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ECONOMIES of SIZE in FARMING

Theory, Analytical Procedures, and a Review of Selected Studies

ECONOMIC RESEARCH SERVICE
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CONTENTS

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HIGHLIGHTS

Selected studies of the economies of size in crop production, specialized beef feedlots, and dairy farms were reviewed. The theoretical basis for analyzing economies of size was discussed, and several alternative analytical procedures were examined.

The analytical procedure that provides the most reliable results in studying economies of size in farming is the synthetic-firm or economic-engineering approach. When the farm organization includes relatively few choices, this type of analysis may be done through manual budgeting. But when more complex farming operations are analyzed, linear programming is helpful. Choice of a residual claimant (the factors that absorb profit) strongly influences the height and shape of the average cost curve. For example, as more factors are included in the residual claimant, total cost is reduced, thus lowering average cost.

A modified concept of the farm firm--viewing the farm as a goods-and-services firm--provides a realistic basis for explaining the persistence of a relatively large number of small farms and part-time farms. This concept also helps to account for the rising importance of custom-hired farm operations.

A number of studies of crop-farming situations in various States were reviewed. In most of these situations, all of the economies of size could be achieved by modern and fully mechanized 1-man or 2-man farms.

Three studies showed 1-man farms were capable of achieving average costs as low as any larger size. In the production of cling peaches in California, average cost was found to be a minimum as orchard size reached 90 to 110 acres--basically a 1-man operation--when mechanized practices were used. The utmost efficiency was attained by a highly mechanized 440-acre irrigated cotton farm in Texas and a 1,600-acre wheat-summer fallow farm in Oregon.

Studies of Iowa crop farms and crop-livestock farms in the 1-man and 2-man size range were reviewed. When full ownership of all machinery was assumed, 2-man farms were found to be more efficient than 1-man farms. But when the hiring of timely and reliable custom service was considered for certain field operations, the average cost per unit of output for the smaller farms was reduced considerably. Under this assumption, the 1-man farms were nearly as efficient as 2-man farms.

In a study of vegetable farms in the Imperial Valley of California, farms of less than 640 acres were found to be nearly as efficient as larger sizes. Among field-crop farms in this area, economies of size were found to occur up to about 1,500 to 2,000 acres. Custom hiring was found to be very advantageous to smaller farms in this area.

Three other California studies reviewed gave similar results. Cash-crop farms in Yolo County achieved lowest average unit cost at a farm size of 600 to 800 acres, producing sugarbeets, tomatoes, milo, barley, alfalfa, and safflower. In Kern County, farms producing cotton, alfalfa, milo, and barley achieved their lowest average cost at about 640 acres. Cotton farms in the light-soils area of Fresno County were found to be most efficient at about 1,400 acres, while farms in the heavy-soils area of the county achieved their greatest efficiency at 700 acres.

Even though most of the studies show that all the economies of size may be attained by moderate sized farms, they also show that total profit may frequently be increased by extending beyond the most efficient size. However, uncertainty and management problems often become troublesome as farms become very large. This may discourage farm enlargement in many cases.

In specialized beef feeding businesses, the studies reviewed found that nearly all the economies of size are attainable in an intermediate size range of 1,500- to 5,000-head capacity. Beyond this size range, the average cost curve continues to decline slightly, but the savings per head are relatively unimportant--in the range of $1 to $2 per head fed. Slight reductions in the price of feeder cattle or feed have a much greater influence on the overall cost and profit of the feeding operation. Also, the rather small technical economies of size attainable beyond the intermediate size range are readily erased if the facilities are not utilized at full capacity throughout the year.

Management problems do not seem to become prohibitively difficult as feedlot size increases. A relatively small geographic area is involved, and the labor functions are quite routine and repetitive throughout the year. Thus, supervision of several hired men is not burdensome. Coordination also seems to be fairly easy for a wide range of feedlot sizes, because the biological and mechanical processes involve relatively little uncertainty. The empirical findings examined in this report suggest that beef feedlots will continue to exist in a wide variety of sizes, with a continued decline in the number and relative importance of small feedlot operations.

