The Economies of Scale Revisited: Comparing Census Costs, Engineering Estimates, and the Survivor Technique

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Abstract

The *Census of Manufactures* is used to compute average costs for various plant sizes in the flour milling, cheese, and fluid milk industries. Adjustments are made for systematic differences in wages among large and small plants as well as unreported proprietor wages. The costs are compared over Census years 1958 to 1982. The minimum optimum sizes suggested by Census costs are similar to those obtained by the survivor technique. They are also roughly in accord with engineering estimates, although only the latter show continuous economies of size in milk and flour.

Introduction

Are the costs of concentrated economic power offset by the benefits of lower unit costs? Is minimum optimum size small enough to permit many firms in the market? Do big firms enjoy enough cost advantage to impede the entry of small firms? These questions have been fundamental ones about economic organization for a century, but the answers remain elusive. As George Stigler [24] wrote more than 30 years ago, "We have been dangerously close to denying Lincoln, for all economists have been ignorant of the optimum size of firm in almost every industry all of the time..." The situation remains the same today for the same reason: inability to measure economies of size.

This paper offers no panacea for the problem of measurement. Like many other studies, it concentrates on what Scherer [20] calls plant-specific economies and thereby bypasses the complexity and controversy surrounding firm-specific or multiplant economies in such areas as sales promotion, management, acquisition of capital, research and development, service, and image.[1] The paper

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[1]See Scherer [20] and Scherer, Beckenstein, Kaufer, and Murphy [21].

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uses U.S. Census cost data as a source of information.[2] Various approaches are compared through intensive analysis of the flour, milk, and cheese industries. The paper concludes that economists may have discarded U.S. Census costs prematurely. This source of information may provide insights about economies of size.

Review of Accounting, Engineering, and Survivor Approaches

Theoretically, economists derive long-run average costs for plants of various sizes that could be built with the best technology available. Estimates of cost-output relations are constructed from given capital, labor, and materials prices and from the quantities of those inputs that would be employed optimally in different size plants. Any empirical study of existing plants of different sizes never will yield more than an approximation of the theoretical construct. Whenever economies of size are determined on the basis of existing operating plants, for example, several eras of technology probably will be represented. Even engineering estimates of model plant costs do not resolve the problem of different technologies over time, because engineers may have difficulty applying their knowledge to plant sizes outside their realm of experience. All empirical work on this subject is subject to this qualification.[3]

There are three direct ways of measuring economies of size.[4] In the first approach, average costs are estimated from accounting data on existing plants and firms. This procedure has fallen into disfavor, however, because of conceptual and empirical problems. Proprietary secrecy makes data on individual firms difficult to obtain. Different accounting conventions limit comparability. They often lead to arbitrary asset valuations and variable methods of allocating the costs of administration, planning, sales promotion, and research and development. Interfirm differences in product mix, technology, input prices, and

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[2]This idea may have originated with Caves, Khalilzadeh-Shirazi, and Porter [3], who observed in 1975 that "[o]ur finding that usable evidence of unit-cost variations lies embedded in U.S. Census data on value-added by plant size may support their use in other studies as well."

[3]For surveys of work in this area, see French [8], Garcia and Sonka [10], and McGee [15]. Accounting cost problems have been addressed recently by Cowing and Holtman [6] and Akridge and Hertel [1].

[4]The indirect method of calculating rates of return on investment by size and the *ad hoc* technique of measuring optimum size by actual median size are ignored. This paper also concentrates on the empirical concept of size rather than on the theoretical construct of scale, although Stigler's [24] convention is used in the title.

lengths of product runs add to the distortions. Furthermore, when sample size is small, managerial errors and the vagaries of the market cause observed costs and quantities of output to depart from the long-run equilibrium values. According to Friedman [9], the most fundamental problem confronting cost estimates is that of capitalizing rents of specialized resources into costs. These problems have led John McGee [15] to conclude that "All in all, such studies are at least as likely to mislead as to inform." These problems also led researchers, beginning with Joe Bain [2], to approach the task of measurement via the so-called engineering approach.

The most popular and enduring method of measuring size economies relies on expert knowledge of best practice technology. This information is used to construct average production costs for various sizes of plants or firms. Information-gathering varies from sample questionnaires to detailed analysis of each machine or process in actual and/or model plants.[5] The question-and-answer method has the disadvantages of misinterpretation, oversimplification, and subjectivity on both sides. Even detailed models usually assume a lack of substitutability among factors and techniques; such models may ignore less costly alternatives to engineering ideals. These models may neglect certain aspects of labor or management organization that would alter efficiency. Some economists believe that expert opinion has relatively low value in comparison to the decisions of managers or owners who have their economic fortunes at stake.[6] Finally, this approach is expensive and yields results applicable only to the year of study and the particular plant sizes considered.

