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Optimal Number, Size and Location of Milk Manufacturing Plants in the Southeast with Implications for Industry Policy

by

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Abstract

The optimal number, size and location of milk manufacturing plants in the Southeast was determined subject to both seasonal fluctuations in production and the practical restrictions on the assembly, movement and processing of raw milk. The results indicate that substantial technical efficienceis could be gained from an industry wide re-organization which would permit milk movement patterns approximately as they are shown in this research.

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For many years agricultural economists have dealt with the problems of industrial organization, spatial equilibrium and optimum product flows. Plant location studies in particular have helped to make explicit the potential savings in resource use which could result from restructuring an existing production-processing-consumption pattern. While such efforts seldom consider the potential social losses (in terms of reduced price competition) from such a restructuring they do provide a benchmark estimate of what the current system is costing. Such studies provide at least one method of analyzing the impact of prevailing institutional constraints.

In the present paper we report the results of our attempt to consider explicitly several "real world" restrictions on the assembly and movement of raw milk in determining what would be the optimal (technically efficient) number, size and location of milk manufacturing plants in the Southeast given current milk production and fluid consumption. The solution serves as a benchmark for a technically efficient industry organization from producer to processor given present production and consumption levels. Implications regarding current and proposed impediments to such an organization are drawn.

The problem may be stated as follows.

Given:

(a) a highly seasonal and uneven spatial distribution of raw milk production,

(b) a seasonal and spatially uneven commitment to deliver milk to fluid bottling centers for fluid consumption,

(c) a highly perishable raw product with physical limitations on movement, and

(d) economies of size in raw product processing.

Determine:

The number, size and location of milk manufacturing plants in the southeastern U. S. that will minimize the aggregate costs of milk assembly and processing into a manufactured product form the Grade A milk produced in the region in excess of fluid bottling commitments. That is, delivery commitments to fluid bottling centers must be satisfied.

The problem was simplified somewhat by assuming that both raw milk supply and final product demand were perfectly inelastic, that is, fixed at points in time. It was further assumed that only one manufacturing plant of a specified type would be permitted to operate at each potential location. No assumption with respect to either the number or the capacity of fluid bottling plants operating at each bottling center was needed since fluid processing costs were ignored. All product distribution costs were ignored.

Economies of Size

The level of disaggregation proposed for the problem prohibited the use of solution methods which deal explicitly with non-linearities in the processing cost function. Following King and Logan, Roe and others, economies of scale in raw product processing were incorporated into the solution procedure by employing the transportation algorithm in an iterative fashion. The algorithm is used to obtain a series of "optimal" subsolutions to problems which approximate the "real" problem. Per unit processing costs at each plant location are readjusted after each subsolution, based on the quantity processed at that location during the previous subsolution, until *ex post* per unit processing costs are equal to those assumed *ex ante*. For the first subsolution, average processing costs at each location are set at their lowest level possible (plant at capacity). As the solution progresses plants with relatively small volumes are eliminated from the plant location set until the total costs of transporting to a smaller number of plants are greater than the reductions in total processing costs made possible by eliminating additional plants.[1/] The solution system used for this study has been documented and is available on request from the authors [Boehm].

Data Development [2/]

For purposes of the study, the southeast region was identified as that area east of the Mississippi River and extending south from Kentucky and Virginia. Florida was excluded except that it was treated as an external source of raw milk production in the spring season (May) and an external bottling center in the fall (October). The entire state of Louisiana was included.

Raw milk production (Grade A) by county and fluid milk deliveries to bottling plants in 97 major bottling centers in the Southeast were obtained for October 1974 and May 1975. While the county was the base unit of observation for production data, counties in the lower density production areas were aggregated to form single production sources. In those areas, a distance adjustment factor based on milk density in the aggregated area was applied to all movements from the aggregated source. County identifications were maintained for Southern Indiana, Kentucky, Tennessee, Southern Mississippi and Southeastern Louisiana. Total production from 290 sources was approximately 760 million pounds in October and 856 million pounds in May. Grade A deliveries to the fluid bottling centers were about 717 million pounds in October and 737 million pounds in May. Thus, approximately 43 million pounds of raw milk in October and 119 million pounds in May were available for processing in the manufactured form.

A total of 31 potential manufacturing plant sites were selected. Several of the potential plant sites were located in the Kentucky and Tennessee areas where excess milk might logically be expected to accumulate. At least one potential site was selected for each of the remaining states except Alabama. The 31 plant sites provided the model with at least six times the capacity which would ultimately be needed to process the available milk.