Studies of dairy farms in various parts of the country showed that 1-man and 2-man dairies can achieve highly efficient operation if they have control of sufficient capital and utilize the modern milking and housing technologies. Very little evidence is currently available regarding the efficiency of larger dairies--over 100 head. However, the results of one study suggest that management problems become troublesome at about 150 head. For instance, it is difficult to feed each cow according to her production as herd size and the number of hired men increase. Also, the operator of a large dairy does not have time to "shop around" and obtain the lowest possible feed prices.

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INTRODUCTION

Since World War II, the number of farms in the United States has decreased substantially. Those remaining are getting larger, more specialized, and more highly capitalized. This is largely the result of a shift from small, self-sufficient farms to highly commercial farms. The direction and speed of these trends raise questions of public policy: Where are we headed? Are these trends necessary for efficient production? Are the resulting gains in efficiency offset by less tangible, but important, losses to society? Should the trends be encouraged or discouraged--or should we follow the doctrine of laissez faire?

This report is concerned with one aspect of these questions--the relationship between farm size and efficiency of production. Farmers, farm leaders, Government officials, businesses serving agriculture, and others continue to raise questions related to the economies of farm size. How large must a farm be to achieve the most efficient operation? Are larger farms always more efficient than small and intermediate-size farms? Are size-efficiency relationships of major or minor economic consequence? Many studies of the economies of size have been made, dealing with a wide variety of commodities and locations. The present report is an attempt to provide a conceptual framework within which to assimilate some of these independent studies into a unified body of information.

Considerable misunderstanding has centered around divergent definitions of the terms "size" and "scale." The term scale is used many places in the literature when proportions of resources are held constant, as in Euler's theorem (105). 1/ However, there appears to be almost universal agreement among economists that in real life firms do not expand all resources and products in exactly equal proportions as the level of the firm's activity is increased. An increase in just the same proportions would probably be due to accident rather than to overt design of the entrepreneur. Thus, virtually every empirical study examining the relationship between average cost and level of production allows for changes in the proportions of factors and products, whether the analysis is done under the name "economies of scale" or "economies of size." The term "economies of size," as used in this report, means reductions in total cost per unit of production resulting from changes in the quantity of resources employed by the firm or in the firm's output.

1/ Underscored numbers in parentheses refer to Selected References, p. 72.

The cost curves resulting from the many studies on the subject vary from one study to another. Most studies show that the ultimate in efficiency is attained by 1-man or 2-man farms; others show larger farms to be most efficient. Some of these differences are "real" variations in the size-efficiency relationships of the farms studied. Real variations may occur because of differences in (a) factors associated with the type of farming analyzed, (b) factors associated with the location of the farming area, such as climate, soil type, prices, wage rates, and yields, and (c) factors influenced by the date of the analysis, such as technologies considered, secular price changes, and Government price-support and supply-control programs.

Unfortunately, not all of the variation among study results is "real." Much of the variation is methodological--caused by differences in assumptions and procedures It is often difficult for the reader to discern how much of the difference between the shapes of the cost curves derived in separate studies is due to real differences in size-efficiency relationships and how much is methodological. A primary purpose of this report is to clarify the concepts underlying the procedures and assumptions used in economies-of-size studies. This in turn will aid in interpretation of published studies, and guide the design of future studies.

The reader who is primarily interested in learning the general size-efficiency relationships for various types of farming may prefer to skip the theory and method sections of this report, and proceed directly to the discussion of the individual studies on page 34. However, researchers and others interested in the precise interpretations and the procedures underlying the findings of these studies will find a careful examination of the theory and methods sections to be useful.

THEORETICAL BASIS FOR ECONOMIES OF SIZE--A REFORMULATION

An economist relies heavily on economic theory and theoretical models in his day-to-day dealings with real-world problems. The more realistic these theories are, the better equipped the economist is to work effectively with actual problems. The heart of economic research is economic theory. But the coronary artery that keeps this heart alive and useful is the feedback of improvements in the theory that are generalized from research experience in the real world. Thus, theories are made more realistic, and consequently more useful, as they are modified and broadened to take account of observations and phenomena not previously explained by the existing body of economic theory (74, p. 7).