The third approach, which Stigler [24] first employed in 1958, classifies "the firms in an industry by size, and calculate(s) the share of industry output coming from each class over time. If the share of a given class falls, it is relatively inefficient the more rapidly the share falls." Estimation of optimal

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[5]The diversity of so-called engineering studies makes it difficult to distinguish some of them from accounting cost research. In particular, the estimates by Weiss [27] and the National Commission on Food Marketing [16] reported below were obtained by surveys of management experts, but the responses are based on each firm's measurement of costs. The Cobia and Babb estimates [4] below are based on regression analysis of independent engineering and other estimates. Thus, a broad definition of engineering estimates is adopted.

[6]McGee [15] observes that "engineers ... break down utterly when they are asked, but not paid very well to answer, questions about a plant whose production rate and volume will be, say, twice as large as anything they have personally seen." Stigler [24] concludes that in engineering studies, "much of the problem is solved only in the unhappy sense of being delegated to a technologist."

size firms and plants by the survivor technique became popular for several reasons:

1. It avoided the scarcity and inconsistencies in the accounting data by ignoring costs;
2. Its analytical simplicity and use of readily available data made calculations relatively inexpensive and expedient;
3. It relied on fairly accurate and complete U.S. Census employment and output data, making it seem more objective and comprehensive than the engineering results;
4. It reflected the evolution of industries, rather than focusing on cost structure at some fixed date in the past.

Shepherd [22] has pointed out that the survivor technique also possesses a number of serious disadvantages. As Stigler [24] noted, it

> reveals the optimum size in terms of private costs. . .social efficiency may be a very different thing: the most efficient firm size may arise from possession of monopoly power, undesirable labor practices, discriminatory legislation, etc...

It also fails to measure the amount of size economies, and therefore cannot answer important questions about the height of the entry barriers and the benefits of industrial concentration. Survivor technique computations only yield the optimum quantity of shipments and do not provide any further information on the shape of the long-run average cost function. Even when confined to plants, the survivor estimates may be distorted by firm-specific economies, because the technique does not distinguish plants operated by one plant or multiplant firms. There is some ambiguity over the relevant time period for measuring changes in market shares, over the interpretation of stable shares, and over the relevance of relative or absolute shares.

Another Look at Census Measures of Cost

The *Census of Manufactures* [28] constitutes the primary database for the survivor technique, but it also contains information on costs, albeit much abused and largely neglected. Costs are reported for labor and materials only, but these two items account for the bulk of total costs in most industries. If size economies are significant, there must be savings in payroll as well as in materials use and procurement. If size and scale are equated, it would be possible to say that capital cost savings should be proportional to cost savings for other factors of production.

The central question is under what circumstances are U.S. Census cost reports worthwhile as a source of data?

1. If a U.S. Census industry consists of a large number of geographically dispersed plants in each size category, there probably will be sufficient observations to avoid distortions of averages based on local demand differences, management errors, windfalls, and technical innovations. This presumes that the distribution of these phenomena is independent of firm size.

2. If an industry's products and raw materials are defined narrowly over long periods of time and if the industry coverage and specialization ratios are high, then the value of shipments and cost data should be relatively free of distortions due to variations in product mix, model volume, and quality.

3. If geographic product markets are linked closely enough so that price does not vary systematically among areas or if plants are distributed randomly among these areas, then the value of shipments is expected to vary in direct proportion to quantity of sales.

4. If production factors are not specialized and are exchanged in open markets, then actual transaction costs probably reflect comparable social costs.

The stringent conditions placed on the use of U.S. Census data suggest that the economies-of-size conundrum cannot be solved easily. Nevertheless, the data are readily available; they cover large samples; they are collected in a consistent manner; they are available over long periods of time; and they provide evidence (albeit imperfect) of the degree of size economies. At a minimum, these data can be assembled into a structure that serves as a check on the ambiguous, asocial survivor technique and on the subjective, small sample engineering approach.

Census Cost Estimates: A Trial Run

Given the severe conditions imposed on cost analysis, are there any industries for which U.S. Census data are meaningful? If so, how do the results compare with those of the survivor technique and the engineering approach? In order to answer these questions, comprehensive estimates for many industries are discarded in favor of close examination of a few. In particular, three food processing industries (SIC 2041, Flour Milling; SIC 2022, Cheese; and SIC 2026, Fluid Milk) are considered. These industries seem to satisfy most of the criteria established for the validity of U.S. Census data. Where they do not, some adjustments of the data are possible. Costs in these industries also have been estimated by several studies employing the engineering approach.

