Processing Costs, Labor Efficiency, and Economics of Size in Cooperatively Owned Fluid Milk Plants

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This article examines the operating cost structure of 15 cooperatively owned fluid milk processing plants. The selected plants range from small, low-volume facilities to large, high-volume plants with varying levels of capital and labor inputs. Operating costs are presented for the plants by converting monthly fiscal data to averages and grouping the plants by relative processing volume. The functional relationship between total and unit costs and average plant volume is estimated. Processing cost per gallon declines by 1.6 percent for a 10 percent increase in plant volume. Approximately 85 percent of the reduction in unit cost is attributable to lower labor, packaging, energy, repair, maintenance, and depreciation costs.

The structure and performance of the U.S. fluid milk processing industry continues to change, consistent with the trends of the past several decades. The average fluid milk processing plant is becoming larger, more capital intensive, and more likely to be vertically integrated. Structural changes include chain food retailers integrating backward to fluid milk processing and dairy farmers integrating forward through their cooperatives.

Between 1964 and 1980, the number of cooperatives processing and manufacturing dairy products in the United States declined from 856 to 192, and the number distributing packaged fluid milk decreased from 215 to 59. During the same period, the volume of packaged fluid milk products distributed by cooperatives rose from 9 percent to 16 percent of the total for all processors. The size of the cooperatives processing fluid milk products also changed. In 1964, 49 percent of the cooperatives processed fewer than 2.5 million quarts annually. Only 15 percent processed more than

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20 million quarts. By 1980, 45 percent of the cooperatives processed more than 20 million quarts, accounting for 95 percent of total cooperative fluid milk volume (Stafford and Roof).

Supermarket chains integrating vertically backward to fluid milk processing increased the number of their plants 71 percent between 1964 and 1979 (Roof, p. 3). Food chains and wholesalers have recognized the potential savings that can be achieved by vertical integration. These savings come about through more efficient technology, the ability to tailor plant size to market needs, and efficiency in product distribution. This integration has put pressure on competing cooperatives and proprietary milk handlers, many of which operate plants designed and built in the 1950s and 1960s, to achieve maximum operating efficiencies and lower per-unit costs of production and product distribution.

Vertical integration forward into processing by dairy cooperatives and horizontal expansion by cooperatives already involved in processing is occurring for a number of reasons. Among them are to strengthen market share, to diversify the employment of cooperative assets to reduce cyclical movements in margins and losses, to acquire markets for members' increasing raw milk supplies, and to earn higher margins than available from other types of marketing activities. Vertical integration also occurs as the result of mergers among cooperatives and as a means of recovering bad debts by acquiring debtors' assets.

Recent structural changes in the fluid milk processing sector also stem from an interest among cooperatives in forming joint venture operations in which a cooperative jointly operates and manages a fluid milk plant with a proprietary firm or another cooperative. Interest in joint ventures comes as a response to increasing pressure to operate existing plants at or near capacity. Given high fixed and quasi-fixed operating costs, shortfalls in plant capacity utilization can increase per-unit product costs significantly. Also, combining management skills and pooling market share can lead to potentially lower per-unit operating costs.

A central cost component of the processing business is plant operating costs. Cooperatively owned fluid milk processing plants employ widely varying levels of technology, resulting in wide variations in capital costs. Although similar technological levels may be employed among plants, the ages of their capital equipment can be quite different, also resulting in differences in capital costs. In addition, unit labor costs and individual plant labor efficiency can vary significantly. An older plant with depreciated equipment but efficient labor use management may be able to achieve short-run unit costs equal to a very modern plant with new equipment.

Past studies of operating cost economies in the milk processing industry have been based on cost data collected from a sample of operating plants or on engineered synthetic plants of various sizes and types utilizing technical coefficients and factor prices. A series of cost studies using the sample plant approach has been reported by Jones (1981, 1983) and Lasley, Jones, and Sitzman. Examples of engineered or synthesized processing cost studies include Devino, Bradfield, Mengel, and Webster; and Fischer, Hammond, and Hardie. Both types of studies document the existence of declining unit costs with larger capacity plants.

This paper reports on research undertaken to increase our knowledge of the cost-volume relationship experienced by cooperatively owned fluid milk processing plants. Cooperatively owned plants were used in this study to provide a detailed cost-volume analysis to cooperative firms and plant managers. Although past studies have provided cost analyses of fluid milk plants, they have not focused directly on plants owned and managed by cooperatives. There is no presumption that cooperative plants are any more or less efficient than their noncooperative counterparts. However, data from plants owned and managed by cooperative firms should be of greater interest to cooperative management than analyses of milk plants in general. In addition, past studies have not explicitly provided an estimate of the economies-of-size coefficient relating total plant costs to volume over a range of plant sizes.[1]

Objectives and Procedures

The objectives of this study were to: (1) develop a detailed total and unit cost analysis based on a selected sample of well-managed fluid milk plants with a representative range of operating volumes; (2) evaluate labor use efficiency on a gallons-per-labor-hour basis for the participating plants; and (3) provide a summary of the cost-volume relationship as measured by the economies-of-size coefficient.

