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# Estimating Optimum Size of Dairy Plants

# Using Survivor Analysis

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As applied to manufacturing plants, optimum size commonly refers to the range in volume of production for which average total costs, as depicted by the industry's long-run planning curve, are at a minimum (Bain, p. 53). Knowledge of the range in optimum size in an industry is important information to those concerned about either a segment or the totality of that industry.

Various procedures have been used to determine optimum size. These include economic-engineering studies (French, Sammet, and Bressler), cost studies of existing plants (Pratten and Dean, p. 21), and survivor analysis (Stigler; Saving). Markov chain analysis also has been used to project the future size distribution of plants, and thus indirectly to indicate optimum size (Judge and Swanson).

Engineering studies are comparatively expensive (French, Sammet and Bressler, pp. 70-79) and may not take into account all factors in the environment in which plants operate (Saving, p. 522; Sosnick, pp. 92-93). Heterogeneity of products and of operating conditions, differences in age and in the basis of valuation of physical assets, the operation of many plants at below their optimum volumes, and other problems make it impractical to determine the dimensions of the industry's long-run planning curve by plant-cost surveys (Smith, pp. 216-220; Johnston, pp. 186-194). Markov chain analysis requires knowledge of what happens to each plant from period to period (Judge and Swanson, p. 17). Moreover, as it commonly has been used, Markov analysis has been based upon the rather restrictive assumption that transition probabilities remain constant over time. Although Hallberg has suggested a modification of the Markov technique to provide more reliable results, the need for this modification furthar complicates use of that technique.

The survivor technique, by comparison, is a relatively simple means of estimating optimum size. The technique as described by Stigler rests upon the hypothesis that "the competition of different sizes of firms [or plants] sifts out the more efficient enterprises" (p.55). If the proportion of industry output by firms or plants of a specified size[1] decreases over a period of time, firms or plants of that size are presumed to be comparatively inefficient. On the other hand, a size category that maintains or increases its proportion of industry output is presumed to be of optimum size.

Survival of some firms may be influenced by their ability to exercise market power, to exploit monopsonistic positions in local labor markets, to use inexpensive family labor, or even to circumvent the law. For reasons such as these, survivor analysis may be more suitably applied to determination of optimum size of plants than of firms (Weiss, pp. 246-247; Mead, p. 12).

The purpose of this analysis was to appraise the potential usefulness of the survival technique as an indicator of optimum size of dairy manufacturing plants. Optimum size was determined by the survival technique for the various dairy manufacturing industries at time periods for which information was available. To the fullest extent practicable, the most recent of these results were then compared with findings of the latest economic-engineering studies of relationships between volume and unit costs in those industries.

## Data Used

The application of survivor analysis considered here is based upon information about numbers of dairy manufacturing units, by size groups, reported in four U.S.D.A. publications (Cowden and Trelogan; U.S. Department of Agriculture, 1959, 1965, 1974). The data originate in reports of production by firms which manufacture dairy products to the Statistical Reporting Service (S.R.S.).

S.R.S. reports production and numbers of manufacturing units separately for each type of product. In this analysis each unit manufacturing a product is treated as a "plant." This procedure, to which there is no feasible alternative, disregards the fact that two or more manufactured dairy products are produced in some plants, and that some products such as cottage cheese, ice cream, and butter are produced, in some cases in relatively small volumes, in some plants primarily devoted to processing and packaging fluid milk. For each product the analysis thus involves manufacturing operations which range from specialized single-product plants to parts of multiproduct operations. There is no adequate basis for determining what, if any, relationship existed during years to which the data apply between degree of plant specialization and volume of output of a particular product. In 1961 the bulk of the production of butter and nonfat dry milk was in butter-powder plants, and of American cheese and evaporated milk was in specialized plants (Williams, <u>et al</u>., pp. 138-143). No matter what the situation in the years to which our data apply, the trends in survival noted in this application possibly have been influenced to an unknown extent by differences in the degree of specialization of manufacturing operations of different size.

## Application of the Technique

### American Cheese

The use of survivor analysis to indicate optimum size may be illustrated with data from the American cheese industry.[2] In terms of annual production, minimum optimum size doubled from 750,000 pounds in 1957 to 1.5 million pounds in 1963, then doubled again to 3.0 million pounds in 1972 (Table 1). If the group intervals in the frequency distribution had been narrower, minimum optimum size shown by this technique might have been above the 3.0 million pound level in 1972. The changes in these size distributions of American cheese plants reflect the shift between 1944 and 1972 from an industry characterized largely by family-operated processing operations to an industry in which much of the production was in large, highly mechanized establishments (Miller).

Since the analysis deals with an industry using a comparatively homogeneous raw material that is adaptable to flow processes, a high level of mechanization is possible. Consequently, during the period under analysis there was no indication of an upper limit to optimum size.