Criterion 1: Large Numbers

All three industry groups contain several hundred plants across a wide range of sizes,[7] as measured by employment. Only in the largest size categories do the numbers drop below levels that would make averages subject to suspicion. Their geographic distribution is nationwide, although plains states have a disproportionate number of flour mills and Wisconsin and Minnesota have a disproportionate number of cheese plants.

Criterion 2: Narrowly Defined Products

The industry coverage and specialization ratios are relatively high in all three industry groups, indicating few multiproduct plants.[8] In addition, quality has remained stable over the years; there have been no new models, nor are there fundamental differences among products (with the exception of processed and natural cheeses). With respect to natural cheese processing, little difference exists among production processes, materials, or equipment for the major domestically produced varieties. Production cost differences are probably minimal.

In terms of product mix, milk fares the best.[9] The flour industry, on the other hand, mills both hard and soft wheat as well as corn flour which may alter production costs slightly. Cheese presents similar difficulties because it includes both natural and processed cheeses. This U.S. Census industry does not include cottage cheese, however, and its product mixes have remained stable over time.

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[7]Over 90 percent of the establishments in all three industries have more than three-quarters of their shipments in their respective industry's major product class. The distribution of establishments by size in 1977 is as follows:

	Employment Size							
SIC Code	1-4	5-9	10 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500+
2041	141	44	49	67	59	42	4	1
2022	253	102	143	161	80	34	12	6
2026	580	227	208	332	259	270	43	5

[8]According to the U.S. Bureau of the Census [28], concentration and specialization ratios are all above 85 percent.

[9]For a description of goods produced by each industry, see [23].

Criterion 3: Uniform Product Prices

Available information indicates that small and large plants operate in geographic proximity to one another.[10] There is also sketchy information suggesting that prices are similar across the country.[11] If these data reflect general conditions, the use of uniform wholesale prices to obtain quantities from values of shipments seems sound.

Criterion 4: Uniform Input Prices

Raw materials for the industries generally are produced nationwide and are purchased largely on the open market. In the case of cheese and milk, Dobson and Salathe [7] find that government intervention apparently leads to interregional uniformity of materials and prices. Labor markets, however, may be characterized by geographic immobility and unionization which could result in wages varying systematically with size. Small plants in rural areas, for instance, may pay lower wages than large unionized plants in urban areas. In addition, there is evidence that small plants were generally proprietorships in which the owner's labor was not included in reported payrolls.[12] These problems led to adjustments in the U.S. Census data that are discussed in detail below.

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[10]For dairies, see [4]. For flour mills, see [16].

[11]In the two U.S. Census years for which the information was available, the wholesale price of fluid milk, in cents per quart, was reported by the Bureau of Labor Statistics as follows:

	New York City	Chicago	San Francisco	Washington D.C.	Dallas
1958	23.8	21.0	20.5	23.0	21.0
1963	22.8	26.0	23.5	28.0	26.0

According to the National Commission on Food Marketing [16], the wholesale prices of baker's white bread type flour per hundredweight in the 1964-1965 marketing year by region were as follows:

North Central	Mountain	Pacific	South Central	Middle Atlantic	South Atlantic
$5.83	$5.92	$6.00	$5.86	$6.15	$6.03

[12]For example, see the appendix to the *Census of Manufactures* [28] reports on four digit industry SIC groups, p. A1: "proprietorships and partners of unincorporated firms are, however, excluded from the total" of all employees.

Cost and Quantity Computations

For each U.S. Census year, four digit SIC industry, and plant-size category defined by employment, the computation of average labor plus materials costs for different average quantities of output was performed as follows:

1. Value of shipments (VS) is divided by wholesale price (P) to find the average quantity of output per size category: $Q = VS/P$;
2. The sum of total payroll (L) plus cost of materials (MC) is divided by the quantity of output (Q) to find average labor plus materials costs per establishment: $(ALMC = (L + MC)/Q$.

The estimate of ALMC is an approximation of average variable cost. Two columns for each plant size measured by average number of employees were computed: an average quantity-of-output column, measured in physical units, and an average labor-plus-materials cost column, measured in monetary units. The resulting ALMC is used to determine the range and degree of size economies.

Adjustments in Census Data

Wage rates paid by small plants were systematically lower than those paid by large ones, and the U.S. Census ignored the labor of proprietors/partners in small plants. In an attempt to deal with these problems, data were adjusted in the following ways.

All payroll costs were derived on the basis of the average wage rate for the entire industry, and the payrolls of plants with fewer than 20 employees were augmented by the imputed wage of a proprietor, which was assumed to be double the industry average wage.