In the study, the plant activities of: (1) receiving/processing, (2) packaging, (3) cooler/loadout, (4) maintenance, and (5) supervision were considered. The activities of farm assembly and product distribution were not included. Although these activities are important to total plant profitability, this study focused exclusively on those cost factors associated with processing raw fluid milk into a packaged consumer item.

Each plant in the study was visited, and management was interviewed about the operating features of the plant. These visits provided an understanding of the general operation of the plant and any unique features that might affect plant volumes and/or accounting costs. Monthly financial and labor use statements were obtained for one operating year for each of the plants. The data collected from each plant were for a consecutive 12-month period between January 1983 and April 1986.[2] These data permitted an examination and comparison of plant capacity utilization, labor usage, and cost fluctuations during the recorded operating year.

The specific steps of the study were: (1) 19 plants of varying age, technology, and capacity were initially selected, of which 4 plants were removed due to data procurement difficulties; (2) each plant was visited to gain a general understanding of the plant layout, management style, and unique operating features; (3) monthly plant operating statements were obtained, cost account items were standardized across plants and operating periods, labor hour usage by plant function was obtained, and summary cost and labor tables were prepared for each plant; (4) average operating cost for each expense category was calculated for each plant's operating year; (5) labor efficiency ratios were calculated for each plant and compared against the average by size group and plant function; and (6) average monthly plant data were used to estimate the economies of plant size after adjusting for wage rate and fringe benefit cost variances across plants.

Each plant was asked to provide expense and volume data in a standardized format that was designed in consultation with a number of cooperating plant managers. Data were provided on the number of regular and overtime hours worked by direct wage laborers, total direct and indirect wage expense, supervisory salary and benefits expense, plant energy consumption and expense, plant operating materials expense, rent and depreciation expenses, and other operating expenses. All data were based on monthly operating totals. Data on the volume of milk processed were standardized for bulk shipments and interplant transfers. A detailed breakdown of milk processed by package size also was available for 9 of the 15 plants.

Product Flow in a Fluid Milk Plant

Plant operation, input use, and expense categories can be illustrated by figure 1, which represents a simplified overview of product flow through a typical fluid milk "white" plant. Processing functions within the plant are described as: (1) the receiving and processing function, (2) the packaging function, and (3) the cooler and loadout function. The receiving and processing function consists of the operations of the milk receiving bay and the separation, pasteurization, and homogenization processes. The packaging function consists of the flow of product from the storage tanks into the packaged item. This typically includes the filling of milk cartons, bottles, jugs, and/or bags and the stacking and casing of the packaged product. The cooler and loadout function consists of the operation of the cooler or cold storage room and the preparation of the various fluid milk items for distribution. Packaged milk is moved from the filling area to refrigerated storage and onto trucks for distribution.

In a typical fluid milk processing plant, cooled milk flows from the receiving bay to raw milk storage tanks. From storage, milk is pasteurized by the application of a high-temperature/short-time (HTST) process and pumped through the separator. This process allows the product to be blended to the desired fat percentage. Excess milk fat is stored for further processing and/or bulk distribution. The blended fluid milk is then sent to the homogenizer and onto pasteurized storage tanks. From these tanks, the milk is pumped to the filling machines for packaging. Then the packaged milk is cased and moved to the cooler for storage. From the cooler, the cased product is organized and loaded out to delivery trucks for distribution.

Additional functions involved in the operation of a fluid plant include maintenance and general labor and indirect labor in the form of supervisors and clerical and office workers. Although the plants selected for this study primarily process milk, some of the plants processed other items. In those cases, an effort was made to exclude direct and indirect labor, supervisor, packaging, and other costs not related to the processing of fluid milk.[3]

Cost Data

Table 1 reports the mean average cost per gallon of processing fluid milk and the range of these costs in the sample plants for each of the individual

