Cost-of-Service vs. Uniform Pricing in a Cooperative Feed Manufacturing and Distribution System

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A 40-region nonlinear programming model of a cooperative livestock feed production and distribution system, including possibilities for on-farm processing, is used to compare system organization and performance given two pricing strategies. Use of one price regardless of location results in higher average costs to patrons than pricing products to reflect cost to each region. Transportation costs are increased using uniform pricing. Cost effects are small and may be offset by other benefits of uniform pricing.

Product pricing is an important variable in the strategy of any firm, whether it is investor-oriented or a patron-oriented cooperative. Pricing decisions by a cooperative whose objective is to maximize the welfare of its patron-owners carry an added equity dimension that is not present for the investor-oriented firm.

An investor-oriented agribusiness firm must provide products and/or services that benefit users, and it must be perceived as treating customers fairly. The investor-oriented firm has no tie to a user other than the customer relationship. Both the firm and customer enter each transaction for their own benefit; the firm for its owners and the customers for themselves.

Cooperative patrons are the owners. With limited (more often no) return to capital as such, cooperative patrons receive a return to their ownership interest in the firm only to the extent of their use of it. To at least some degree, the cooperative has an obligation to a fixed set of patron-owners. This tie to a set of patrons brings the added dimension of equitable treatment of patrons as owners and as customers.

The added equity dimension is illustrated clearly in the selection of a depreciation method. An investor-oriented firm chooses a depreciation

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method to benefit owners—usually maximizing depreciation to minimize (or defer) income taxes. The owners benefit and so also will their customers in a competitive industry. If a cooperative elects to write off an asset in a period shorter than its expected useful life, patrons in the early years receive smaller patronage refunds and later patrons receive larger refunds than would be justified by service at cost. Similarly, the allocation of overhead among lines of business having separately calculated patronage refunds has an equity dimension for cooperatives that does not exist for the investor-oriented firm.

Service at cost is a generally accepted principle of cooperation. It usually is accomplished by the allocation of net margins to patrons on the basis of business done with the cooperative. This procedure may or may not result in all patrons receiving service at the cooperative's cost of serving their class of transaction. Net margins (and patronage refunds) often are computed for all marketing or purchasing lines combined. Unless prices reflect the cost of service by line of business and class of patron (size, location, etc.), some patrons will be served below cost and others above. Although the membership of a cooperative may elect to subsidize one group at the expense of another, this must be recognized as having equity implications. The concept of cost-of-service pricing in this paper means pricing to reflect the cost of servicing patrons in each transaction class. That is, prices may differ with volume of purchase, location, time of payment or delivery, etc., to achieve what Knutson calls equal-net-margin pricing.

The equity and efficiency effects of pricing to achieve equal net margins in the spatial dimension are not clear, and seldom are they discussed. The costs of providing products to patrons or the costs of assembly of products marketed vary with the distance of individual patrons from the distribution or marketing facility. Equal net margins or cost-of-service pricing implies equal prices to all at the cooperative's facility; that is, the patron pays the freight. Curiously, one often finds the same organization using both uniform pricing and cost-of-service pricing. Grain usually is priced the same to all delivered to the elevator (cost-of-service at the farm), while feed or fertilizer delivered to the farm often is priced uniformly over relatively large areas.

Neither pricing strategy is unique to cooperatives. However, certain equity and efficiency effects of cost-of-service vs. uniform pricing in space are unique to cooperatives. Consider a somewhat idealized situation in which a group of farmers forms a cooperative to produce feed. Feed manufacturing involves significant economies of size. The group must be large and usually distributed over a fairly large area to take advantage of plant size economies. The plant, located centrally to minimize system costs, will be closer to some of its patron-owners than to others. Cost-of-service pricing is unfair to the distant patrons without whom the project might not be feasible. Equity may be best served by uniform prices for feed delivered to the farm. Such a uniform pricing system has been called postage stamp pricing (Scherer). That is, the charge for mailing a letter across town is the same as across the country.