These adjustments were made for all three SIC groups for the U.S. Census years 1967, 1972, 1977, and 1982. Because the 1958 and 1963 versions of the U.S. Census reported no labor hours, adjusted costs could not be calculated for those years. Unadjusted estimates of average labor and materials costs (ALMC) are presented, as well as adjusted average labor and materials costs (AALMC). In order to facilitate comparisons with engineering estimates that ignored materials costs, the adjusted average labor costs (AALC) are reported separately.

Results

The unadjusted ALMC results in Table 1 consist of nearly constant costs. In many cases, the smallest plants appear to have the lowest costs. This relation probably reflects the labor problems discussed above, although it may be argued that larger plants required more skilled labor or that small plants have the advantage of being able to locate in low wage areas, in which cases the differences in wage rates reflect social economies of scale.

The AALCs for milk and flour in Table 2 appear to fit textbook envelope cost functions. The AALCs for cheese, on the other hand, are suggestive of cost curves that would be predominantly L-shaped with the largest plants having a slight cost advantage over mid-size plants. As expected in low value-added industries, the addition of materials has a leveling influence on the costs of different size plants. AALMCs for 1982, however, seem to vary more than in previous years and also differed more among industries. Flour mills exhibited continuous size economies, whereas diseconomies appeared in dairies. AALMC for 1982 in cheese shows more discontinuity, but the largest plants incurred the lowest average costs.

The minimum optimum size (MOS) suggested by U.S. Census data has changed over the years in each industry. AALC in milk and flour is minimized in plants employing only 20-49 workers in most years. In contrast, MOS is generally the largest size plant in cheese according to AALC. The MOS implied by AALMC is in the largest size category for flour during all years, while it appears to have grown to the largest size plant in cheese over time. In milk, only the largest plants minimize AALMC in early years, but MOS appears to have fallen to the 100-249 employee range recently.

Comparisons with Survivor and Engineering Estimates

Shares of market shipments by plant size were computed in the application of the survivor technique. Although value-added data could be used as well, its use in these industries would provide similar results. The engineering estimates were taken from cost-output research generally performed by agricultural economists between 1947 and 1975. The results of these approaches are summarized and then compared with U.S. Census cost estimates.

Survivor Technique

The survivor technique is applied to the three industries over the quarter century spanning six business censi. Table 3 contains calculations of the percentages of shipments for plants in several size categories.

Survivor results are similar for the three industries--both the largest absolute shares and the most growth in shares are associated with relatively large plants. For milk and flour, plants with 100-249 employees appeared to be dominant. In cheese, the largest (250-999 employee) plants possess the largest market shares, although their position is challenged by the fast growth of plants in the 100-249 employee range. Thus, the survivor technique suggests cost envelopes for milk and flour and an L-shaped long-run average cost curve for cheese.

One of the most remarkable features of the survivor results is their similarity to the U.S. Census cost estimates. Both approaches agree that there are economies of scale throughout the observed range of plant sizes in cheese. For milk and flour, the AALC and survivor approaches both suggest the appearance of diseconomies in large plants, although MOS according to the survivor technique is one or two categories larger than estimated with U.S. Census data.

Engineering Estimates

With respect to engineering estimates, the studies pertained only to wheat flour in SIC 2041, natural cheddar cheese in SIC 2022, and Grade A fluid milk in SIC 2026. The results, which were reported in different forms and units, have been standardized for purposes of comparisons and appear in Tables 4 to 6.

Few studies on which to report were found, perhaps because of the high cost of conducting them. Available studies are dated and complex, considering the relative simplicity of the production processes involved. Only a couple of studies covered the largest plant sizes in existence. This is an important area of ignorance, because the largest plants generally account for half or more of industry output. A final shortcoming of the engineering studies is their neglect of raw material procurement costs.

The results differ markedly, depending on the type of equipment, years, operating hours, and operating days chosen, but generally the studies conclude that there are substantial economies of size (up to the limit included in the studies). They also indicate that economies diminished in the biggest plants studied, although these plants were relatively small by industry standards.

Because the engineering studies cover different years and different cost measures, absolute amounts cannot be compared with U.S. Census cost estimates. Nevertheless, it may be of interest to observe the relative changes in costs associated with similar changes in plant size under the two approaches. In almost all cases, the engineering estimates agree with the AALC that the smallest plants have the highest costs. Furthermore, costs tend to fall by roughly the same proportions according to both sets of estimates and they both yield similar MOS in the cheese industry. On the other hand, the engineering estimates for milk and flour imply that the MOS plants in these industries are several times larger than those implied by the U.S. Census [28]. It also was noted that the engineering estimates generally are based on higher output per worker than found in the U.S. Census [28].