Figure 1.—Milk Flow in a Typical Fluid Processing Plant

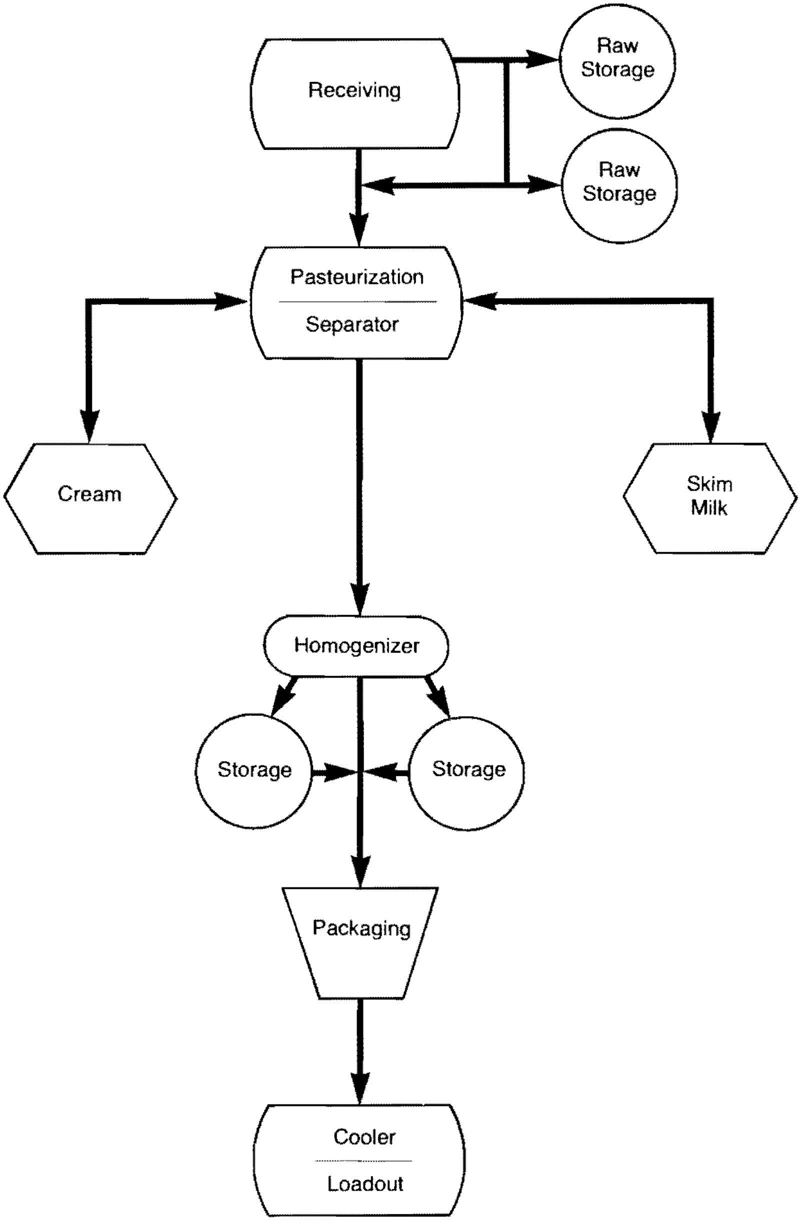


Table 1.—Mean and Range of Average Costs Per Gallon of Fluid Milk for Selected Account Items, Unadjusted Data[a]

Cost Item	Mean	Range Minimum	Range Maximum
		Dollars	
Labor:			
Direct Labor	0.067	0.049	0.083
Supervisory/Indirect Labor	0.011	0.002	0.014
Fringe Benefits	0.022	0.011	0.033
Total Labor	0.099	0.062	0.129
Energy:			
Electricity	0.014	0.004	0.020
Fuel	0.009	0.004	0.019
Total Energy	0.023	0.008	0.038
Water and Sewer	0.004	0.0001	0.007
Plant Packaging Supplies	0.137	0.0931	0.205
Other Plant Supplies	0.012	0.0043	0.022
Repairs and Maintenance	0.015	0.0058	0.025
Depreciation	0.018	0.0076	0.031
Taxes, Insurance, and Fees	0.004	0.0003	0.007
Other Expenses	0.005	0.0002	0.009
Total Other	0.195	0.111	0.307
Total Cost Per Gallon	0.317	0.253	0.429

[a]Figures are based on each plant's average monthly costs during its operating year. Data are unadjusted for differences in labor rates and fringe benefits.

cost categories. The data in this table are based on unadjusted actual expenses incurred by the plants. Direct labor averaged 6.7 cents per processed gallon with a range of 4.9 to 8.3 cents. Energy averaged 2.3 cents per gallon with a range of 0.8 to 3.8 cents. Packaging supplies averaged 13.7 cents with a range of 9.31 to 20.5 cents.

Adjusted costs per gallon of fluid milk are grouped by relative average monthly plant volume in table 2. Average unit cost figures are presented for five size groups. Group A consists of the smallest plants, with an average monthly volume of 388,295 gallons. Group E represents the largest plants, with an average monthly volume of 2,512,825 gallons. Labor costs in table 2 were adjusted to reflect the average total cost per labor hour for the 15 plants, including both direct and indirect labor expenses and total fringe benefits. This adjustment was necessary because of the wide variation in labor rates and fringe benefits paid by plants and the fact that labor rates are not likely to be independent of the location and volume of the plants (Ling, p. 9).