Transportation cost functions were developed to reflect the cost differentials associated with terrain, production density and certain of the physical limitations imposed on milk movement by the highly perishable nature of the product. The specific cost functions used in this study are contained in the referenced report by Boehm and Conner. One cost function was used to calculate per unit movement costs for direct haul to plants in the higher density, rough terrrin areas of Southern Indiana and Illinois, Kentucky, Tennessee, Western Virginia and Northwestern North Carolina. Direct haul shipments in these areas were restricted to approximately 100 road miles. A second function based on the implied use of a somewhat larger pick-up tank truck and a maximum direct haul of 150 miles was used for the other production areas. A third function was used to calculate costs for milk movements beyond the "short haul" distance. It was assumed that such movements could only be made by first moving the milk to a receiving station within the direct haul mileage range, unloading, cooling and then reloading it for shipment in over-the-road long haul tankers. Sixteen such receiving stations were geographically dispersed throughout the study region.

Processing costs for both cheddar cheese and butter/powder plants were synthesized using engineering cost data prepared by Dairymen, Inc. (Conner, Boehm and Pardue). Given these data, linear total processing cost functions were estimated for both cheddar cheese and butter/powder operations. An envelope of least cost points from the synthesized data provided the observations for the estimations. Maximum raw milk capacity for cheddar cheese plants was 25.585 million pounds per month. Butter/powder plants had an assumed maximum raw milk capacity of 33.100 million pounds per month. The estimated processing cost functions used in the study, where Q is monthly cwt. of milk processed, are as follows:

$$\text{CHEDDAR CHEESE:} \quad TC = \$42,466 + .5292\ (Q)$$

$$\text{BUTTER/POWDER} \quad TC = \$49,730 + .4788\ (Q)$$

Results

Milk movement patterns and optimal plant locations were initially obtained for four base situations using the solution method and the data described above. Two plant location sets, one for each season, were obtained assuming that all plants manufacturing excess Grade A milk in the region were cheese plants. The other two base solutions were obtained by assuming that all manufacturing plants were butter/powder operations. The plant location sets obtained in these solutions provided the information needed to select both the type and placement of manufacturing plants which would result in minimizing the total costs of assembly and raw product processing throughout the year.

The results of the various static solutions for both May and October and the two product types are summarized in Table 1. The impact of processing economies on ultimate plant site selection as well as plant size is obvious. Plants tended to operate at the maximum capacity permitted for the type of plant being considered. In May, five locations, fairly dispersed throughout the region, were ultimately selected to process the available 119 million pounds of milk into cheese. Plants at four of these locations operated at the maximum volume permitted for cheese plants (225,850 cwt./mo.). The final subsolution obtained in May when all plants were assumed to be butter/powder operations resulted in plants at four locations.

With each reduction in the number of plants total assembly costs increased. As the number of cheese plants in the solution dropped from the initial 18 to 8, assembly costs for all milk (856 million pounds) increased from $2.93 million to $2.97 million. Total costs however declined $390,000. By consolidating the processing from eight plants to the five finally selected, assembly costs increased to $2.98 million but total costs were reduced an additional $115,000. Similar cost reductions were noted for the May butter/powder solutions. However, since milk shipments were only being made to four processing plants, assembly costs were slightly higher than when only cheese plants were permitted in solution.

In the initial solutions for October, which considered only a minimization of assembly costs, milk was moved to only 13 of the 31 potential plant sites. Since the volume of milk available in this period was much less than that available in the May period (64% less), the optimal number of plants was reduced to only two when either cheese or butter/powder operations were considered. Four subsolutions were required to reach the final cheese plant location set in October, one more than was requaired for the October butter/powder solution.

Roughly, the same pattern of cost change occurred in these solutions as was the case for those obtained during the May period. Total assembly costs for all milk (760 million pounds) increased from $2.67 million to $2.70 million as the number of operating cheese plants decreased from 13 to three. Total costs, however, declined by $392,000. Assembly costs were increased slightly when milk shipments were made to only two of the plants but total costs declined by an additional $36,000. In October, when only butter/powder processing facilities were permitted total assembly costs changed very little but total costs declined $503,000 by consolidating the processing in two plants.

Processing cost per cwt. of milk for cheese was 2 cents higher in October than in May reflecting the fact that one out of two plants in the optimal plant set for October operated below the maximum volume permitted compared to only one out of five in May. Average processing cost was 6.5 cents higher for the butter/powder plant set in October than was the case for the May plant set. Average assembly costs per cwt. were approximately $0.35 for all four final plant location sets.