Summary and Conclusions

Since economists dismissed accounting cost data as erroneous and irrelevant, many have relied on Stigler's [24] survivor technique and Bain's [2] engineering approach to infer the shape of the long-run average cost function. As has been noted, however, the latter approaches also possess shortcomings. The analysis in this paper resurrects U.S. Census cost measures as estimates of scale economies, admittedly subject to severe qualifications, but probably no more severe than those for other approaches.

It also is possible to compute average cost per unit of physical output produced in various sizes of plants, but this must be done with great care. It is possible to identify minimum optimal size plants from U.S. Census costs, in some cases consistent with the survivor and engineering estimates. Wherever inconsistencies arise, investigation of the reasons for different results would add to the reliability of any conclusions about size economies in an industry. Some adjustments must be made in the U.S. Census data, especially for small plants, in order to account for proprietorships and wage differences. Another problem is the procedure for computing quantity from value of shipments, because this calculation relies on the use of a single average selling price for the entire year for all plants. Finally, there is an aggregation problem that does not allow precise location of the minimum optimal size plant because several categories, especially for larger plants, span extremely wide ranges of employees and outputs.

Obviously, more work needs to be done to determine whether the procedures discussed here are valid. More information on plant locations may enable us to adjust for regional differences in price. Some way still is needed to estimate capital costs. Comparisons of the results of the U.S. Census cost estimates need to be expanded to other industries. Even for the three industries analyzed in this paper, additional engineering studies need to be undertaken for larger plants. Despite these unsolved problems, this U.S. Census cost estimation procedure should be returned to the industry economist's tool kit.

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Table 1

Unadjusted Average Labor and Materials Costs (ALMC) and Average Annual Volume of Shipments (Q) by Size of Plant in SICs 2041, 2022, and 2026, United States, Selected Years, 1958 to 1977

Number of Employees SIC 2041	1958 Q (000 lbs.)	1958 ALMC ($/lb.)	1963 Q (000 lbs.)	1963 ALMC ($/lb.)	1967 Q (000 lbs.)	1967 ALMC ($/lb.)
1-4					1,525	4.62
5-9					7,031	3.85
10-19					15,442	4.67
20-49					66,347	4.93
50-99					173,319	4.96
100-249					343,538	4.86
250-499					776,286	4.54
500-999					*	*

Number of Employees SIC 2041	1972 Q (000 lbs.)	1972 ALMC ($/lb.)	1977 Q (000 lbs.)	1977 ALMC ($/lb.)	1982 Q (000 lbs.)	1982 ALMC ($/lb.)
1-4	2,779	5.02	5,305	5.44	5,510	10.01
5-9	6,664	4.99	19,043	5.33	8,400	9.80
10-19	24,418	5.24	42,454	5.44	29,081	9.57
20-49	87,488	4.98	158,837	5.26	108,439	9.81
50-99	202,243	5.14	268,384	5.35	222,333	9.79
100-249	391,312	5.07	567,530	5.12	439,286	9.36
250-499	807,496	4.54	1,028,250	4.86	888,691	7.48
500-999	*	*		*		

Table 1 (continued)
Unadjusted Average Labor and Materials Costs (ALMC) and Average Annual Volume of Shipments (Q) by Size of Plant in SICs 2041, 2022, and 2026, United States, Selected Years, 1958 to 1977

Number of Employees SIC 2022	1958 Q (000 lbs.)	1958 ALMC ($/lb.)	1963 Q (000 lbs.)	1963 ALMC ($/lb.)	1967 Q (000 lbs.)	1967 ALMC ($/lb.)
1-4	479	28.7	494	31.7	390	38.3
5-9	978	29.9	1,158	30.0	1,238	39.4
10-19	1,745	30.3	1,945	31.3	2,165	38.1
20-49	3,431	29.8	4,548	31.1	4,483	39.6
50-99	10,211	29.2	10,455	30.4	11,193	39.3
100-249	15,572	28.7	18,982	31.1	36,468	39.7
250-499	102,778	30.6	144,306	27.8	144,329	41.3
500-999					*	*
1,000 +					*	*

Number of Employees SIC 2022	1972 Q (000 lbs.)	1972 ALMC ($/lb.)	1977 Q (000 lbs.)	1977 ALMC ($/lb.)	1982 Q (000 lbs.)	1982 ALMC ($/lb.)
1-4	451	52.7	398	90.0	356	120.7
5-9	1,107	51.8	1,493	89.8	1,166	126.4
10-19	2,500	53.1	2,708	87.5	2,825	130.0
20-49	5,338	52.2	6,004	86.3	8,133	123.8
50-99	12,715	53.3	16,799	86.8	18,865	124.5
100-249	33,297	53.7	35,771	86.2	37,030	120.7
250-499	133,528	56.9	120,081	86.6	118,367	118.6
500-999	*	*	*	*		
1,000 +	*	*	*	*		