A recent economic-engineering study of cheddar cheese production emphasized the cost advantage of large volume and, like our analysis, did not indicate any upper limit to optimum size. Lilwall and Hammond in 1970 pointed out (p. 15) that "...plants processing less than 500,000 pounds of milk a day at the peak are at a considerable cost disadvantage compared with larger plants, regardless of the technology chosen." They showed that with some technologies costs continue to decline with larger volume to levels considerably larger than 500,000-pounds-per-day peak intake, which is equivalent to annual cheese production of about 15 million pounds.

Other Manufactured Dairy Products

Using data and procedures similar to those described for American cheese, optimum size also was estimated for other manufactured dairy products.[3] As with American cheese, increases in minimum optimum plant size occurred in most of these other industries (Table 2). Moreover, as in economic-engineering studies, no clear indication was found in any of these industries of an upper limit to optimum size.

The nonfat dry milk and evaporated milk industries were exceptions to the general rule. Nearly all nonfat dry milk manufacturing operations were established during or since World War II and use relatively modern technology. Accordingly, substitution of capital for labor with consequent increases in optimum size of plant have not occurred in production of nonfat dry milk to anything like the extent they have in the production of cheese and butter. The decline in minimum optimum size of evaporated milk plants between 1963 and 1972 was associated with a decline of approximately 40 percent in industry output. Despite a corresponding decline in number of plants, those producing 55 million or more pounds of product annually barely maintained their share of industry output, while the share of industry output of plants producing 45.0-54.999 million pounds increased sharply.

With these other industries, as with American cheese, detailed cost studies support the findings of this analysis. For example, a recent study of milk assembly and processing costs in the butter-dry milk industry in Minnesota showed that at all four levels of milk-supply density considered, the sum of assembly and processing costs per hundredweight of milk declined sharply up to volumes of 250 million or more pounds of milk annually and then, depending on the density of supplies, either were relatively stable or declined slightly over a wide additional range in volume (Nolte and Koller). The authors concluded"...farmers should be thinking in terms of processing plants and assembly areas with volume of 300 million pounds of milk or more a year if they want to minimize the cost of assembly and processing" (Nolte and Koller, p. 28). This is a volume of milk that will produce roughly 14 million pounds of butter and 25 million pounds of nonfat dry milk annually. Boles, in an analysis of economies of scale in evaporated milk plants (which did not consider milk collection and product distribution costs) showed that costs declined with increasing volume up to approximately 40 million pounds annually, the largest plant synthesized (pp. 694-697). Other studies have shown economies of scale in the manufacture of ice cream and of cottage cheese over all of the limited volume ranges examined (Taylor, Bartlett and French; Miller and Graf). However, because these studies were made in the late 1950's and early 1960's, and dramatic changes have occurred since then, those ranges did not extend upward as far as the levels of minimum optimum size found in this analysis.

## Limitations

Experience of the authors with this technique suggests that several factors may affect the reliability of results. These include:

1. Lags in adjustment. Lilwall and Hammond's findings with respect to American cheese--and the fact that 11 plants with annual production of 20 million pounds or more, and an average of more than 30 million pounds, accounted for more than one-fifth of the industry's production in 1972 (U.S.

Department of Agriculture, 1974, p. 11)--raise question about how to interpret the 3.0 million-pound minimum optimum size for American cheese indicated by survivor analysis for 1972. That minimum signifies only that in the nine-year period ended in 1972 American cheese manufacturing operations with annual output of 3.0 million pounds or more maintained or increased their proportion of total American cheese production. As is noted later, if the period analyzed had been shorter than nine years, or if the groups in that portion of the frequency distribution had been narrower, the indicated minimum might have been somewhat higher.

More important, however, we are considering an industry in a period of drastic change. Among plants built at recent price levels, large operations have a distinct economic advantage, and as new or remodeled facilities are constructed the industry is adjusting to that situation. But, because the process of replacing old with new facilities takes time, there is a lag in adjustment which is reflected in the findings of survivor analysis. Because of this, even if there are no further developments in production techniques, survivor analysis would be expected to show further increases in minimum optimum size in the future as data for later years become available.

Partly for the reason which has just been discussed with respect to American cheese, so also in each other industry in which recent economic-engineering studies have been made (which excludes evaporated milk, ice cream, and cottage cheese [Boles; Taylor, Bartlett, and French; Miller and Graf]), minimum optimum size as determined by survivor analysis was smaller than the volume at which minimum average costs are shown on that industry's long run planning curve in the pertinent engineering sutdy. This lag in adjustment may involve relatively little disadvantage to plants operating in that portion of the industry's long run planning curve in which unit costs decline gradually as volume increases.

