A RISK PROGRAMMING ANALYSIS OF CATTLE PROCUREMENT BY BEEF PACKERS

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Producers and processors of many agricultural commodities can choose from among several coordination arrangements including spot-market exchange, contractual arrangements, and vertical integration. Firm decisions about coordination arrangements are important because they affect the success or even the survival of the firm and also cause broader impacts. The choice of marketing arrangements will influence a firm's profitability through prices received or paid, quality premiums or discounts, marketing costs incurred, exposure to production or price risk, and perhaps capital requirements. These firm decisions may have repercussions throughout the industry. For example, decisions by processing firms to shift from spot purchases to contract purchases may effectively foreclose the opportunity for producers to make spot sales. Decisions by processors to vertically integrate into production may force specialized producers out of business by limiting their marketing alternatives. Firm decision models focusing on choices among coordination arrangements should be helpful for prescribing and predicting firm behavior, predicting trends in relative importance of alternative arrangements, and evaluating policies (e.g., laws prohibiting processor ownership of production facilities) that are designed to influence these trends.

In earlier studies, Mighell and Jones [12] and Williamson [18] identified conditions that may lead to a transition from spot-market exchange to contracting or vertical integration. Greenhut and Ohta [8] investigated impacts of vertical integration on market price and output, and on aggregate profits. Snyder and Candler [14] concluded that contracting or vertical integration would lead to significant improvements in operating efficiency in hog slaughtering and processing. Other studies [1-3, 17] have addressed agricultural producers' choices between spot-market sales and contracts, and producers' decisions about vertical integration of selected successive production stages (e.g., feeder calf and fed-cattle production). Except for the Snyder and Candler study, however, agricultural processors' choices among alternative arrangements for procurement of raw products have received relatively little attention. Information about processor choices among spot-market purchases, contract purchases, and vertical integration is essential to an understanding of trends underway in the use of alternative arrangements and factors that are likely to affect these trends.

This study is an examination of processor choices among raw-product procurement alternatives. The objectives are to specify a decision model incorporating procurement alternatives for processors and to use the model to analyze beef-packer choices among selected fed-cattle procurement arrangements. The approach used should be applicable to analyses of processor procurement of several agricultural commodities. Beef-packer procurement of fed cattle was selected for study for several reasons. Cattle feeding and beef packing are both large and important industries. Several different types of marketing arrangements between feeders and packers are now in use, and are generating concern among cattle feeders and others about trends in the relative importance of alternative arrangements. For example, in Iowa a law now prohibits packing firms from owning and operating feedlots. The results of the study should not only be useful to persons advising packing firms about choices among coordination arrangements, but should also provide information about trends in relative importance of arrangements that will be useful to firms dealing with beef packers, to cattle feeders, and to policymakers.

MODEL

In making decisions about fed-cattle procurement, beef packers consider not only the range of procurement alternatives available but associated slaughter, carcass-marketing, and other activities, constraints limiting the activity combinations that may be chosen, and

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expected returns and risk related to various plans. Fed-cattle procurement alternatives may differ in the average and dispersion of prices paid for a given quality and type of cattle, the average and range of qualities procured, marketing and capital investment costs incurred, and the packer's control over both quality of cattle (grade and weight) and timing of deliveries. Related factors that must be considered in conjunction with procurement alternatives are slaughtering activities, alternative marketing outlets for carcasses and byproducts, borrowing and debt repayment, payment of income taxes, investment in feedlot capacity (vertical integration), and investment in slaughter capacity (horizontal integration). A multiperiod planning horizon is needed to permit accurate representation of investment costs and to permit changes over time in activity combinations. Constraints on activity combinations include initial levels of slaughter and feedlot capacity and limits on the rate of capacity expansion (reflecting competing firms), cash flow and credit constraints, and legal restrictions on packer feeding. Expected return and risk are the major considerations in evaluating alternative plans. Risk is an especially important consideration in choosing among procurement alternatives because the time elapsed between purchase of live cattle and sale of carcasses and byproducts differs between alternatives and thus the exposure to risk of price changes differs.

The decision problem faced by a beef-packing firm that may procure fed cattle through one or more of several arrangements can be formulated by using a multiperiod, parametric, quadratic programming model.