Total processing cost per gallon among the five plant size groups ranged from 26.5 cents for the largest plants to 37.4 cents for the smallest plants. The smallest plants processed only 15.5 percent of the volume of the largest plants and had a 41.1 percent higher average unit cost. A significant part

Table 2.—Adjusted Costs Per Gallon of Fluid Milk by Plant Size Group

Cost Item	Plant Size Group A		B		C		D		E	
					Thousand Gallons					
Plant Volume Range	299–452		500–700		900–1,100		1,400–1,600		2,300–2,700	
					Gallons					
Average Monthly Plant Volume	388,295		608,945		1,016,557		1,494,805		2,512,825	
	Dollars Per Gallon	*Percent Total Cost*	*Dollars Per Gallon*	*Percent Total Cost*	*Dollars Per Gallon*	*Percent Total Cost*	*Dollars Per Gallon*	*Percent Total Cost*	*Dollars Per Gallon*	*Percent Total Cost*
Labor:										
Direct Labor	0.094	25.2	0.101	27.5	0.070	20.4	0.072	24.8	0.063	24.0
Supervisory/Indirect Labor	0.012	3.2	0.012	3.4	0.014	4.1	0.010	3.6	0.005	2.1
Fringe Benefits	0.023	6.3	0.027	7.2	0.021	6.1	0.018	6.1	0.018	6.6
Total Labor	0.130	34.7	0.140	38.2	0.104	30.6	0.100	34.5	0.086	32.7
Energy:										
Electricity	0.015	3.9	0.012	3.3	0.015	4.4	0.016	5.4	0.008	2.9
Fuel	0.013	3.4	0.007	2.0	0.009	2.5	0.008	2.9	0.013	5.0
Total Energy	0.028	7.4	0.019	5.3	0.024	6.9	0.024	8.3	0.021	7.9
Water and Sewer	0.005	1.4	0.005	1.3	0.003	0.8	0.004	1.6	0.005	1.9
Plant Packaging Supplies	0.149	39.7	0.144	39.4	0.155	45.5	0.116	40.1	0.108	40.9
Other Plant Supplies	0.015	3.9	0.010	2.7	0.015	4.4	0.010	3.6	0.010	3.7
Repairs and Maintenance	0.020	5.4	0.017	4.6	0.016	4.8	0.014	4.7	0.013	4.8
Depreciation	0.018	4.9	0.024	6.4	0.019	5.7	0.013	4.6	0.013	5.0
Taxes, Insurance, and Fees	0.004	1.0	0.004	1.1	0.003	0.9	0.005	1.8	0.004	1.5
Other Expenses	0.006	1.6	0.004	1.1	0.002	0.5	0.003	0.9	0.005	1.7
Total Cost	0.374	100.0	0.367	100.0	0.341	100.0	0.290	100.0	0.265	100.0

of this difference resulted from the higher total labor and packaging supplies costs. These two items accounted for 8.5 cents or 78 percent of the difference between the average processing cost per gallon between the smallest and largest plants.

Product Mix and Packaging Expense

Fluid milk processing plants package milk into a variety of container sizes. These include bags, which generally are five-gallon containers and serve the institutional and restaurant market, one gallon and one-half gallon plastic and/or paper containers, quart containers, and pint and one-half pint units. There also are other sizes such as 10-ounce containers. In all the plants studied, packaging expense accounted for the largest percentage of total processing cost per gallon.

Given the relative importance of packaging costs, it would be useful to adjust or standardize the data for product mix. The importance of this item was considered by Jones, who concluded that the reduction in unit cost as volume increased was more pronounced when container costs were excluded (1983, p. v). However, a detailed product mix accounting was available for only 9 of the 15 plants included in this study, and only approximate comparisons could be made across those 9 plants because of differences in reporting. For the 9 plants with detailed product mix accounting, 15 percent of the processed volume of fluid milk was packaged in quart or smaller units. One-half gallon or larger units accounted for about 85 percent of the volume. For individual plants, this product mix ranged from 12 percent to 23 percent for one-half quarts and smaller units and from 80 percent to 88 percent for one-gallon and larger containers.

Variations in the packaging expense category from one plant to another appeared to be directly related to product mix of the plants and not plant volume. The largest plant in the study packaged 87 percent of its volume as one-half gallon or larger units, while the smallest plant packaged 85 percent of its volume as one-half gallon or larger units. This relationship was consistent across plant volumes. Thus these data do not provide evidence to support the conclusion that small plants incur higher costs than larger plants due to product mix considerations.

Labor Usage and Costs

Labor requirements in the typical fluid milk processing plant increase as the milk is moved toward the cooler and loadout function. In plants employing older technology, labor requirements at this stage can be quite high. Newer, more modern plants are equipped with automated features that lessen the labor required to move the packaged product into and out of the cooler. In addition to processing labor needs, fluid milk plants utilize laborers in empty case washing, general labor and cleanup, and plant maintenance. Some plants employ additional labor to produce plastic milk bottles directly at the plant.

Plant supervision typically is accomplished by a salaried plant manager and salaried supervisors responsible for specific in-plant functions. For example, in the typical plant included in this study, plant supervision consisted of a plant manager and supervisors for the plant maintenance and cooler/loadout functions. In many plants, the maintenance function is provided by direct labor within the plant. In other cases, maintenance is performed by hiring an outside firm or firms to perform the services.