Moreover, some of the apparent lag in adjustment may reflect continuing profitable operation of moderately large plants. After a period of sharply increasing prices, lower levels of capitalization could help to account for the continuing competitiveness of moderately large plants built before the rise in prices. Facilities constructed when buildings and equipment involved smaller capital investments have much lower fixed costs than plants of similar capacity constructed at recent price levels. This advantage, which is not taken into account by economic-engineering studies, may contribute to the apparent lag in adjustment. While such plants are in operation, their comparatively small fixed costs, and consequent ability to remain competitive, is a factor to which survivor analysis is sensitive.

2. Characteristics of the frequency distribution. The width of the group intervals influences the precision of findings. Very wide group intervals reduce precision. This effect is intensified if there is a wide open-end group at the top of the distribution, particularly if without indication of the total volume of production of plants in that group. We found it necessary, for American cheese and several other dairy industries, to estimate the breakdown of the top group for 1963 in order to approximate minimum optimum size by 1972 more realistically. S.R.S. improved the reporting of data for 1972 by carrying the frequency distributions to higher levels and also by reporting total production of plants in the top open-end groups.

Analysis is most practical in industries composed of large numbers of plants. Very narrow group intervals in a distribution of a limited number of plants may lead to some confusion as to trends in minimum optimum size. It may be possible to overcome this problem by combining groups. Whatever the characteristics of the frequency distribution, it is highly desirable that, except for the specification of new group intervals at the top of the distribution as plants become larger, group intervals be uniform in all reports.

3. Degree of specialization of the industry. Obviously, the more specialized the plants in the industry, the more likely it is that the apparent trends in optimum size reflect efficiencies in production of relatively homogeneous products rather than developments which directly or indirectly are influenced by production of nonhomogeneous products, divergent trends among plants with different product mixes, or the like. There was, however, no evidence that the inclusion in our analysis of some manufacturing operations that were parts of multiproduct plants significantly distorted findings. Similarly, Mead used survivor analysis, apparently with dependable results, in analyzing the Douglas Fir sawmilling industry, which included both grade recovery and dimension mills (p. 18).

4. Reporting intervals. More enlightened conclusions might be drawn if numbers of plants by size groups could be determined at relatively frequent and uniform time intervals rather than at longer and irregular intervals. In industries in which optimum plant size is increasing, the additional data might provide insights as to when and for how long various intermediate size categories were in the range of optimum size. Unlike the bulk of our findings, it might suggest that under some conditions the upward trend in optimum size is not a steadily progressive phenomenon without reversals.

5. Comparatively normal conditions. Mead pointed out that in the Douglas Fir milling industry survival analysis in the period 1941-51 would have been meaningless because the industry was so profitable that all but the completely inept could survive and prosper (pp. 12-13). There is no indication that such conditions existed in any of the dairy industries during substantial portions of the periods included in this analysis.

## Conclusions

In reasonably competitive industries in which there are relatively large numbers of manufacturing plants producing comparatively homogeneous products--as were most of those included in this project--survivor analysis approximately delineates the range of optimum plant size.[4] In industries in which optimum size is increasing substantially over time, the lower limits to optimum size shown by survivor analysis reflect some lag in adjustment. However, survivor analysis, like recent economic-engineering studies in the American cheese, butter, and nonfat dry milk industries, gives no indication that an upper limit to optimum size has been reached in those industries.

The bounds of optimum size shown by survivor analysis are influenced by all conditions affecting plant operations, external as well as internal. As a consequence, those bounds would not necessarily be expected to coincide exactly with that portion of the industry's long run planning curve over which unit costs are lowest, though a high degree of operating efficiency presumably is essential to survival.

In industries in which a substantial displacement of labor by capital is underway, lags in adjustment appear to be responsible for some downward bias in the indicated minimum optimum size. However, in times like the present, following periods of sharply rising prices, some of the apparent lag in adjustment might reflect the continuing profitable operation of moderately large plants which have comparatively low fixed costs because their facilities were constructed when capital investments were lower. To the extent that this may be true, survivor analysis may more accurately reflect conditions responsible for the existing industry organization in terms of plants than do economic-engineering studies. The latter, however, obviously should guide the planning of new facilities which would be constructed at the higher price level.

In our case, too long time periods and other deficiencies in the data may also have contributed to some downward distortion in the indicated minimum optimum size. Overall, our analysis suggests that in competitive industries survivor analysis, as an indicator of optimum size of plants, may be more seriously limited by lags in adjustment in dynamic industries, and in this case by deficiencies in the data, than by sensitivity to antisocial market conditions.

To a realist, it may also be important that survivor analysis can be based upon relatively unsophisticated information. Consequently, it can be used to estimate optimum size in situations in which it either is impossible, too expensive, or too time consuming to determine optimum size by other techniques.