The mathematical model is

$$\text{Maximize } U = \lambda CX - X'DX$$
$$\text{subject to } AX \leqslant B$$
$$X \geqslant O$$

where

- U = the value of the objective function
- λ = a scalar to be varied parametrically from zero to infinity
- C = a row vector of present values of mean returns
- X = a column vector of activity levels
- D = the covariance matrix of present values of mean returns
- A = a matrix of technical coefficients for activities and constraints
- B = a column vector of resource levels and other constraints.

Precedent for use of this risk programming model dates back to an article on mean variance analysis by Markowitz [11].

In specifying the beef-packer decision model a planning horizon consisting of four one-year decision periods was assumed. If shorter decision periods had been used, program capacity would have shortened the planning horizon to a length less than that needed to depict investments in feedlot and slaughter capacity and to monitor shifts in procurement plans.

The activities included in each of the four periods were: slaughter and marketing of carcasses of fed cattle procured through each of five different arrangements, investment in feedlot capacity, investment in slaughter capacity, borrowing, withdrawal of cash for expenses, payment of taxes, and repayment of debt. The five fed-cattle procurement alternatives considered were day-to-day spot purchases, purchases through forward contracts which were hedged by the packer, purchases through forward contracts which were not hedged by the packer, purchases of feeder cattle that were custom fed for the packer, and purchases of feeder cattle that were fed in a packer-owned feedlot.

These approaches cover the range of procurement alternatives from spot-market purchases of fed cattle through vertical integration of fed-cattle production and processing. Forward contracts were assumed to be entered into at the beginning of the feeding period. Forward contracting without a hedge, then, is similar to the custom feeding and packer feeding alternatives in that the price paid for slaughter cattle is largely determined at the beginning of the feeding period. The price paid for fed cattle that are spot purchased, in contrast, is determined at the end of the feeding period. The price paid in forward contracting with a hedge is similar to the spot purchase price. At the beginning of a feeding period the packer contracts with a producer to purchase cattle at a price determined by subtracting an amount (usually the estimated basis plus hedging costs) from the price of the futures contract maturing nearest to, but not before, the end of the feeding period. At that time the packer sells a future contract to place the hedge. When the feeding period ends the packer offsells a futures contract to place the hedge. of the cattle at the previously contracted price. Any difference between the producer-packer contract price and the spot price prevailing at the time cattle are delivered will be approximately equal to the change in the futures price during the feeding period. Thus, when the packer adds his loss (or subtracts his gain) in the futures market to the producer-packer contracted price, it will approximately equal the prevailing spot price at delivery time.

Slaughter costs and revenues from carcass marketing were assumed to be the same for all procurement alternatives. Investment activities add to capacities in the year after investment. Either intermediate-term loans (five years) or internal funds can be used to finance investments.

The elements in the C vector for the procurement activities are expected gross margins, appropriately discounted. The gross margin is the total receipts per animal from sales of carcasses and byproducts less all variable costs including the cost of the animal slaughtered. The C vector also includes present values of initial investment costs per unit of slaughter capacity and feedlot capacity for each period in the horizon and present values of the depreciated added capacity units at the end of the planning horizon. The linear portion of the objective function (CX) is the expected present value of gross margins earned during the planning horizon less cash expenses, interest, and tax payments, and plus the present value of added feedlot and slaughter capacity as of the end of the horizon for the activity levels in the X vector.

The nonlinear portion of the objective function, X'DX, is the variance of the present value of gross margins earned during the planning horizon for the activity vector X. The D matrix consists of the variances and covariances of discounted gross margins for the five fed-cattle procurement activities for each period in the planning horizon. Variances and covariances of costs associated with other activities and of ending values of added capacity were assumed to be zero.

Variance of present value is included in the objective function to measure risk. Limitations of the use of variance as a measure of risk are that it requires assumptions that the decisionmaker is risk averse, and that the decisionmaker's expected utility is a function only of the mean and variance of returns (i.e., third and higher derivatives of the decisionmaker's utility function with respect to returns are zero, or third and higher moments of the distribution of returns are zero) [5, 9]. In addition, Fishburn [7] has argued that variance is inferior to measures of risk based on deviations of returns below a target level. The overriding advantage of variance as a risk measure in this study, however, was computational ease.