The two pricing strategies are expected to affect the pattern of product use and efficiency of a cooperative system. This paper compares the pattern of product use by farmers, system organization, and the cost of feed preparation and delivery to livestock in a cooperative system under the two pricing strategies. A spatial model is used to assess the impact of product pricing on product mix, processing costs, plant location, transportation costs, and the extent of on-farm feed preparation.

The Case Situation

The model used in this analysis represents the feed manufacture and distribution system of a cooperative including on-farm feed preparation by cooperative patrons (Menzie). The objective of the cooperative system is assumed to be provision of the feed desired by patrons to the livestock at minimum cost. Demands for beef, dairy, hogs, and laying hens are represented separately as typical composite diets for each enterprise. The location of patron-owners and their use of finished feeds are taken as given. That is, the cooperative system is treated as a set of patron-owners and their cooperative as a unit. This treatment would not be appropriate for the analysis of an investor-oriented firm without the correspondence between owners and patrons.

Three feed product forms are possible for each livestock species. Premix contains vitamins, minerals, drugs, and a carrier. It is used at a rate of 100 pounds or less per ton of complete feed. Supplement is a combination of premix ingredients and high-protein ingredients to be used at a rate of approximately 400 pounds per ton of complete feed. Complete feed includes a premix, high-protein ingredients, and an energy source such as corn. It is ready for use by livestock.

Cooperative mills may make premix, supplement, or complete feed; premix or supplement may be transferred to other cooperative mills to prepare supplement or complete feed; and any of the three products can be used on appropriately equipped farms. Livestock producers are assumed to choose the feed program that minimizes the cost of finished feed to their animals including the cost of any required on-farm processing.

The case situation represents that of a cooperative feed manufacturing and distribution system operating in Illinois, Iowa, and Wisconsin, an area of about 160 thousand square miles. Plant and transportation costs were estimated based on published research. Although representative of costs in the study area, they are not the costs experienced by the case cooperative. Final demands for feed are computed assuming the cooperative's patrons represent 10 percent of each livestock type and size of enterprise in each region served by the cooperative. This uniform market share is used for illustrative purposes only and does not represent the share of the case cooperative. Market share is assumed not to vary with feed price under either pricing strategy.

The Model

A 40-region nonlinear spatial model of the case cooperative situation developed by Menzie was used in this analysis. The objective is to minimize the sum of ingredient, processing, and transportation costs to supply fixed demands for feed to the four livestock species at the farm. The number of regions is arbitrary. It is considered to be large enough to provide interesting answers at reasonable computing cost. Regions represent groups of counties selected in consultation with the case cooperative.

Processing Costs

Processing costs at both the cooperative mill and farm levels represent long-run average costs. Commercial mill cost-volume relationships were based on costs for four plant sizes reported by Vosloh in 1976 and updated using a more recent study by McEllhiney (1984b). Average processing cost in commercial mills is represented as:

$$CC = e^{(2.843 - .03632X)} + 12.0$$

where:

CC = cost per ton processed in commercial mills,
X = thousands of tons of feed processed, and
e = the base of natural logarithms.

This functional form allows for economies of size and a lower bound ($12) on unit costs. Each region is a potential mill site, and the plant cost function is assumed to be the same in all regions.

On-farm feed processing costs were estimated assuming use of an automatic blender/grinder based on reports by McEllhiney (1984b); Williams and Bloome; and Baker. Separate on-farm processing cost functions were estimated for each region and animal type such that the enterprise size distribution would be reflected for each region. Given the size economies evident in the data, it was assumed that the largest producers are most likely to process feed on the farm. Smaller units process on-farm only in the presence of a larger differential between the cost of complete feed and the cost of premix (or supplement) plus ingredients added at the farm. Costs were estimated for production units corresponding to the lower limit of size classes reported in the Census of Agriculture. These values were paired with the cumulative feed tonnage represented by the number of livestock in units of that size or larger to estimate a function of the form:

$$FC = e^{(a+bY)}$$

where:

FC = unit cost of processing at the farm size being added, and
Y = volume of feed processed on-farm for a region for one species (thousand tons).