Labor is the second largest individual cost item for each of the five plant groups. This item, including total fringe benefits, averaged 37.5 percent of total cost per gallon of milk processed for all plants. Table 3 reports the average wage rate, the ratio of average fringe benefits to total wages and salaries, labor productivity per hour of direct labor, plant productivity in gallons per total labor dollar, and total direct labor for the average plant and each of the five plant size groups.[4]

The average wage rate across all plants was $13.69 per labor hour. The wage rate rose as the average monthly volume increased from group to group. The group consisting of the smallest plants had the lowest average wage rate, which was $9.11 per labor hour. The average wage rate was $14.68 per hour for the largest plants. The average ratio of fringe benefits to total wages and salaries was 28.5 percent with a range of only 27.3 percent to 28.7 percent.

It is not surprising that the average wage rate increases with average monthly plant volume. The largest plants were geographically located in or near metropolitan or urban centers, while the smaller plants tended to be located in less urban areas. Because greater employment opportunities exist in urban areas, basic wage rates are likely to be higher than in rural areas.

Table 3.—Labor Costs and Productivity by Plant Size Group

Item	Plant Size Group					
	A	B	C	D	E	Average
			Dollars Per Hour			
Average Wage Rate[a]	9.11	9.32	9.54	12.65	14.68	13.69
			Percent			
Average Fringe Benefits to Total Wages and Salaries[b]	27.8	28.6	27.3	28.7	27.7	28.5
			Gallons			
Productivity Per Hour of Direct Labor	118	117	141	177	173	120
Productivity Per Dollar of Total Labor	9.25	8.28	10.00	9.35	8.58	8.80
			Hours			
Total Direct Labor (Including Overtime)[c]	3,317	5,341	7,046	8,920	14,700	8,878

[a]Including all plant labor except supervisor labor.
[b]Fringe benefits divided by direct plant wages.
[c]Excluding supervisor hours.

Labor Productivity

Average productivity per hour of direct labor was 120 gallons of milk with a range of 117 to 173 gallons. This measure of productivity generally increased from group to group as average monthly volume increased. Average productivity per dollar of total labor was 8.80 gallons with a range of 8.28 to 10.00 gallons. This measure of productivity does not appear to have been directly related to average monthly plant volume because of the variation in wage rates and fringe benefits.

Table 4 reports the average volume of milk processed per labor hour for each of the three general processing functions: (1) receiving and processing of raw fluid milk, (2) packaging of processed fluid milk, and (3) the cooler and loadout operations. In receiving and processing raw fluid milk, the average volume of milk processed per labor hour ranged from 670 gallons for the smallest plants to 2,109 gallons for the largest plants. In the cooler and loadout operations, the average volume of milk processed per labor hour ranged from 118 gallons to 177 gallons, generally increasing from group to group as average monthly plant volume rose. In packaging processed fluid milk, the average volume of milk processed per labor hour ranged from 397 to 957 gallons. Packaging was the only processing function for which it appeared there was no direct relationship between productivity and average monthly plant volume.

The increasing throughput per labor hour as plant volume increases suggests that larger plants maintain higher capital-to-labor ratios than smaller plants. Whether or not this shift toward more capital is economically more efficient depends on the relative prices of capital and labor inputs. Total labor cost averaged $14.68 per hour for the largest plants, compared with $9.11 per hour for the smallest plants. Data from table 2 on the cost items most closely associated with the use of capital services, such as repairs and maintenance, depreciation, and energy use, suggest that the larger plants are at least as efficient as the smaller plants. The per-unit costs for these items decline with larger plant volume. The largest plants' average expense for these items was 4.7 cents per gallon, compared with 6.6 cents per gallon for the smallest plants.

Table 4.—Average Monthly Labor Productivity by Plant Size Group and Function

	Plant Size Group				
Plant Processing Function	A	B	C	D	E
	Gallons Per Labor Hour				
Receiving/Processing	670	779	1,181	1,107	2,109
Packaging	473	397	957	606	583
Cooler/Loadout	384	364	602	459	468
Plant Average	118	117	141	177	173

Economies of Size

One objective of this study was to explore the economies of plant size as indicated by the data from the 15 sample plants. It is important to keep in mind the distinction between economies (diseconomies) of plant size and similar economies (diseconomies) of scale (Debertin, pp. 151–58). "Economies of scale" refers to the behavior of total cost as plant output or volume is varied with all inputs increased in equal proportion and all factor input prices constant. These are not very reasonable assumptions when working with data from plants of differing capital maturity and management practices and objectives. Although the sample of 15 plants reflects a range of plant processing volumes and associated costs, it is apparent that the levels of capital and labor used in these plants do not meet the conditions necessary to provide an estimate of the economies-of-scale coefficient (Silberberg, pp. 303–5).[5]

"Economies of size" is an alternative, less restrictive (albeit more general) concept relating plant volume to total plant processing cost. Capital, labor, and raw materials are recognized as not being combined in equal ratios across all plants. For example, it is clear from the sample of plants surveyed that as larger and newer plants are put into operation, a primary goal is to increase the level of automated capital for materials and product handling. Automatic casers replace manual labor, and sophisticated computerized finished product handling systems replace manual labor in the cooler and on the loadout dock.