Several modifications of the traditional economic theories are suggested here. Since theoretical treatments of production and cost curves abound in economic literature, only a brief statement of the conventional theory is given.2/ Two sets of interconnected concepts are reformulated to facilitate proper interpretation of economies-of-size studies. These are the concepts of (a) longrun versus shortrun planning horizons as related to fixed versus variable resources and costs, and (b) resource divisibility. Other modifications of economic theory are suggested to better take account of some apparent inconsistencies between existing theory and the observed behavior of farms.

2/ An excellent treatment of the theory of production and cost is given by Walters (136) His article, particularly the bibliography, is highly recommended to the student of economies of size.

Length of Run and Fixity of Resources and Costs

Economies-of-size analysis is usually couched in terms of longrun and shortrun situations.3/ Shortrun economies are viewed as resulting from fuller utilization of a fixed plant, longrun economies as resulting from efficiencies obtained by changing plant size, presumably involving a longer time period. This concept is represented graphically in figure 1. The shortrun average cost curves (SAC) assume one or more resources to be fixed--available only in specified quantities--in the short run. The typical "u" shape of these shortrun average cost curves is explained as follows: Average costs per unit of output decline with an initial increase of output because fixed costs are spread over more units; eventually, however, average costs level off and then rise as other resources must be added in increasing proportions to the fixed resources to reach greater levels of output. A separate shortrun average cost curve applies for each level of the fixed resources--that is, for each size of plant.