This function represents the marginal cost of on-farm processing volume in a region for an increase in one livestock type. Total cost used in the model objective function is the integral of the computed marginal cost function. Total cost increases at an increasing rate as volume increases for each region and animal type as unit costs reflect the addition of smaller and smaller livestock enterprises.

Table 1 displays an example of the procedure used to construct the data for estimation of the parameters a and b. The example is for dairy cattle

Table 1.—On-Farm Cost Estimation for Dairy Cattle in a Single Region

Item	Farm Size Class			
	100 or More Animals	50–99 Animals	20–49 Animals	1–19 Animals
		Number		
Animals	4,999	7,237	6,103	4,499
		Tons		
Feed Consumption[a]	15,053	24,213	20,419	13,216
Cumulative Feed Consumption[b]	15,053	39,266	59,685	72,902
		Number		
Lower Bound for Size Class	100	50	20	10[c]
		Dollars		
Average Cost at Lower Bound[d]	7.91	12.31	19.33	33.34

[a]Feed rate is 3.3459 tons per head per year.
[b]Feed consumed on farms larger than 100 head, larger than 50 head, etc.
[c]The midpoint of the smallest size class is used.
[d]Derived from costs in Baker.

in a single region. The estimated values corresponding to the data in the table are a = 1.6296 and b = 0.0239.

Transportation Costs

A 1980 study of feed trucking by McEllhiney (1984a) served as the basis for estimation of transportation costs. Cost-distance relationships were estimated assuming that all complete feed is shipped in bulk, all premix is bagged, and supplement is half bagged and half bulk. Costs are represented as a fixed cost for loading and unloading plus a constant per round trip ton-mile.

Road distances between points representing each region were estimated based on air miles (Menzie). An arbitrary delivery distance limit of 150 one-way miles is imposed on feed from cooperative mills to limit problem size. An average one-way trip of 20 miles is assumed for within-region shipments. In effect, uniform pricing is imposed within a region in all cases.

Ingredient Costs

Premix ingredient supplies for each species are assumed to be available to commercial mills in all regions at the same price without regard to volume used. Soybean meal is used to represent all high-protein ingredients. Prices of soybean meal delivered to each region represent the lowest net price from any one of 17 supply sources in the case cooperative area. Five percent is added to soybean meal prices for farm delivery.

Corn is used to represent the energy component of feeds. Corn at the farm is priced at the average Commodity Credit Corporation loan rates for the counties in a region. Prices to cooperative mills are 10 cents per bushel higher to reflect additional handling and transportation.

Feed Demand

Regional demands for finished feeds are computed as the concentrate feed use for the production animal unit including supporting animals where appropriate. For example, the feed associated with a slaughter hog includes a share of feed used to maintain a breeding herd. The set of feeds used by supporting animals and at various stages in production are aggregated to a single composite diet for each of the four species. Requirements for this composite diet were calculated using 1982 Census of Agriculture animal numbers and the assumed market share of 10 percent.

Model Solution

The use of nonlinear processing cost functions to reflect economies of size results in a nonconvex minimization problem. Given convexity, there is no distinction between local and global minima of the objective function. In the absence of convexity, one can no longer conclude that a local solution is also a global solution. Due to the high computational cost of determining a global solution, the choice is to compute local minima for this nonconvex problem.

Several authors have proposed techniques for computing local optima for nonconvex programming problems (e.g., Baumol and Wolfe; King and Logan; and Baritelle and Holland). These techniques are based on the solution of a sequence of linear programs that are approximations to the nonlinear problem. A somewhat different approach is taken here.

State-of-the-art nonlinear programming packages do not require that the objective function be convex. For this study, the MINOS nonlinear optimization package (Murtagh and Saunders) was used to solve directly for local minima. While this approach can be guaranteed to compute only local optima, the burden of formulating approximations to the true problem is no longer required.

