A RISK-PROCESSING ANALYSIS OF CATTLE PROCUREMENT BY BEEF PACKERS

by

Katherine S. Miller and Ronald Raikes

WP-16 May, 1978

Journal Paper No. J-9099 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 2017.

Katherine S. Miller and Ronald Raikes are respectively graduate assistant and associate professor in economics at Iowa State University.

ABSTRACT

Shifts in the relative importance of alternative coordination arrangements among agricultural producers and processors, and particularly shifts from spot market transactions to forward contracts or vertical integration, may have substantial impacts on the control of agricultural production and thus may be the target of policy actions. One approach to the problem of identifying trends under way in the relative importance of alternative arrangements is to focus on producer and processor choices among marketing and procurement alternatives.

In the study reported in this paper, the cattle-procurement decision problem faced by a beef packer was formulated by using a multiperiod, parametric quadratic-programming model. Five alternative arrangements for procuring fed cattle were included in the model: spot purchases, purchases through forward contracts with hedging, purchases through forward contracts without hedging, custom feeding, and packer feeding. Gross margins for procurement alternatives were found to be autocorrelated, and this was taken into account in computing variances of present values of returns.

A major conclusion is that, given the dominance of spot transactions in sales of beef carcasses and by-products, a trend away from reliance on spot purchases of fed cattle and toward vertical integration is not likely, especially for risk-averse packers.

A RISK-PROGRAMMING ANALYSIS OF CATTLE PROCUREMENT BY BEEF PACKERS

Coordination arrangements between agricultural producers and processors include spot-market exchange, exchange through contractual arrangements, and vertical integration. Trends in the relative importance of these different arrangements concern both individual firms and policy makers. Coordination arrangements affect: (1) the level of rewards for production and processing activities, (2) the costs incurred in production, exchange, and processing activities, (3) the amounts and allocations of production and price risks, (4) capital requirements, and (5) opportunities for firm growth. Furthermore, trends in relative importance of spot-market exchange, contracting, and vertical integration affect the distribution of decision-making authority and thus have important implications for control of agriculture.

In earlier studies, efforts have been made to explain, prescribe, or predict trends in the relative importance of alternative coordination arrangements and implications of these trends. Mighell and Jones [12], Williamson [18], and Trifon [15] have identified conditions that may lead to a transition from spot-market exchange to contracting or vertical integration. Greenhut and Ohta [9] 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. In some other studies [1,2,3, 17], the focus has been on agricultural producers' choices between spot-market sales and contracts and on producers' decisions concerning vertical integration of selected successive production stages (e.g., feeder calf and fed-cattle production). Agricultural processors' choices among alternative arrangements for procurement of raw products, however, have received relatively little attention in earlier studies. But processor as well as producer decisions are reflected in the combination of coordination arrangements used. Thus, information about processor choices among spot-market purchases, contract purchases, and vertical integration is vital to an understanding of trends under way in relative use of alternative arrangements and factors, including policy actions, that are likely to affect these trends.

The focus of the study reported in this paper was on processor choices among raw-product procurement alternatives. The specific objective was to specify a model and use it to analyze the decision problem a beef-packing firm faces in choosing among various fed-cattle procurement arrangements. The model, data, results, and conclusions are presented in the following sections.

Model

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

$$\text{Maximize } U = \lambda CX - X'DX$$

$$\text{Subject to: } AX \leq B$$

$$X \geq 0$$

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

The planning horizon in the beef-packer decision model consists of four, 1-year decision periods. The activities (represented by elements of the X vector) 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, payment of taxes, and repayment of debt. The five fed-cattle procurement alternatives considered were day-to-day spot purchases, purchases through forward contracts that were hedged by the packer, purchases through forward contracts that 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 cover the range of procurement alternatives from spot-market purchases of fed cattle through vertical integration of fed-cattle production and processing. It was assumed that forward contracts were entered 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, on the other hand, is determined at the end of the feeding period. Forward contracting with a hedge is similar to spot purchasing because losses (gains) to the packer resulting from increases (decreases) in the price of slaughter cattle between the time the forward contract is entered and the time of slaughter are largely offset by gains (losses) from future transactions.

Slaughter and carcass marketing components of the activities for each procurement alternative were the same. Investment activities add to capacities in the year following investment. Either intermediate-term loans (five years) or internal funds could be used to finance investments.