Constraints imposed on the activity levels are embodied in the elements of the A matrix and B vector. In the beef-packer model, constraints restrict use of feedlot and slaughter capacity in the first year to initial capacity levels, restrict use of slaughter and feedlot capacity in later years to initial capacity plus any added capacity, limit additions to slaughter capacity, restrict the amount of custom feeding permitted, provide for payment of taxes, require that expenditures and cash withdrawals do not exceed earnings plus amounts borrowed, require repayment of debt, and limit the amount borrowed. Also, all activities are constrained to nonnegative levels.

Several different solutions can be obtained from a given model, one for each value assigned to the parameter λ. The solution for a zero value of λ is the minimum variance solution and the solution for the maximum value of λ is the linear programming solution in which present value of expected return is maximized without regard to variance. These solutions and the solutions for intermediate values of λ can be used to trace out an E-V frontier. Each solution prescribes levels of alternative fed-cattle procurement, investment, and other activities for each period in the planning horizon that maximize expected present value of return for a given level of risk. Different E-V frontiers can be obtained by changing elements of the B or C vectors, or the A or D matrices. The choice of a specific solution on an E-V frontier depends on the decisionmaker's degree of risk aversion.

DATA

Expected gross margins for activities corresponding to the five procurement alternatives were estimated by averaging 1968-76 annual average gross margins for choice steers with a seven-month feeding period. Expectations of packers about future gross margins were assumed to be strongly influenced by experience during this period. Carcass values and hide and offal prices were obtained from *Livestock, Meat, and Wool Market News* [16]. Estimates of variable slaughtering costs were obtained from Cothern et al. [6]. Interior Iowa choice steer prices were used to compute costs of spot-purchased cattle, and costs of feeding in a packer-owned feedlot were estimated by using results of a study on cattle-feeding returns [10]. Costs of cattle purchased on forward contracts without a hedge were estimated by subtracting central Iowa basis values [13] and hedging costs from a futures price. The futures price used was the price, at the time cattle were placed on feed, of the futures contract maturing nearest to, but not before, the time the cattle were to be slaughtered. Costs of cattle purchased on contract with a hedge were estimated by subtracting gains, or adding losses, from holding a short futures position during the feeding period to the cost for forward contracting without a hedge. Estimates of custom

feeding costs were obtained by surveying Iowa custom feedlot operators. Costs of building feedlot capacity were estimated by updating a 1974 study [4], and costs of building slaughter capacity were obtained from the study by Cothern et al. [6]. An interest rate of 8 percent was used to obtain present values.

In the model, beginning slaughter capacity was set at 100,000 head to correspond to a medium-size plant [6], packer-owned feedlot capacity was 12,000 head per year, and the maximum number of cattle custom fed for the packer was 50,000 per year.

RESULTS

The means, variances, and covariances for the five fed-cattle procurement alternatives based on 1968-76 data are shown in Table 1.

TABLE 1. VARIANCES, COVARIANCES, AND MEANS OF THE 1968-1976 GROSS MARGINS ($) FOR THE FIVE CATTLE PROCUREMENT ALTERNATIVES

Alternative	Variances and Covariances					Means
Direct purchases	116.97					31.87
Forward contracting without a hedge	-308.69	1970.53				45.51
Forward contracting with a hedge	106.50	-195.27	116.61			28.23
Fed in packer-owned feedlot	-247.92	1980.61	-120.99	2081.07		33.38
Custom feeding	-262.49	2035.10	-126.17	2117.75	2216.45	30.74

These values were the elements of the first-year portions of the C and D matrices, and were appropriately discounted to obtain the matrix element values for later years in the horizon. The mean gross margin is highest for forward contracting without a hedge ($45.51/head). In comparison, the mean gross margin for feeding in a packer-owned feedlot is substantially lower and the variance is somewhat higher at 2081.07. The mean gross margin for direct purchases is third highest and the variance is second lowest. Custom feeding is relatively unattractive, having the second lowest mean and highest variance. Foward contracting with a hedge has the lowest mean and the variance is only slightly lower than that for direct purchases. Given these values one would expect that forward contracting without a hedge would dominate high-risk plans and that direct purchases would dominate low-risk plans. Neither custom feeding nor packer feeding seems likely to enter any optimum plans. The several negative covariances suggest that most optimum plans would contain a combination of procurement alternatives.