The economies-of-size concept relates to the behavior of cost and plant volume and is a measure of the degree of curvature of total cost to plant volume inherent in the sample data. Total costs that do not increase as fast as volume can reflect both physical economies of scale and pecuniary economies. The production technology may be such that doubling all inputs more than doubles output. Pecuniary economies exist when larger plants are able to purchase inputs at a lower unit cost than smaller volume plants. The economies-of-size concept generally does not permit separation of these two effects and, as such, restricts the generality of the conclusions drawn from the data sample.[6]

Economies of size were estimated from the data on all 15 plants using average monthly total cost and processed volume. The functional relationship between total cost per unit and plant volume used to estimate the economies of size was specified as a multiplicative function of the form:

$$C_i = A \cdot V_i^{(b+1)} \cdot e^{u_i} \quad (i = 1, \ldots, 15) \tag{1}$$

where C_i is the average monthly total operating cost and V_i is the average monthly volume for the i^{th} plant and u_i is the stochastic disturbance term assumed to be normally distributed with zero mean and constant variance.[7] Taking the natural logarithm of both sides of equation (1) yields an equation linear in the parameters A and (b + 1):

$$\ln(C_i) = \ln(A) + (b+1) \cdot \ln(V_i) + u_i \quad (i = 1, \ldots, 15) \tag{2}$$

Rearranging equation (2) and applying the quotient rule for logarithms yields the per-unit cost equation for fluid milk processing:

$$\ln(C_i/V_i) = \ln(A) + b \cdot \ln(V_i) + u_i \quad (i=1, \ldots, 15) \qquad (3)$$

An estimate of the coefficient (b + 1) in (2) measures the percentage change in total cost due to a 1 percent change in plant volume. The parameter b is the economies-of-size coefficient and represents the percentage change in per-unit cost due to a 1 percent change in volume.

The parameters in equation (2) were estimated by ordinary least squares regression applied to the logarithms of the data. The estimated total cost schedule derived from equation (2) and individual plant observations are presented in figure 2. Most of the observations fall within the 95 percent confidence interval with the exception of those plants clustered at about the one million gallon per month level. These plants exhibit a relatively larger disparity in total cost for their size group than do the other plants.

Table 5 reports the estimated ordinary least squares equation and the derived per-unit economies-of-size coefficient b. This value indicates the percentage change in the average cost per gallon for a 1 percent change in average monthly plant volume. The estimated economies-of-size coefficient b is −0.162, which indicates that, on the average, a 10 percent increase in average monthly plant volume is accompanied by a 1.62 percent decline in processing cost per gallon.[8]

The derived relationship between per-unit cost and volume is presented in figure 3. Increases in average monthly plant volume result in more efficient capital and labor utilization and lower per-unit costs of processing fluid milk. As an example of the use of the economies-of-size coefficient, a 10 percent increase in plant volume from the sample average of 1.06 million gallons per month results in an estimated 1.62 percent reduction in cost per gallon. The estimated cost per gallon at the sample average is 31.0¢. Reducing this by 1.62 percent would lower cost per gallon by 0.5¢. Total cost reduction would be $5,830 per month and $69,960 per operating year.

Table 5.—Estimated Relationship Between Adjusted Total Processing Cost and Plant Volume[a]

$$C_i = \underset{(1.29)}{1.09249} + \underset{(13.58)}{0.838}\, V_i$$

$$R^2 = .93$$

Durbin-Watson Statistic = 1.7
Standard Error of Estimate = 0.156
Economies-of-Size Coefficient b = −0.162

[a] t-ratios in parentheses.

Figure 2.—Ordinary Least Squares Regression of Total Adjusted Processing Cost on Gallons Processed