The cost-of-service pricing problem is solved using this direct procedure. For the uniform pricing problem, a two-stage iterative solution procedure is employed. The first stage of the problem determines the farmers' decisions regarding feed procurement given a uniform pricing structure. First-round prices for premixes, supplements, and complete feeds by animal type are the weighted average dual prices for these products from the cost-of-service pricing solution. The first-stage problem minimizes feed acquisition plus on-farm processing costs subject to feed demands for each region and animal type.

Demand for feed products from cooperative mills generated in the first stage becomes the feed requirements in the second-stage problem. The second-stage problem is to minimize the cost of providing these quantities of premix, supplement, and complete feed by region and animal type by the cooperative. Dual prices from stage 2 are used to compute new prices to be used in the next round of stage 1. The process is repeated until no further price changes are indicated.

Results

The model is solved as a straightforward minimization problem to represent prices for feed products within each region at cost to that region (cost-of-service pricing). This solution represents the least-cost (cost-efficient) system organization. The model is then modified to represent uniform pricing to all regions at the average system cost for each product from cooperative mills. Comparison of system costs under the two pricing strategies provides an estimate of the cost to the system of a pricing strategy that does not induce cost-efficient behavior of patron livestock feeders.

Given cost-of-service pricing, livestock feeders respond to costs associated specifically with products at their farm. This results in a total system cost of $361.382 million. Of this, ingredient costs are $325.429 million, transportation costs are $5.261 million, and processing costs (farm and commercial) are $30.692 million. Twelve cooperative mills with annual capacities ranging from 53 thousand tons to 136 thousand tons per year were included in the solution for the case situation. The average mill size is 82 thousand tons.

A summary of the product mix for the feed manufacturing system under cost-of-service pricing appears in table 2. Premix accounts for 11.1 percent of the commercial mill output, supplement accounts for 3.0 percent, and complete feed accounts for 85.9 percent. Although supplement represents a higher percentage of product mix for many feed manufacturing firms, the low fraction found in the solution is explained by the accounting of processing costs. A processing cost is incurred when supplement is produced; then an additional processing cost is incurred when the supplement is processed into complete feed at the farm. All else equal, premix programs would be selected to avoid these reprocessing costs. On-farm feed processing rates for the entire marketing area were: beef 51.1 percent; dairy 70.2 percent; hogs 83.5 percent; and layers 96.1 percent.

Average prices for each feed product produced by cooperative mills appear in table 3 by livestock species. These prices were computed as weighted averages of the dual prices for each region as generated in the solution to the cost-of-service price model. Prices reflect ingredient, processing, and transportation costs for each product.

Total system cost using uniform pricing is $361.613 million, an increase of $231 thousand. Ingredient costs totaled $325.090 million, slightly lower because of an increase in on-farm processing. Processing costs account for $30.086 million of the total. Processing cost decreases at cooperative

Table 2.—Product Mix Under Cost-of-Service Pricing

Livestock	Product: Premix	Supplement	Complete	Total
	Thousand Tons Per Year			
Beef	32.397	29.286	346.891	408.574
Dairy	27.631	0.000	219.891	247.347
Hogs	48.517	0.000	274.010	322.526
Layers	0.768	0.000	2.875	3.644
Total	109.314	29.286	843.491	982.091

Table 3.—Average Feed Product Prices Under Cost-of-Service Pricing

	Product		
Livestock	Premix	Supplement	Complete
		Dollars Per Ton	
Beef	100.07	143.62	116.30
Dairy	238.07	165.53	126.81
Hogs	164.07	150.29	121.74
Layers	218.07	158.26	123.41

mills more than offset increased costs of on-farm processing. Transportation costs of $6.437 million are 22.4 percent higher using this pricing alternative. The increase is due to the feed procurement decisions of farmers located relatively far from a mill that no longer pay the full cost of transportation services. These producers may use more supplements or complete feeds than with cost-of-service pricing.