Each element of the C vector in the objective function is an expected present value for a specific activity in a specific period of the planning horizon. 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 by-products less all variable costs, including the cost of the animal slaughtered. The C vector also includes present values of investment costs per unit of slaughter capacity and feedlot capacity for each period in the horizon and present values of units of added capacity 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 plus the present value of added feedlot and slaughter capacity at 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 includes discounted variances and co-variances of 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. Variances of present values of gross margins depend upon the autocorrelation of gross margins. If first-order autocorrelation is assumed, the variance of present value of gross margin (σ^2) is [6]:

$$\sigma^2 = \sum_{t=1}^{n} \frac{\sigma_t^2}{(1+i)^{2t}} + 2 \sum_{\substack{\tau=1 \\ \tau<\theta}}^{h-1} \sum_{\theta=2}^{n} \frac{\rho\,\sigma_\tau \sigma_\theta}{(1+i)^{\tau+\theta}}$$

where n is the number of periods in the planning horizon, σ_t^2 is the variance of the gross margin in the t^{th} period of the planning horizon, i is the discount rate, ρ is the autocorrelation coefficient, and σ_τ and σ_θ are standard deviations of gross margins in the τ^{th} and θ^{th} periods, respectively. If values of gross margins are not autocorrelated, the second term on the right-hand side of the expression drops out. If there is positive autocorrelation, as there would be if margin tends to remain above, or below, average values for several consecutive years, then variance is greater than if there is no autocorrelation. If there is negative autocorrelation, on the other hand, as there would be if margin tends to be above average one year and below the next, then variance of present value is less than if there is no autocorrelation. In applications of risk-programming models, it usually has been assumed that there is no autocorrelation of cash flows. But, if incorrect, this assumption leads to inaccurate estimates of variances of present values.

Variance of present value is included in the objective function to measure risk. Both expected return and risk likely affect packers' choices among procurement alternatives. Limitations of the use of variance as a measure of risk are that it requires assumptions that the decision maker is risk averse and that the decision maker's expected utility is a function only of the mean and variance of returns (i.e., third and higher derivatives of the decision maker's utility function are zero, or third and higher moments of the distributions of returns are zero) [5,10]. In addition, Fishburn [8] 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, 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. The activities and constraints for one year and the transfer activities between one year and the next are depicted in Table 1.

Several different solutions may be obtained from a given model, one for each value assigned to the parameter λ. The solution for $\lambda=0$ is the minimum variance solution,and the solution for λ = a large value 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 may 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 may 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 is dependent upon the decision maker's degree of risk aversion.

Data

Expected gross margins for activities corresponding to the five procurement alternatives were estimated by averaging annual average gross margins for 1968-76. It was assumed that expectations of packers about future gross margins are strongly influenced by experience during this period. Gross margins were for choice steers. A 7-month feeding period was assumed. Carcass values and hide and offal prices were obtained from a USDA publication [16]. Estimates of variable slaughtering costs were obtained from a recently completed study of slaughtering costs [7]. Interior-Iowa, Choice-steer prices were used to compute costs of spot-purchased cattle, and costs of

Table 1. Illustration of Activities and Constraints for Quadratic Programming Model of Beef-Packing Firm.

	Fed cattle procured through:																
	Spot purchases	Forward contracts w/hedge	Forward contracts w/o hedge	Feeding in a packer-owned feed-lot	Custom feeding	Increase slaughter capacity	Build feedlot	Borrow	Repay debt	Transfer debt	Transfer cash	Withdraw cash	Pay income taxes	Slaughter capacity accounting	Feedlot capacity accounting	Relation	Constraint level
Objective Function	c	c	c	c	c			-i						-c	-c		
Period 1																	
Slaughter capacity	1	1	1	1	1											≤	b
Custom feeding limit					1											≤	b
Packer-owned feedlot cap.			1	1												≤	b
Cash flow	-c	-c	-c	-c	-c	a	a	-1	1+i		1	1	1			=	o
Credit	-c	-c	-c	-c	-c	a	a	1	-1							≤	b
Debt balance								1	1	1						=	o
Minimum debt repayment								a	-1							=	o
Withdrawal of cash	-a	-a	-a	-a	-a							1				≤	o
Pay income taxes	-a	-a	-a	-a	-a				i				1	c	c	=	o
Slaughter capacity acctg.						1								-1		=	o
Feedlot capacity acctg.							1								-1	=	o
Period 2																	
Slaughter capacity						-1										≤	b
Custom feeding limit																≤	b
Packer-owned feedlot cap.							-1									≤	b
Cash flow											-1					=	b
Credit										1						≤	b
Debt balance										-1						=	o
Minimum debt repayment								a								=	o
Withdrawal of cash																≤	o
Pay income taxes																=	o
Slaughter capacity acctg.						1										=	o
Feedlot capacity acctg.							1									=	o

feeding in a packer-owned feedlot were estimated by using results of a study of cattle-feeding returns [11]. Costs of cattle purchased on forward contract without a hedge were estimated by subtracting central-Iowa basis values [13] and hedging costs from the price, at the time cattle are placed, of the futures contract maturing when the cattle are to be slaughtered. Costs of cattle purchased on contract with a hedge were estimated by adding gains or losses from holding a short futurers position during the feeding period to the cost for forward contracting without a hedge. Estimates of costs of custom feeding 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 a more recent study [7]. A discount rate of 8 percent was used to obtain present values.