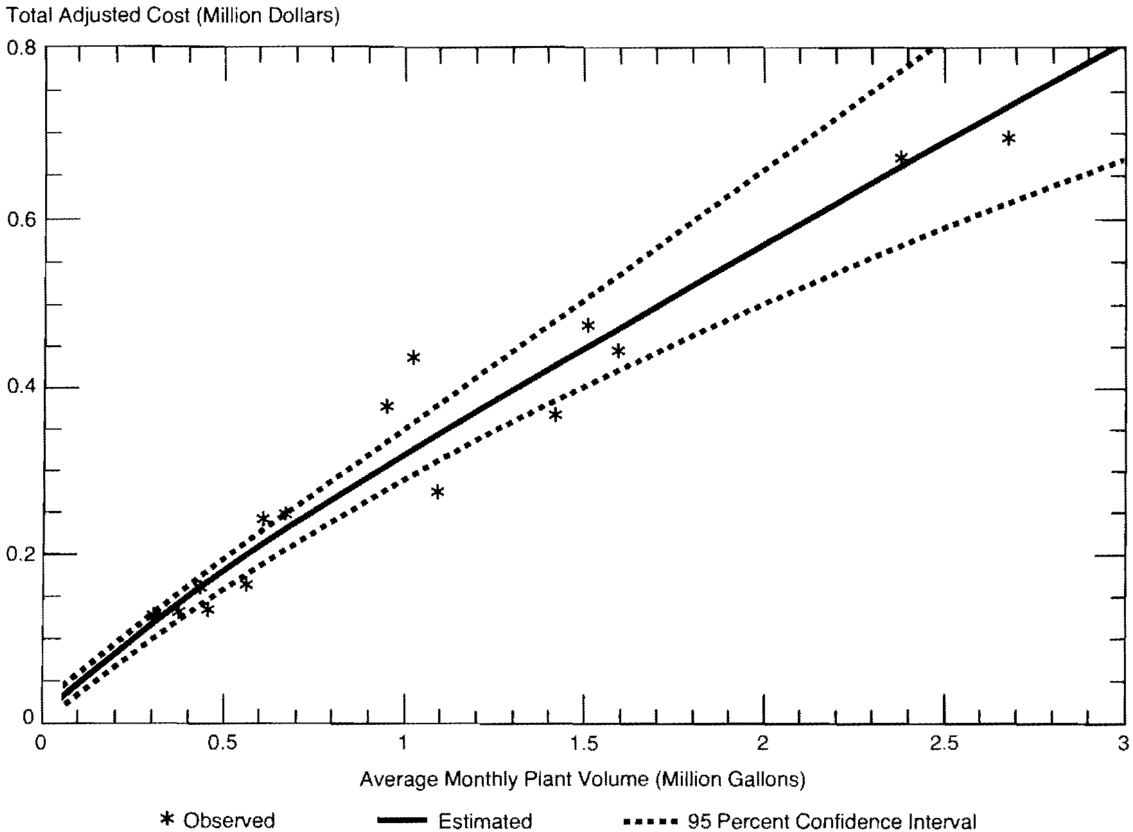
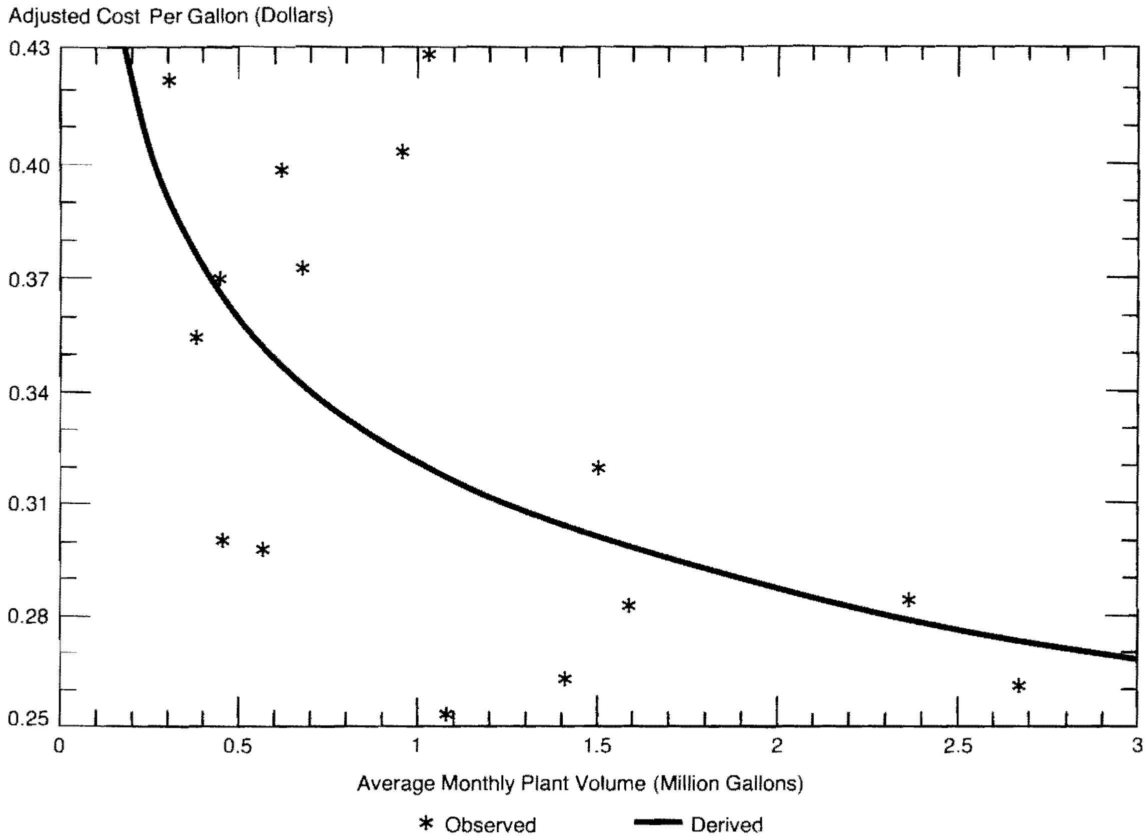


Figure 3.—Derived Cost Per Gallon of Fluid Milk



Summary

This study was conducted to provide an economic analysis of the costs and labor efficiencies in processing fluid milk. The plants included in the study were owned and managed by cooperatives. The data sample consisted of 15 fluid milk plants that reported cost and volume data on a monthly basis over a 12-month operating period. In all cases, the data collected and used in the analysis were carefully reviewed by plant management before the final stages of the analysis were conducted.