A summary of the cooperative product mix with uniform pricing appears in table 4. Premixes account for 11.6 percent of system output with supplements and complete feeds accounting for 4.8 percent and 83.7 percent respectively. The most notable change from the cost-of-service solution is the increase in supplement output relative to total commercial mill production. The 15 thousand ton per year increase in supplement production reflects the effect of the pricing strategy on prices paid for ingredients. Soybean meal may be less expensive for some distant producers if it is purchased as part of a supplement than if it is bought separately for use with premix programs at local market prices. Eleven cooperative mills ranging from 23 thousand tons to 143 thousand tons per year were included in the solution. Only three of these were located in the same regions as in the cost-of-service pricing case. Sensitivity analyses indicate that system costs are not highly sensitive to small changes in mill location. The mill location pattern was similar under both pricing systems. Thus the result probably would not be much different if the optimum pattern of mill locations determined under one pricing strategy were used for the other.

Table 4.—Product Mix Under Uniform Pricing

	Product			
Livestock	Premix	Supplement	Complete	Total
		Thousand Tons Per Year		
Beef	31.464	44.736	328.389	404.589
Dairy	27.634	0.000	207.288	234.922
Hogs	48.506	0.000	247.592	296.098
Layers	0.768	0.000	0.888	1.656
Total	108.372	44.736	784.158	937.265

Total cooperative mill output is 4.6 percent lower with uniform pricing, reflecting a shift from complete feed programs to supplements and premixes. Complete feed production is 12.5 percent less than with cost-of-service pricing. This change is due in part to the soybean meal price effect and in part to the overall effect of higher transportation costs experienced under uniform pricing. Average on-farm feed preparation rates increased 2.6 percentage points for beef, 1.7 percentage points for dairy, 1.6 percentage points for hogs, and 2.6 percentage points for layers.

Strong regional effects are seen under alternative pricing strategies. In one region with a commercial mill, cost-of-service pricing resulted in on-farm feed preparation programs used for 66.4 percent of beef, 58.1 percent of dairy, 77.7 percent of hogs, and 90.8 percent of layers. The same region had a mill under uniform pricing, yet on-farm feeding rates increased to 75.3 percent for beef, 78.3 percent for dairy, 88.7 percent for hogs, and 100 percent for layers. Whereas complete feed programs are selected by some producers under cost-of-service pricing, many producers located close to mills shift to on-farm feed preparation programs with systemwide shared transportation costs. Average product prices for the uniform pricing system appear in table 5. Supplement prices vary more than premix or complete feed prices because the regional pattern of use varies. Given the lack of use for three of the four species in the optimal systems, this variation is not considered particularly important.

Conclusion

Pricing strategy is shown to have an impact on product mix, optimal plant location, farmer behavior, and system cost in a cooperative feed manufacturing and distribution system. Cost-of-service pricing (pricing to each region at the cost of production for and delivery to that region) results in farmers' decisions based on marginal costs. Thus patrons' cost-minimizing behavior induces system cost minimization.

Uniform pricing across regions results in patrons responding to average cost signals from the cooperative. In the case situation, uniform pricing results in a 4.6 percent smaller tonnage of feed produced in cooperative mills because of increased on-farm feed processing. Transportation costs are significantly higher. Products from cooperative mills become relatively less expensive for distant patrons and more expensive for those near the

Table 5.—Average Feed Product Prices Under Uniform Pricing

	Product		
Livestock	Premix	Supplement	Complete
		Dollars Per Ton	
Beef	101.50	140.82	115.73
Dairy	238.23	175.60	126.52
Hogs	164.46	160.81	121.23
Layers	219.16	172.62	126.82

mills. The change in total system costs of $231 thousand is quite small relative to total costs (0.64 percent at the ingredient prices used in the analysis).

The choice of pricing strategy is shown to affect the location of cooperative processing facilities and the product mix that would minimize system costs. That is, the pricing pattern chosen by a cooperative may affect the way it should be organized to serve its patrons best.

This analysis represents a long-run or planning perspective given the set of patron-owners to be served. A short-run analysis might show quite different results depending on the existing plant location pattern. The unchanged patron set represents an idealized view of a cooperative system. When, as is often the case, cooperative patrons behave as customers, regional demand for feed using the cooperative system also may be affected by the pricing strategy chosen.

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