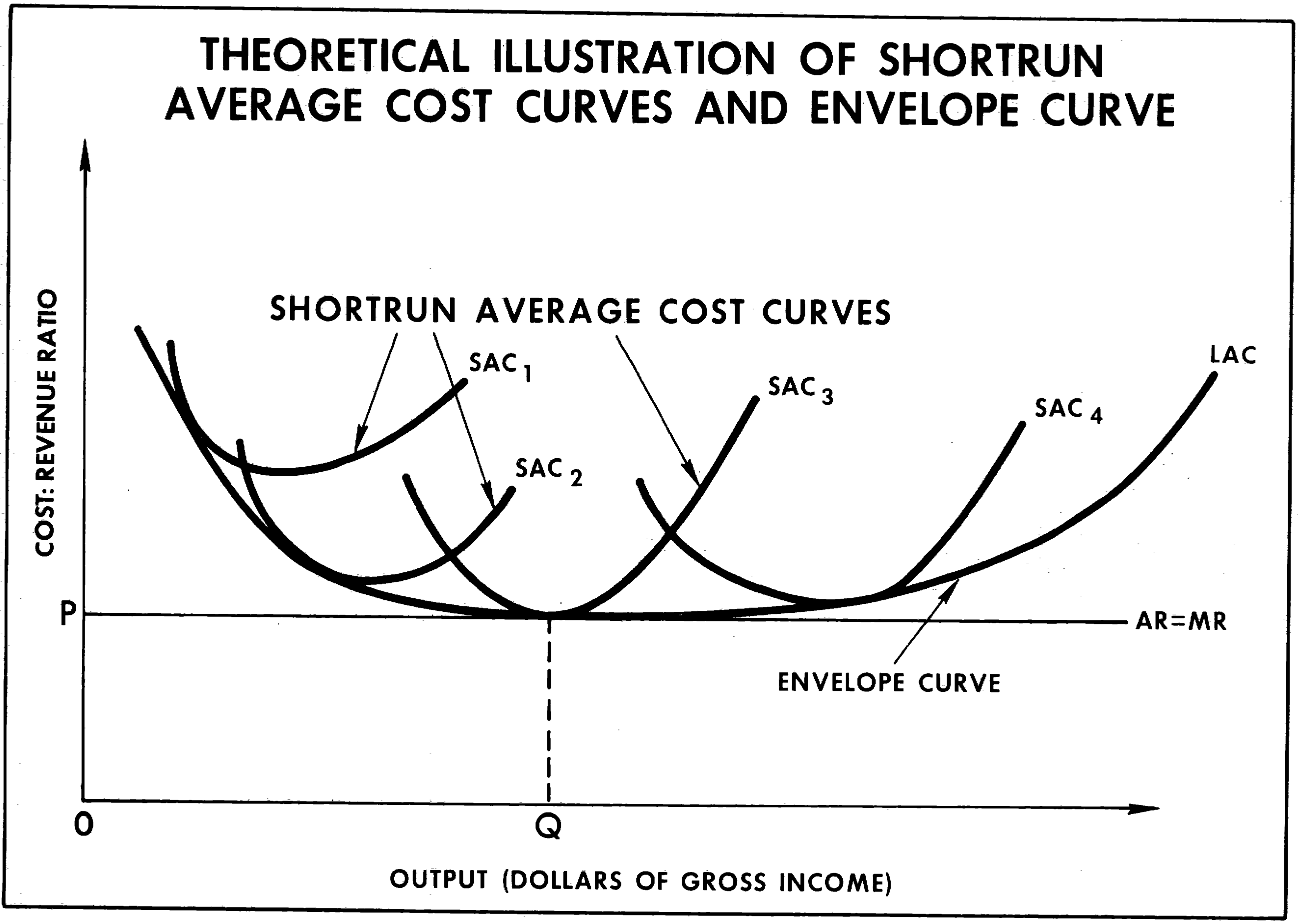

Figure 1

3/ One of the best statements of the theory underlying cost curves is given by Jacob Viner (135).

The selection of any resource as fixed in the short run is usually an arbitrary decision, based on observed practices of operators, the length of planning horizon being examined, and the longevity of the resources involved. This decision has no effect on the eventual shape of the longrun average cost curve. The longrun average cost curve (LAC) assumes all resources are variable, including those designated as fixed in the short run. A curve that is drawn tangent to shortrun curves approximates the longrun economies-of-size curve for that segment of the industry represented by the shortrun curves. This curve indicates the average total cost of production that would be experienced by firms of different sizes under assumed price relationships and technologies.

The fixed versus variable classification of costs and the longrun versus shortrun classification of planning periods have no effect on the basic size-efficiency relationships represented by the envelope curve. However, several other important economic principles related to equilibrium size of firm and survival of the firm owe much to this dichotomy.

Of first consideration is the principle that in the short run the firm will continue producing as long as revenue is great enough to cover variable costs, or conversely, as long as average variable cost is less than or equal to average revenue (price). Variable costs are the costs associated with the resources that are not fixed in the short run. Fixed costs are associated with the existing plant, or the resources that are considered fixed in the short run.

Another familiar principle is that in the long run, the firm can remain in production in its present form only if revenue is great enough to cover total cost (fixed plus variable)--in other words, if average total cost is less than or equal to average revenue.

A third important principle is that under conditions of atomistic competition, prices will gravitate toward a level such that all profits tend to be erased. Thus, the return to each resource will tend toward the level that provides exactly enough return to keep it from being drawn into alternative employment, but not enough to attract additional resources that would expand production. In equilibrium all firms would produce a level of output corresponding to the low point on their average total cost curve (level Q in figure 1). The theoretical average cost curve for a typical firm, as shown in figure 1, assumes that all firms produce under identical conditions. The line at p, lying tangent to the longrun average cost curve at point Q, is the average and marginal revenue schedule for a firm in perfect competition. Profit is zero at this point; firms producing larger or smaller quantities would suffer a net loss.

These concepts seem very clear and simple, until we try to apply them to an actual farming situation. When is the end of the longrun reached? Which resources are included in the fixed plant, and conversely, which resources are variable? These questions are complicated by the complex nature of farm resources. Durable resources have various life spans, ranging from 2 or 3 to 30 or 40 years or even longer. The number of years that an individual farmer keeps a tractor or implement depends on a series of considerations. Land is sometimes considered a fixed resource, but not always. The number of regular laborers is often viewed as one of the basic factors defining the size of a farm, but in some studies even this resource is considered variable.

A similar lack of precision surrounds the longrun-shortrun dichotomy. The long run implies a length of time sufficient to allow changes in the levels of all resources employed by the firm. The short run is viewed as a "short" period of time, such as one production season--a period so short that the firm does not have time to change the amounts of the fixed resources.