Table 1 (continued)
Unadjusted Average Labor and Materials Costs (ALMC) and Average Annual Volume of Shipments (Q) by Size of Plant in SICs 2041, 2022, and 2026, United States, Selected Years, 1958 to 1977

Number of Employees SIC 2026	1958 Q (000 qts.)	1958 ALMC ($/qt.)	1963 Q (000 qts.)	1963 ALMC ($/qt.)	1967 Q (000 qts.)	1967 ALMC ($/qt.)
1-4	434	18.1	369	21.3	330	21.2
5-9	956	18.0	956	22.0	1,350	22.8
10-19	1,789	18.1	1,849	22.3	2,417	22.1
20-49	4,593	18.0	4,537	22.0	6,057	22.1
50-99	10,890	17.6	10,759	21.7	13,594	22.0
100-249	21,921	17.9	22,808	21.6	28,087	21.7
250-499	46,289	17.3	46,261	21.2	59,968	21.6
500-999	91,650	17.8	96,185	21.6	122,660	20.5
1,000 +					*	*

Number of Employees SIC 2026	1972 Q (000 qts.)	1972 ALMC ($/qt.)	1977 Q (000 qts.)	1977 ALMC ($/qt.)	1982 Q (000 qts.)	1982 ALMC ($/qt.)
1-4	491	23.3	565	32.4	867	56.5
5-9	1,747	24.3	2,067	32.3	3,262	57.1
10-19	3,156	24.9	5,607	32.5	7,844	57.7
20-49	8,013	24.8	14,572	32.4	30,807	55.2
50-99	20,950	25.0	30,486	32.2	65,599	55.8
100-249	40,467	24.3	61,552	31.3	122,528	55.5
250-499	75,660	20.6	119,350	31.8	250,668	58.0
500-999	182,220	23.9	162,480	33.1	439,532	56.2
1,000 +	*	*	*	*		

Sources: Derived from *Census of Manufactures* [28] and wholesale prices and price indexes [20]
*Data included in line above due to disclosure rules

Table 2

Adjusted Average Labor Costs (AALC) and Adjusted Average Labor Plus Materials Costs (AALMC)
by Plant Employee Size and Physical Output, SICs 2041, 2022, 2026, United States, Selected Years 1967 to 1982

Number of Employees SIC 2041	Q (000 lbs.)	1967 ALMC ($/lb.)	AALMC ($/lb.)	Q (000 lbs.)	1972 ALMC ($/lb.)	AALMC ($/lb.)
1-4	1,525	1.8	5.9	2,779	1.4	5.9
5-9	7,031	1.0	5.3	6,664	1.2	5.5
10-19	15,442	0.7	4.9	24,418	0.6	5.4
20-49	66,347	0.3	5.0	87,488	0.3	5.0
50-99	173,319	0.3	5.0	202,243	0.3	5.1
100-249	343,538	0.3	4.9	391,312	0.4	5.1
250-499	776,286	0.3	4.5	807,496	0.5	4.6
500-999	*			*		

Number of Employees SIC 2041	Q (000 lbs.)	1977 ALMC ($/lb.)	AALMC ($/lb.)	Q (000 lbs.)	1982 ALMC ($/lb.)	AALMC ($/lb.)
1-4	5,305	0.9	6.4	5,510	3.2	12.8
5-9	19,043	0.6	5.9	8,400	2.4	11.3
10-19	42,454	0.6	6.1	29,081	2.2	11.2
20-49	158,837	0.3	5.3	108,439	0.8	10.0
50-99	268,384	0.4	5.4	222,333	0.7	9.8
100-249	567,530	0.4	5.1	439,286	0.9	9.4
250-499	1,028,250	0.4	4.8	888,691	0.9	7.4
500-999						

Table 2 (continued)
Adjusted Average Labor Costs (AALC) and Adjusted Average Labor Plus Materials Costs (AALMC)
by Plant Employee Size and Physical Output, SICs 2041, 2022, 2026, United States, Selected Years 1967 to 1982

Number of Employees SIC 2022	1967 Q (000 lbs.)	1967 ALMC ($/lb.)	1967 AALMC ($/lb.)	1972 Q (000 lbs.)	1972 ALMC ($/lb.)	1972 AALMC ($/lb.)
1-4	398	10.7	95.3	356	12.6	127.0
5-9	1,493	5.6	90.9	1,166	11.7	131.3
10-19	2,708	6.2	88.9	2,825	5.1	128.8
20-49	6,004	5.6	87.0	8,133	6.2	124.4
50-99	16,799	4.6	87.1	18,865	6.1	124.8
100-249	35,771	4.6	86.0	37,050	6.1	130.9
250-499	120,081	3.8	86.1	118,367	5.6	118.0
500-999	*	*				
1,000 +						