Seasonal Impact on Plant Location Set

Given the seasonal nature of the problem (only 36% as much raw milk to be manufactured in October as in May) and the above determined optimal static solutions, a single plant location set had to be selected such that total processing and assembly costs would be minimized subject to the following constraints. First, there had to be sufficient capacity to process the milk available during the May season. Second, implicitly recognizing the revenue considerations, there had to be a reasonable degree of flexability, with respect to product type, provided by the plant set ultimately selected. Third, the critical role skilled labor plays in the successful operation of cheese processing facilities as well as the more perishable nature of the product suggests that cheese plants be located in areas which permit, in as much as possible, continual operation throughout the year. [3/] Fourth, the plant location set should be chosen so that assembly costs throughout the year would be low relative to other locations.

These considerations led to our heuristic selection of five plant site locations for the region. Three plant locations 102, 112 and 128 were designated as cheese plants each with monthly capacities of 25.585 million pounds. Two additional sites, locations 115 and 121, were designated as butter/powder plants with monthly capacities of 33.1 million pounds. Given these locations, with the product type and capacity specified, additional solutions were obtained for each month (May and October). The results of these analyses are shown in Table 2.

Two of the cheese and one of the butter/powder plants operated at or near maximum capacity permitted for that product type during the May period. The average per unit cost of processing during that period was $0.697

pet cwt. During the October season none of the five plants operated at capacity. The cheese plant at location 128 actually ceased operating entirely. The other four plants operated at between 30 and 50 percent of capacity. If a fixed cost of $42,466 is assumed for the cheese plant, 4/ per unit costs of processing the 43 million pounds of raw milk not consumed in the fluid form during October would be approximately $1.034, almost a $0.34 per cwt. increase from the May season. Assembly costs in October were approximately $0.353 per cwt. The costs of the existing seasonal fluctuations in raw milk production and fluid milk consumption, at least in terms of hard product processing, are indeed substantial.

Implications

The results of these solutions clearly indicate that, in the framework of this regional problem, economies of size in the processing of raw milk into manufactured products tend to override transport costs in determining the optimal number of processing plants. Total costs continue to decline as plant numbers are reduced to the point where the number of the largest size plants operating at capacity is just adequate to process the available production. A major factor permitting these results is the fact that only a small proportion of total milk production actually moves to the manufacturing plants. Thus, with a reduction in processing plant numbers, incremental adjustments in the allocation of milk to some of all of the fluid bottling centers can be easily made. In this way, quantities can be reallocated from sources near to a remaining manufacturing plant with relatively small additions to overall transportation costs.

The technical efficiencies which could be gained from an industry wide re-organization which would permit and encourage movement patterns and plant locations approximately as shown in this research appear substantial. While the analysis does not present the evidence needed to specify the probable impact such changes would ultimately have on either retail or farm level price it does suggest that attempts to atomize the milk marketing function and thereby "increase competition" would not necessarily put long-run downward pressure on retail prices. It appears that costs, especially processing costs per unit, would tend to rise if the number of decision units, with less ability to coordinate total raw milk movements and the processing function, were increased. From a public policy viewpoint, consumer interest groups and others concerned about the effect of increasing industry concentration on retail prices should at least be made more cognizant of the important trade-off in technical efficiency often required to increase pricing competition. At least in this case, reducing industry concentration in an attempt to improve pricing competition, which is difficult to specify at best, would probably not lead to lower retail prices for milk and other dairy products.

The results of this analysis also indicate that those federal and state regulations which affect the movement of milk within the region should be examined. While it is true that almost no movement of milk is strictly prohibited by the existing regulations, some provisions in the milk marketing orders operate to effectively constrain movement patterns such that a month-to-month reallocation of available production within the region in order to minimize total industry costs over the year is not now possible.

The most dramatically apparent and easily identified inefficiency in the present system from producer through processor appears to be the rather substantial seasonal variation in the amount of raw milk available for manufacturing. While total production in the region only varies by 12.6 percent over the year, the amount of milk available for manufacturing nearly triples from October to May, reflecting the fact that milk for manufacturing is treated as a residual. There is some question, of course, about the ability of producers to match production more nearly with approximate seasonal consumption but it is clear that this inability is a costly component of the total system.