Selected solutions obtained from the model are summarized in Table 2. Plan A has the lowest variance of the plans obtained and plans B, C, and D provide successively higher levels of both expected present value and risk. Plan D is the linear programming solution. As shown in the table for plan B, the present value of net after-tax return is $1,725,000 and the standard deviation of present value is $1,271,801. In moving from plan A to plan B the expected present value increases 1.3 times as much as the standard deviation of present value increases, and in year 1 of plan B the firm direct purchases 83,522 cattle and purchases 16,748 cattle on forward contracts without a hedge. For years 2, 3, and 4 of the horizon plan B calls for successive slight decreases in direct purchases and successive slight increases in forward contract purchases. In each year the 100,000-head initial slaughter capacity is fully utilized. Plans providing higher expected returns and risk than plan B call for fewer direct purchases and more forward contracting without a hedge than plan B. In plan A, the $\lambda=0$ solution, direct purchases are used more than in plan B, and in the first three years of the horizon some slaughter capacity is not utilized. Custom feeding, packer feeding, and forward contracting with a hedge do not enter

TABLE 2. COMPOSITION OF FOUR SELECTED FOUR-YEAR GROWTH PLANS FOR BEEF PACKING FIRMS

Firm plan	Expected present value (E) ($)	Standard deviation (σ) ($)	$\frac{\Delta E}{\Delta \sigma}$	Year	Number of cattle procured through:[a] Direct purchases	Number of cattle procured through:[a] Forward contracts without a hedge
A	1,457,055	1,065,683		1	59,467	11,733
				2	66,502	13,121
				3	74,485	14,695
				4	83,522	16,478
B	1,725,000	1,271,801	1.30	1	83,522	16,478
				2	83,434	16,566
				3	83,335	16,665
				4	83,227	16,773
C	2,209,994	6,719,160	.09	1	24,243	75,757
				2	17,109	82,891
				3	9,103	90,897
				4		100,000
D	2,299,780	7,968,748	.07	1		100,000
				2		100,000
				3		100,000
				4		100,000

[a] Initial slaughter capacity is 100,000 head.

any of the plans. Thus, initial feedlot capacity is not used and there is no investment in either additional slaughter or feedlot capacity in any of the plans.

The dominance of spot purchases in low-risk plans can be explained by noting that packing firms sell carcasses and byproducts in spot markets. Spot prices for fed cattle depend largely on current spot prices for carcasses and byproducts. Thus, gross margins for cattle purchased on spot markets vary within relatively narrow limits. Purchasing cattle on forward contracts without a hedge is more risky than spot purchasing because the price the packer pays for forward-contracted cattle is established long before, rather than at the same time, prices for carcasses and byproducts are established. For this reason and because in some periods during 1968-76 substantial cattle price increases resulted in a relatively higher gross margins for forward-contracting without a hedge, this procurement alternative dominated high-income plans. Considerable periods of unfavorable returns to cattle feeding during 1968-76 made custom feeding and packer feeding relatively unattractive. Forward contracting with a hedge was similar to, but dominated by, spot purchases.

CONCLUSIONS

A risk programming model appears to be a useful tool for analyzing processing firm decisions about raw product procurement alternatives and may be of help in identifying trends in the relative importance of various alternatives. The results of this analysis suggest that risk averse beef-packing firms are likely to continue relying mainly on spot purchases of fed cattle rather than on forward contracts, custom feeding, or packer feeding. Less risk averse firms will rely more heavily on unhedged forward contracts. The estimates of gross margins and investment costs show that neither expansion of slaughter capacity nor investment in feedlot capacity would be attractive to packers.

The analysis and results could be strengthened by the use of more sophisticated procedures for generating expectations about gross margins, including alternative marketing arrangements for carcasses and byproducts; recognizing possible differences in qualities of inputs procured under different arrangements; and identifying cost savings due to better production scheduling that may be possible with packer feeding and custom feeding. A useful extension would involve an attempt to reconcile optimum packer procurement plans with optimum marketing plans for cattle feeders.

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