Number of Employees SIC 2022	1977 Q (000 lbs.)	1977 ALMC ($/lb.)	1977 AALMC ($/lb.)	1982 Q (000 lbs.)	1982 ALMC ($/lb.)	1982 AALMC ($/lb.)
1-4	390	5.1	41.4	451	6.9	56.7
5-9	1,238	3.4	40.5	1,107	5.3	53.6
10-19	2,165	3.8	38.8	1,500	4.8	54.2
20-49	4,483	3.6	40.0	5,338	4.4	54.8
50-99	11,193	3.1	39.3	12,715	3.9	53.4
100-249	36,468	2.5	39.7	33,297	3.3	53.4
250-499	144,329	1.5	40.9	133,528	2.8	56.6
500-999	*	*		*	*	
1,000 +						

Table 2 (continued)
Adjusted Average Labor Costs (AALC) and Adjusted Average Labor Plus Materials Costs (AALMC)
by Plant Employee Size and Physical Output, SICs 2041, 2022, 2026, United States, Selected Years 1967 to 1982

Number of Employees SIC 2026	1967 Q (000 qts.)	1967 ALMC ($/qt.)	1967 AALMC (000 qts.)	1972 Q ($/qt.)	1972 ALMC (000 qts.)	1972 AALMC ($/qt.)
1-4	330	7.1	25.6	491	5.0	25.5
5-9	1,350	4.6	24.1	1,747	4.3	25.9
10-19	2,417	4.2	23.1	3,156	4.4	26.1
20-49	6,057	3.2	22.2	8,013	3.4	25.0
50-99	13,594	3.2	22.0	20,950	3.0	25.1
100-249	28,087	3.6	21.7	40,467	3.4	24.2
250-499	59,968	3.6	21.3	75,660	3.8	23.9
500-999	122,660	4.1	20.4	182,220	3.3	22.9
1,000 +						

Number of Employees SIC 2026	1977 Q (000 qts.)	1977 ALMC ($/qt.)	1977 AALMC (000 qts.)	1982 Q ($/qt.)	1982 ALMC (000 qts.)	1982 AALMC ($/qt.)
1-4	565	8.2	37.4	867	7.9	68.6
5-9	2,067	5.4	34.1	3,262	5.2	62.5
10-19	5,607	3.7	33.4	7,844	3.7	60.0
20-49	14,572	3.0	32.6	20,807	2.0	54.1
50-99	30,486	3.2	32.3	65,599	2.1	55.1
100-249	61,552	3.2	31.2	122,528	2.4	55.1
250-499	119,350	3.7	31.9	250,668	2.2	57.1
500-999	162,480	4.4	32.8	439,532	4.7	56.5
1,000 +						

Source: Calculations based on *Census of Manufactures* [28] and wholesale (producer) price indexes [29]
*Data included in line above due to disclosure rules

Table 3
Survivor Technique Summary Computations, Percent of Value of Shipments Among Plants of Various Sizes, SICs 2041, 2022, 2026, United States, Selected Years, 1958 to 1982

Plant Size (Number of Employees)	Percentage Share of Total Industry Value of Shipments					
	1958	1963	1967	1972	1977	1982
SIC 2041						
1-4	1.3	1.2	0.7	1.1	1.3	1.0
5-9	1.6	1.8	1.0	1.1	1.5	0.9
10-19	2.4	3.1	2.0	3.0	3.6	3.7
20-49	10.6	10.4	12.8	16.4	18.5	19.3
50-99	18.6	20.4	29.4	29.9	27.5	24.9
100-249	39.7	39.5	34.6	35.6	41.4	44.1
250-499	17.2	15.8	19.6	10.0	8.9	6.1
500-999 +	8.4	7.7	*	*	*	
SIC 2022						
1-4	14.0	7.8	4.3	2.3	1.6	0.6
5-9	11.6	6.8	5.3	3.2	2.4	1.8
10-19	14.9	11.1	9.5	7.6	6.1	5.2
20-49	19.1	18.0	16.6	17.9	15.3	17.2
50-99	15.6	13.2	16.2	12.8	21.2	20.1
100-249	5.2	17.8	22.8	21.2	19.2	24.8
250-499	19.6	25.4	25.3	35.0	34.2	30.4
500-999 +		*	*	*	*	*
SIC 2026						
1-4	2.0	1.5	1.1	1.0	0.9	0.3
5-9	3.4	2.7	1.6	1.3	1.3	0.6
10-19	6.2	5.5	4.1	3.1	3.1	1.7
20-49	17.3	15.7	14.1	12.3	13.0	11.8
50-99	20.5	20.4	20.0	26.8	21.2	23.0
100-249	27.7	33.9	36.5	39.1	44.6	44.3
250-499	15.8	13.9	16.9	12.4	13.8	14.3
500-999	7.2	6.4	5.7	3.9	2.2	4.1
1,000 +	*	*	*	*	*	