Footnotes

[1]Size should be measured, as it is in this analysis, by physical volume of output. In industries in which technological change is replacing labor with equipment, use of number of employees as an indicator of size, though perhaps the only alternative in some situations, may lead to confusing if not misleading results.

[2]The data for 1944, which were reported for slightly different class intervals, were adjusted to conform to the groupings used in later years. Likewise, for 1963 plants with production of 2.0 million pounds or more were subdivided into three groups to permit more detailed comparison of changes between 1963 and 1972. The estimated breakdown was into groups of 2.000-2.999, 3.000-4.999, and 5.000 or more million pounds annual production. In making the breakdown, estimated total production in groups with defined intervals was subtracted from reported total American cheese production in 1963. Average production of all plants in groups with defined limits was assumed to be at the midpoint of their respective group intervals. The validity of this assumption was tested with data for 1972, when aggregate output of plants in the top, open-end group was reported. For seven dairy products (American, Swiss, Italian, and creamed cottage cheese, butter, evaporated and condensed milk [case goods], and ice cream) total production in 1972 was overestimated 2.6 percent by use of that procedure. Although this suggests that volume assigned to the top, open-end group in 1963 by the indicated procedure was slightly underestimated, the error is too small to bias conclusions if minor differences in those estimates are not considered significant.

The estimated 1963 volume of plants with production of 2.0 million pounds or more was distributed among the three indicated groups by making successive estimates by trial and error. Three constraints (total number of plants, total volume of production, and estimated shape of that portion of the frequency distribution curve) closely limited the number of acceptable estimates. The estimate which subjectively appeared best to describe the distribution was used, but the distributions described by all estimates which appeared to be acceptable were taken into account in drawing conclusions that depended upon the estimated breakdown.

[3]Data for 1944 were available only for American cheese and creamery butter.

[4]The objection that survivor analysis, as a measure of optimum size of firm, may reflect the consequences of socially unwanted conditions, is most applicable to noncompetitive situations (Weiss, p. 246). That objection, as has been noted by Weiss, p. 247, and Mead, p. 12, carries much less weight when applied to plants than to firms, and in industries as competitive as are most of the dairy manufacturing industries.

Table 1: Proportion of Total Production of American Cheese by Plant Size Groups, United States, 1944, 1957, 1963, and 1972

| Annual cheese production per plant | 1944 | 1957 | 1963 | 1972[c] |
|---|---|---|---|---|
| 1,000 pounds | Percent | | | |
| Less than 250 | 17.6[a] | 2.7 | 1.3 | .4 |
| 250 - 499 | 27.7[a] | 10.5 | 5.3 | 1.2 |
| 500 - 749 | 15.6[a] | 14.3 | 8.8 | 1.9 |
| 750 - 999 | 9.0[a] | 11.6 | 9.4 | 3.3 |
| 1,000 - 1,499 | 14.6 | 16.1 | 15.2 | 6.2 |
| 1,500 - 1,999 | 7.4 | 9.7 | 13.4 | 6.4 |
| 2,000 - 2,999 | } | } | 13.6[b] | 11.5 |
| 3,000 - 4,999 | 8.1 | 35.1 | 12.5[b] | 13.9 |
| 5,000 or more | } | } | 20.5[b] | 55.2 |
| All plants | 100.0 | 100.0 | 100.0 | 100.0 |

[a] Estimated from frequency distribution in even 100,000-pound intervals.

[b] Estimated by procedure described in footnote 1 of text.

[c] Percentages based on estimates of volume adjusted proportionately to bring total to 100.

Table 2: Minimum Optimum Sizes of Dairy Plants as Determined by Survivor Analysis, United States, 1957, 1963, 1972

| Industry | Minimum optimum plant size 1957 | 1963 | 1972 |
|---|---|---|---|
| | Million pounds or gallons per year[a] | | |
| American cheese | 0.75 | 1.5 | 3.0 |
| Swiss cheese | ---- | 0.5 | 3.0[b] |
| Italian cheese | ---- | 1.0 | 3.0 |
| Creamed cottage cheese | ---- | 2.0 | 4.0 |
| Creamery butter | 1.0 | 2.0 | 5.0 |
| Nonfat dry milk[c] | ---- | 10.0 | 10.0[b] |
| Evaporated, condensed whole milk (case goods) | ---- | 55.0[d] | 45.0[d] |
| Ice cream | ---- | 1.0 | 2.0 |

a/ All products except ice cream in million pounds.

b/ Between 1963 and 1972 the proportion of industry output in one or two groups of smaller plants increased very slightly but not significantly; changes for other groups indicated that optimum plant size was as shown.

c/ Spray and roller, for human food.

d/ Two or more size categories below estimated minimum optimum size increased their shares of industry output slightly during the time intervals ending in both years, but the aggregate proportions of total output of these and other smaller plants declined considerably.

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