Autocorrelation coefficients for annual gross margins were calculated and found to differ significantly from zero. Thus, these coefficients were used in computing elements of the D matrix. A detailed description of the procedure used to obtain estimates of these elements is available from the authors. So that results could be compared, elements of the D matrix also were computed by using procedures that are appropriate if there is no autocorrelation.

In the initial model, beginning slaughter capacity was set at 100,000 head to correspond to a medium-sized plant [7], 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. Solutions also were obtained for other models in which beginning packer-owned feedlot capacity was 25,000 head per year, beginning feedlot capacity was 0 (to reflect an Iowa law prohibiting packers from owning and operating feedlots), and the custom feeding limit was increased to 100,000 head per year.

Results

Results from the initial model are summarized in Table 2. Firm plan A is the minimum variance plan, and firm plan E is the linear-programming solution. The first line shows that, for plan A, expected present value is $16,761,273, standard deviation of present value is $4,007,493, expected present value is 4.18 times standard deviation of present value, and in year 1 of the planning horizon, slaughter capacity is 100,000 head; 81 percent of that capacity is used to slaughter cattle purchased on a spot basis, 19 percent is used to slaughter cattle purchased on forward contracts that are not hedged, and slaughter capacity is increased by 49,600 head. No cattle are purchased on forward contracts that are hedged, none are custom-fed for the packer or fed in a packer-owned feedlot, and feedlot capacity is not increased. In later years of the planning horizon, plan A calls for less use of forward contracting, some custom feeding, and a small amount of packer feeding, but spot purchases remain the dominant method of procurement for this minimum-risk plan.

Plans B through E provide successively higher levels of both expected present value and risk. Values in the third column of Table 2 show that increase in present value per unit increase in standard deviation of present value is 2.98 for change from plan A to plan B, but only 0.49 for change from plan D to plan E; thus, the cost of higher expected present value in terms of increased risk increases with expected present value. Plans providing both higher expected present value and higher risk call for more forward contracting without hedging and less spot purchasing. Custom feeding and packer feeding also decline in importance in higher-risk plans, although packer feeding is relatively unimportant in all plans. Investment in feedlot capacity is not in any of the plans, nor is forward contracting of cattle with a hedge.

Table 2. Composition of Five Selected 4-Year Growth Plans for Beef-Packing Firms.

						Percent of slaughter capacity use for cattle procured by:					Head capacity increase:	
Firm plan	Expected present value(E) ($)	Standard deviation(σ) ($)	$\frac{\Delta E}{\Delta \sigma}$	Year	Slaughter capacity (Hd)[a]	Direct purchases	Forward contracts with hedge	Forward contracts without hedge	Custom feeding	Packer feeding	Feedlot	Slaughter
A	16,761,273	4,007,493	4.18	1	100,000	81		19				49,600
				2	149,600	86		14				
				3	149,600	73			20	1		
				4	149,600	56			21	4		
B	26,321,840	7,233,257	2.98	1	100,000	52		48				109,000
				2	209,000	83		17				48,500
				3	247,500	78			19[b]	3		
				4	247,500	76			19[b]	5[b]		
C	43,716,628	15,479,018	2.11	1	100,000			100				128,900
				2	228,900	60		40				166,000
				3	394,900	81		19				201,400
				4	596,300	81		9	8[b]	2[b]		
D	52,773,186	22,333,830	1.32	1	100,000			100				128,900
				2	228,900			100				218,500
				3	447,400	67		33				243,900
				4	691,300	80		20				
E	72,122,812	61,540,230	.49	1	100,000			100				128,900
				2	228,900			100				218,500
				3	447,400			100				378,000
				4	825,400			100				

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

[b] All available capacity is utilized.