Source: *Census of Manufactures* [28] (computations by the authors)

*Shipments for one or more plants in this size category included in the next larger size(s) to avoid disclosure

Table 4
Engineering Estimates of Size Economies in Flour Milling

Authors		Haskell	National Committee Food Mktg.	Niernberger et al.	Weiss
Location		USA	USA	KA	USA
Data Years		1963	1964-65	1975	1976
Plant Size					
Number of of Employees	Output (000 lbs. per yr.)	Average Cost of Processing Excluding Raw Materials (cents/lb.)			
-	30,667				MOS
25	36,500	1.330			
NA	37,700		0.575		
NA	97,500		0.479		
34	102,900			1.406	
41	109,500	0.640			
NA	162,500		0.392		
39	171,500			1.098	
53	182,500	0.430			
NA	227,500		0.390		
43	240,100			0.973	
60	255,500	0.330			
NA	292,500		0.438		
NA	over 325,500		0.484		

Source: see authors in References

Table 5
Engineering Estimates of Size Economies in Cheese Processing

Authors		Conner et al.	Hines and Blakley	Lilwal and Hammond	Rowe
Locations		KY	OK	MN	OR
Data Years		1975	1965	1968	1946-48
Plant Size: Number of of Employees	Plant Size: Output (000 lbs. per yr.)	Average Cost of Processing Excluding Raw Materials (cents/lb.)			
	201				6.25
	402				5.16
	602				4.71
	1,004				4.35
	1,405				4.24
21	2,298		6.10		
13	2,688			6.77	
	2,850			6.52	
	4,275			5.80	
	5,700			5.13	
20	6,508			4.96	
	11,400			4.35	
	17,100			4.09	
	22,800			3.95	
	34,200			3.87	
90	39,055			3.81	
	77,400	1.25			
	92,880	1.31			
	154,800	0.88			

Source: see authors in References

Note: Lilwal and Hammond [14] estimated costs under different techniques but only the least cost for each plant size is reported

Table 6
Engineering Estimates of Size Economies in Fluid Milk Processing

Authors		Cobia & Babb	Conner et al.	Henry et al.	O'Connell & Snyder	Strain & Christensen	Webster et al.
Locations		Synthesis	NY, VA, PA	CT	CO	OR	New England
Data Years		1947-56	1954-55	1947	1963	1956	1962
Plant Size: Number of Employees	Output (000 lbs. per yr.)	Average Cost of Processing Excluding Raw Materials (cents/qt.)					
1	75			7.85			
1	125			5.97			
NA	200	6.40					
2	250			4.52			
1.5	318		7.48				
NA	400	5.91					
3	499			4.02			
NA	600	5.64					
4	749			3.68			
NA	800	5.45					
2.5	852		4.74				
NA	1,000	5.32					
6	1,498			3.00			
5	1,872						5.70
NA	2,000	4.91					
5	2,031					6.70	
5	2,067		3.69				
4	2,316				5.43		
	4,000	4.53					
6	4,044					4.90	

Table 6 (continued)
Engineering Estimates of Size Economies in Fluid Milk Processing

Authors		Cobia & Babb	Conner et al.	Henry et al.	O'Connell & Snyder	Strain & Christensen	Webster et al.
Locations		Synthesis	NY, VA, PA	CT	CO	OR	New England
Data Years		1947-56	1954-55	1947	1963	1956	1962
Plant Size							
Number of Employees	Output (000 lbs. per yr.)	Average Cost of Processing Excluding Raw Materials (cents/qt.)					
6	4,632				4.41		
8.5	4,810		3.05				
NA	6,000	4.32					
11	6,240						3.90
NA	8,000	4.18					
10	8,128					4.12	
10	9,264				3.80		
NA	10,000	4.08					
23	15,600						3.20
16	16,252					3.52	
15	18,527				3.28		
NA	20,000	3.76					
39	32,448						2.90
32	32,507					3.27	
28	37,054				3.00		
NA	40,000	3.48					
NA	60,000	3.32					
NA	80,000	3.21					
NA	100,000	3.13					
NA	120,000	3.06					

Source: see authors in References