect variability of income in each vertical sequence were included in the analysis.

The annual variance-covariance matrix estimated for alternative livestock production activities is reported in Table 2. Low and negative covariances between selected activities suggest that vertical integration will likely characterize lower income-variance solutions on the E-V boundary. For example, income variance for weaned calf production is $13,184. The ranch manager who considers finishing his calves in a feedlot could expect that phase to increase income variance by $4,278. However, the negative covariance of —$5,333 between the calf and feedlot activities provides an opportunity for integration to reduce total income variance. After the negative covariance combinations are exhausted, with further increases in expected income still possible, combinations of activities with positive covariances may occur in the set of E-V efficient solutions.

TABLE 2. VARIANCE-COVARIANCE ESTIMATES FOR LIVESTOCK PRODUCTION ACTIVITIES, TEXAS ROLLING PLAINS

Livestock Activity Name	Livestock Activity Name			
	WC	WP	FL	WFL
	Variance-covariance ($)			
Weaned calf (WC)	13,184			
Weaned steer-wheat pasture (WP)	-687	2,819		
Weaned steer-feedlot (FL)	-5,333	2,439	4,278	
Wheat steer-feedlot (WFL)	-2,825	698	1,750	800

Efficient E-V growth plans are obtained for a model horizon of five years. The efficient E-V set consisted of 144 solutions; however, results of only four growth plans are reported in Tables 3 and 4 to illustrate the changing composition of solution activities for movements up the E-V boundary.[4]

Vertical production alternatives were utilized in all growth plans to increase income as well as to reduce income variation. At lower levels on the E-V boundary, the preferred sequence was production of weaned calves with subsequent placement in a feedlot, a result consistent with negative covariances. As growth in ranch income increased, a wheat pasture activity was included in the vertical sequence (Table 4).

Size of the ranch firm increased in order to produce greater numbers of livestock and, thus, to allow income to increase. Some interesting trade-offs can be observed between rapid growth in ranch income and the degree of vertical integration required in the five-year growth plan. For example, compare Ranch Plan A to Plan D. Plan A represents the most stable one requiring no increase in ranch size, with all retained steers going directly into a feedlot and few steers being purchased. Plan D, the income maximizing solution, required the ranch to

TABLE 3. FIVE-YEAR NET INCOME AND STATISTICAL CHARACTERISTICS OF FOUR ALTERNATIVE-FIVE YEAR RANCH GROWTH PLANS, TEXAS ROLLING PLAINS[a]

Ranch plan	Net present[b] value of income	Standard[c] deviation
	($)	($)
A	177,001	24,870
B	192,522	36,575
C	209,293	56,591
D	225,651	90,878

[a]All values in the table are present values discounted at six percent.

[b]Total net income represents total 5-year sales less cash expenses associated with production, including interest on borrowed funds (real estate and nonreal estate debt).

[c]Includes price and production variation for livestock and rangeland forage activities in the model.

[3]Variances and covariances were determined as deviations from the mean gross margin using standard statistical techniques. Variances and covariances were not adjusted for trend due to the limited number (five) of observations.

[4]It is assumed that a rational manager will always choose a production strategy which is located on the E-V boundary. This is because any other strategy (off the boundary) will produce a given level of income with greater income variance than one located on the boundary.

TABLE 4. COMPOSITION OF FOUR ALTERNATIVE-FIVE YEAR RANCH GROWTH PLANS, TEXAS ROLLING PLAINS[a]

					Raised steers sold from:					Purchased steers sold from:		
Ranch plan	Year	Total ranch size	Herd[b] size	Steers[c] produced	weaned calves	wheat pastures WP	feed-lot FL	WP and FL	Steers purchased	Wheat pasture WP	Feed-lot FL	WP and FL
		(Ac)	(Hd)	(Hd)	(%)	(%)	(%)	(%)	(Hd)	(%)	(%)	(%)
A												
	1	4,800	265	118	0	0	100	0	50	0	100	0
	2	4,800	347[d]	154	0	0	100	0	61	0	100	0
	3	4,800	347	154	0	0	100	0	61	0	100	0
	4	4,800	347	154	0	0	100	0	64	0	100	0
	5	4,800	347	154	0	0	100	0	66	0	100	0
B												
	1	4,800	265	118	0	0	100	0	159	0	0	100
	2	5,377	388	173	0	0	61	39	161	0	90	10
	3	5,377	388	173	0	0	41	59	152	0	100	0
	4	5,377	388	173	0	0	21	79	171	0	100	0
	5	5,377	388	173	0	0	0	100	198	0	100	0
C												
	1	4,800	265	118	0	0	0	100	238	0	0	100
	2	5,959	429	191	0	0	77	23	341	0	0	100
	3	5,959	429	191	0	0	86	14	316	0	0	100
	4	5,959	429	191	0	0	93	7	290	0	0	100
	5	5,959	429	191	0	0	0	100	339	0	76	24
D												
	1	4,800	265	118	0	0	0	100	238	0	0	100
	2	5,959	429	191	0	19	0	81	385	0	0	100
	3	7,616	549	244	0	6	0	94	493	0	0	100
	4	9,064	654	291	0	0	0	100	586	0	0	100
	5	9,064	654	291	0	0	0	100	586	0	0	100

[a]See Table 3 for mean income and statistical characteristics of alternative plans.

[b]The herd includes cows which will produce a weaned calf for sale during the year.

[c]An equal number of heifers were weaned and used for replacements or were sold at weaning to simplify the model.

[d]All added cows were purchased the previous year. For this model the ranch was assumed initially understocked as a result of new land acquisition the year prior to initiation of the five-year model.

nearly double in size with nearly all retained steers going on wheat pasture prior to finishing in a feedlot. Also, maximum numbers of steers were purchased for grazing on wheat pasture prior to finishing in feedlots (Table 4).

Thus, the composition of a vertical production sequence depended on the rate of growth to be achieved over the planning period. At lower levels on the E-V boundary, the vertical production sequence not only increased ranch income but also contributed to income stability. As growth rate increased, the vertical production sequence was shifted in order to increase income and meet increased cash flow requirements associated with increasing growth rates over the five-year horizon. The increase in income produced from adding cows was not sufficient to meet the debt-servicing requirements specified in the cattle loans. Hence, income from land and cow investments made earlier in the planning horizon, as well as increased income from vertical integration, was needed to meet loan repayment requirements. The principal point is that different rates of income growth required different vertical production sequences. However, shift from one vertical sequence to another resulted in rather significant changes in income stability (Table 3).

IMPLICATIONS OF THE STUDY

Using vertical production alternatives in ranch planning appears as an effective response to risk. However, vertical production alternatives should not be evaluated independently of other risk responses. Other responses in production may include alternative grazing systems, range and forage improvements and use of supplemental livestock feed. The combination of these alternatives and vertical production alternatives provides increased opportunities to manage risks. Moreover, a grazing system successfully reducing forage variability may dominate the reduction in price variability associated with vertical production choices [9].

Since data included in this analysis were developed from a limited (five-year) historical time period, interpretation of specific research findings should be considered within this parameter. Results illustrated the following: (1) the evaluation of vertical integration as response to risk may be accomplished by an E-V analysis, (2) this model can be readily adapted to consider large capital investments and cash-flow considerations which may be required in other types of enterprises and (3) the vertical production sequence changed for movement up the E-V boundary.

While the choice of a particular vertical integration sequence may meet a firm's income criteria, the vertical process may exceed its risk-return criteria. Thus, the form of vertical integration would be determined by the ranch manager's willingness to accept risk, as well as constraints to the growth process such as borrowing capacity, cash flow requirements and existing input-output production relationships.

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