The 15 plants were combined into five groups based on average monthly volume. An analysis of the direct and indirect costs per gallon of processed fluid milk was conducted using average monthly data for these groups. In general, larger plants enjoy uniformly lower costs per gallon for labor, energy, capital maintenance and repairs, and packaging materials. This reduction in unit price results from efficiencies in the use of plant labor and capital. Because the data were drawn from existing plants, it is not possible to separate the efficiency gains into those arising from the physical nature of the processing technology and those attributable to pecuniary gains.

From the data on all 15 plants, the economies-of-size coefficient for direct processing of fluid milk was estimated to be -0.162. Although there is substantial variability in the per-unit processing cost across plants, it is clear that these costs are lower for the larger volume plants. Total processing costs do not increase in direct proportion to plant volume. This suggests that there will continue to be economic pressures to gradually integrate fluid milk processing and to serve given geographic markets with fewer and larger processing plants. This most likely will come about by the elimination of older, less efficient plants and replacement of these plants with large, more capital-intensive plants designed to serve a large market. Although this study did not consider the economies of raw milk assembly or route distribution, it is unlikely there would be sufficient diseconomies in these activities to alter this conclusion.

This study supports past research on the nature of processing economies but is subject to limitations. The number of cooperating firms is being increased to provide more data on the cost distribution for the larger-volume plants currently operating in the industry. The number of plants in each size group also is being increased. This should help reduce the variation in per-unit costs relative to plant group size. In addition, plant cost behavior over time is being addressed. The availability of operating costs over a consecutive number of operating years will help provide estimates of the economies of scale inherent in the industry as well as economies of size.

Notes

1. Economic theory suggests the existence of a "long-run" average cost schedule or curve (LACS) that indicates the minimum average cost that could be obtained at any given plant volume. Precise statistical estimation of this unobserved LACS from empirical cross-section data on plant costs and volumes is difficult. Specific assumptions about the true underlying production technology and the competitive behavior of factor markets must be made before the LACS can be specified and estimated. The relationship estimated in this study reflects only the relationship

between total processing costs and the volume of milk processed. This curve is useful for interplant cost comparisons for similar capacity plants. It is not as useful for plant comparisons across highly dissimilar plant capacities.

2. Although desirable, it was not possible to obtain cost and labor schedules from all plants for the same consecutive 12-month period. Operating years for individual plants varied, and it was judged important not to break the operating year across plants. The largest group of plants reported on the operating year of October 1983 through September 1984. Data for those plants that reported on an operating year prior to or after this period were adjusted for inflation using the producer price index for finished foods.

3. Products processed in addition to fluid milk generally did not exceed 8 to 10 percent of monthly volume and consisted of various juices and specialty products confined to certain months of the year. If a plant processed 10 percent of its volume as juice in a given month, direct and indirect costs were reduced by 10 percent. Although it would be preferable to have an exact measure of the costs associated with processing other fluid products, discussion with plant management suggested that using volume was a reasonable way to delineate these costs.

4. The average wage rate includes overtime and fringe benefits and is divided by total direct and indirect plant hours. Total wage and salary expense is defined as the sum of all direct and indirect wages and salaries paid relative to the fluid milk operation in a particular plant. Fringe benefits include vacation, health and comprehensive insurance, and payroll taxes.

5. The necessary conditions are that each plant must be governed by the same underlying production technology and face the same prices for all inputs and that a larger (smaller) plant volume (scale) can be thought of as a constant factor input ratio expansion (contraction) of any other plant in the sample.

6. The assumption of constant factor prices or, equivalently, perfectly competitive markets for factor inputs ensures that the economies-of-scale coefficient measures only physical, and not pecuniary, returns to scale. It is possible to demonstrate that if the markets for factor inputs are imperfectly competitive, total cost is a function of output only and the economies-of-size coefficient measures both physical and pecuniary returns (Beattie and Taylor, p. 149).

7. The form chosen for this study was selected because it represents a functional form that can be derived from the application of the economic principle of duality under the assumption of a Cobb-Douglas production technology and imperfect factor markets. Other forms for the cost function include reciprocals of plant volume and possibly an additional measure of plant capacity (Smith; Griliches). However, functional forms that include other variables such as plant capacity measures generally imply underlying production technologies that are not well-understood or violate basic assumptions of physical and economic processes.

8. The economies-of-size coefficient applies to small changes in plant volume and should be interpreted with this in mind. It should not be used as a measure of the potential cost advantage from large changes in plant volume.

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