In this analysis existing locations of milk bottling plants were taken as given and distribution costs for both packaged fluid milk and the manufactured product were ignored as were all revenue considerations. An analysis which incorporated the economies of size in fluid bottling and product distribution costs would no doubt change the milk movement patterns obtained in this study but probably would not alter significantly either the number, size or location of manufacturing facilities or the conclusions drawn from the study. It is accepted that economic as well as policical considerations severely limit the ultimate practicality of an industry organization similar to the one which results from this analysis (Kloth and Blakley). It appears, however, that substantial technical economies remain for an industry organization more concentrated and/or vertically integrated than the one which exists today.

Table 1. Optimal Plant Location Sets for Cheese and Butter/Powder Operations During May and October.

Plant ID	Location	Cheese		Butter/Powder	
		May	October	May	October
		(Cwt. Processed)			
102	KY	255,850	255,850	331,000	331,000
112	TN	255,850	170,899	331,000	94,835
115	TN	164,524	---	---	---
121	NC	255,850	---	194,186	---
128	LA	255,850	---	331,000	---
Cost Summary[1/]					
Processing Cost/Cwt.		$0.708	$0.728	$0.646	$0.712
Assembly Cost/Cwt.		0.348	0.356	0.350	0.357

[1/] Processing costs are for the manufactured product only. Assembly costs include the movement of raw milk used for both fluid and manufactured product processing.

Table 2. Impact of Seasonal Variation in Milk Availability on Processing with Location Set and Product Type Specified

Plant ID	Location	Product Type	Volume Processed (Cwt.) May	Volume Processed (Cwt.) October
102	KY	Cheese	250,479	133,900
112	TN	Cheese	129,163	79,575
115	TN	Butter/Powder	318,547	113,970
121	NC	Butter/Powder	234,742	100,847
128	LA	Cheese	255,850	0
		Cost Summary[1/]		
		Processing Cost/Cwt.	$0.697	$1.034
		Assembly Cost/Cwt.	0.348	0.353

[1/] Processing costs are for the manufactured product only. Assembly costs include the movement of raw milk used for both fluid and manufactured product processing.

FOOTNOTES

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1/ One of the earliest discussions regarding the handling of nonlinearities in this way is contained in the article by Seagraves and Giaever.

2/ Most of the data for this study were obtained from records maintained by Dairymen, Inc., Louisville, Kentucky. These data were supplemented where necessary with information from State Experiment Stations, State Departments of Agriculture and U.S.D.A. reports.

3/ Since fixed costs are higher, and per unit processing costs lower at high volumes, in butter/powder plants then in cheese plants a cost minimization solution would lead one to locate butter/powder plants in areas which are not affected by seasonality in milk availability. However, the nature of the product being processed as well as the nature of the labor requirement forced us to choose the other alternative.

4/ Estimated costs for building and equipment depreciation and retaining management labor for cheese plants would approximate $39,000 per month. Thus, the intercept of the estimated total cost function ($42,466) is a reasonable estimate for fixed costs.

REFERENCES

Boehm, W. T., "Generalized Transportation Solution System (GTSS)," Agricultural Economics Research Report #A.E. 19, Virginia Polytechnic Institute and State University, Blacksburg, February 1976.

Boehm, W. T. and M. C. Conner, "Optimal Number and Location of Milk Manufacturing Plants and the Movement of Milk for Minimizing Costs in the Southeast Region", Agricultural Economics Staff Paper, Virginia Polytechnic Institute and State University, January 1976.

Conner, M. C., W. T. Boehm, and T. A. Pardue, "Economies of Size in Processing Manufactured Dairy Products and Implications for the Southern Dairy Industry", Agricultural Economics Staff Paper, Virginia Polytechnic Institute and State University, May 1976.

Giaever, H. and J. Seagraves, "Linear Programming and Economies of Size," Journal of Farm Economics, Volume XLII, Number I, February 1960, pp. 103-117.

Kloth, Donald W. and Leo B. Blakely, "Optimum Dairy Plant Location with Economies of Size and Market-Share Restrictions," American Journal of Agricultural Economics, Volume 53, Number 3, August 1971, pp. 461-466.

King, G. A. and S. H. Logan, "Optimum Location, Number and Size of Processing Plants with Raw Product and Final Product Shipments," Journal of Farm Economics, Volume 46, February 1964, pp. 94-108.

Roe, T. L., "Optimal Spatial Distribution and Size of Cattle Slaughtering Plants in Indiana," unpublished Ph.D. Thesis, Purdue University, January 1969.