An important reason that spot purchases are dominant in low-risk plans may be that packing firms sell carcass and by-products on spot markets. Spot prices for fed cattle are largely dependent upon current spot prices for carcasses and by-products. Thus, gross margins for cattle purchased on spot markets vary within relatively narrow limits. Purchasing cattle on forward contracts without a hedge is much more of a risk that spot purchasing because the price the packer pays for forward-contracted cattle is established long before, rather than at the same time that, prices for carcasses and by-products are established. Because of this and because there were some periods during 1968-76 when cattle prices increased substantially so that expected gross margins for forward-contracting without a hedge were higher than for the other alternatives, 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, and forward contracting with a hedge was similar to, but dominated by, spot purchases.

Changes in elements of the B vector had little effect on optimal plans. Results from the model in which the packer was prohibited from owning feedlot capacity suggest that this is a binding restriction only for firms that are very risk averse. The optimal plans, however, were more sensitive to assumptions underlying computation of variances of present values. Custom feeding and packer feeding were eliminated from all solutions of the model in which the D matrix was constructed by assuming no autocorrelation.

Conclusions

The results suggest that risk-averse beef-packing firms are likely to continue relying much more heavily on spot purchases of fed cattle than on forward contracts, custom feeding, or packer feeding. Less risk-averse firms will rely more heavily on unhedged forward contracts and use earnings and credit to expand slaughter capacity instead of feedlot capacity.

The analysis and results could be strengthened by using more sophisticated procedures for generating expectations about gross margins, including alternative marketing arrangements for carcasses and by-products, recognizing possible differences in qualities of inputs procured under different arrangements, recognizing cost savings due to better production scheduling that may be possible with packer feeding and custom feeding, and attempting to reconcile optimal packer procurement plans with optimal marketing plans for cattle feeders.

References

1. Araji, A. A. "The Effect of Vertical Integration on the Production Efficiency of Beef Cattle Operations," American Journal of Agricultural Economics, 58(1976):101-104.

2. Barry, P. J. and C. B. Baker. "Reservation Prices on Credit Use: A Measure of Response to Uncertainty," American Journal of Agricultural Economics, 53(1971):222-227.

3. Barry, P. J. and D. R. Willmann. "A Risk-Programming Analysis of Forward Contracting with Credit Constraints," American Journal of Agricultural Economics, 58(1976):62-70.

4. Boehlje, M. and L. Trede, "Beef Cattle Feeding in Iowa 1974: Evaluation of Feedlot Systems," PM 602, Cooperative Extension Service, Iowa State University, Ames, 1974.

5. Borch, K. "A Note on Uncertainty and Indifference Curves," Review of Economic Studies, 36(1969):1-4.

6. Bussey, L. E. and G. T. Stevens, Jr. "Formulating Correlated Cash Flow Streams," Engineering Economist, 18(1972):1-30.

7. Cothern, J. "An Analyses of Cattle-Slaughtering Costs," Unpublished manuscript, University of California, Davis.

8. Fishburn, P. C. "Mean-Risk Analysis with Risk Associated with Below-Target Returns," American Economic Review, 67(1977):116-126.

9. Greenhut, M. L. and H. Ohta. "Related Market Conditions and Interindustrial Mergers," American Economic Review, 66(1976):267-277.

10. Hanoch, G. and H. Levy. "The Efficiency Analysis of Choices Involving Risk," Review of Economic Studies 36(1969):335-346.

11. Iowa Cooperative Extension Service. "Estimated Returns from Cattle Feeding in Iowa Under Two Alternate Feeding Programs," Publ. M-1152, Iowa State University, Ames, 1974.

12. Mighell, R. L., and L. A. Jones. "Vertical Coordination in Agriculture," U.S. Dep. Agric., Agric. Econ. Rep. 19, 1963.

13. Raikes, R., J. M. Skadberg, and H. Schaefer. "Slaughter Cattle Basis Information for Iowa, Illinois, Minnesota, and Nebraska Feeders," Iowa Cooperative Extension Service, Publ. M-1168, 1974.

14. Snyder, J. C. and W. Candler. "A Normative Analysis of the Value of Quality, Regularity, and Volume in Hog Marketing," Indiana Agricultural Experiment Station Bulletin SB12, August 1973.

15. Trifon, R. "Guides for Speculation About the Vertical Integration of Agriculture With Allied Industries," Journal of Farm Economics, 41(1959): 734-746.

16. U.S.D.A., Agricultural Marketing Service. Livestock, Meat, and Wool Market News, Washington, D.C., Vols. 36-44.

17. Whitson, R. E., P. J. Barry, and R. D. Lacewell. "Vertical Integration for Risk Management: An Application to a Cattle Ranch," Southern Journal of Agricultural Economics, 8(1976):45-50.

18. Williamson, O. E. "The Vertical Integration of Production: Market Failure Considerations," American Economic Review, 61(1971):112-123.