This time-oriented dichotomy is a somewhat inadequate concept for explaining the behavior of farm firms. Because of the various lengths of time that the different classes of resources are held fixed in an actual firm, no single short run can be exactly specified. Rather, the situation involves a large number of successively longer lengths of run, as additional resources are allowed to vary in quantity, until eventually all resources are variable and the truly longrun planning horizon is achieved.

Two facts further complicate this issue. First, the resources do not necessarily become variable in any predetermined order. For example, land may be held constant while machinery is varied, or vice versa. Second, both the length of run and the amount of time a certain subset of resources is held fixed are fictional time periods, not identified by any amount of calendar time. In real life, new firms are created or disappear every day. The levels of all the various resources are continuously being changed. At any point in time an entrepreneur could inject himself into the long run, simply by considering the effects of changing the levels of all the resources employed by his firm. As long as he considers one or more of his resources to be fixed in quantity, he is operating or planning in one of the many shortrun situations. Thus, length of run and fixity of resources are relative terms, rather than distinct entities. Furthermore, they depend entirely on the entrepreneur's frame of mind.

The moment a resource is committed to production it becomes fixed as far as the day-to-day management decisions are concerned. It becomes essentially a free resource that will be substituted as far as possible for resources that have not yet been committed to production. For example, the firm will tend to delegate as much work as possible to regular hired men or unpaid family workers, rather than hire additional laborers. As long as the farmer considers these regular laborers as a permanent part of his business, their wages become in effect part of the overhead.

In resource substitution language, the price of committed resources is zero. Thus, the shortrun economic optimum calls for increasing the employment of these resources as long as this will increase output; that is, to the point of zero marginal value product of the committed resources, and zero marginal rate of substitution for noncommitted resources that still have an effective nonzero price. But as soon as the entrepreneur considers varying the quantity of one of these resources, its price becomes relevant again. If an increase in this resource is considered, then the current purchase price becomes relevant. If either a decrease in the level of this resource or a shift in its use is anticipated, then the current salvage value or opportunity cost becomes relevant.

Now let us relate these concepts to the interpretation of economies-of-size studies. When average variable costs are presented, the reader should inquire as to which resources are considered as variable and which ones as fixed. Let us denote the variable resources as subset V, and the fixed resources as subset F. With these categories in mind, the reader can then proceed to interpret the empirical results of a cost analysis. The firm will tend to continue operating as long as it receives enough revenue to at least cover the cost of all the variable resources. As the planning horizon is lengthened, the entrepreneur considers variation of additional resources. These resources are conceptually shifted from the fixed to the variable subset, and revenue must be correspondingly larger if the firm is to remain in production for this length of planning horizon. In the longest possible run, all the firm's resources are in the variable subset (V), and the fixed subset (F) becomes empty.4/ Therefore, in the long run, revenue must be equal to or greater than total cost--including the direct cash cost of operating expense items, and the opportunity cost or reservation price of all other resources, including entrepreneurial capacity. In other words, average total cost must be less than or equal to average revenue if the firm is to remain in production indefinitely in its present form.

Resource Divisibility and Economies of Size

In addition to, and independently of, being considered as either fixed or variable, resources may be classified as either divisible or discrete. As the name implies, discrete resources are available to the firm only in counted quantities (whole numbers) of specific size units. The discrete unit may be a single item, such as a boiler, or an increment of a certain size, such as a quarter section of land. Divisible resources are available in measured quantities, in contrast to counted quantities. These include such things as electricity, fuel, and custom-hired services.

The distinction between discrete and divisible resources is not always clear, nor is it the same in all areas. For example, local customs and practices in one area may dictate that land be sold in 40-acre or 160-acre increments as a discrete resource; in another area it may be sold in irregular-sized plots as a divisible resource.

Chamberlin points out that nondivisible resources may sometimes become available to a firm in divisible quantities (22). This can occur when the firm obtains the undivided use of the discrete resource unit for a fraction of the production period. For example, a hay baler may be owned and operated jointly by two or more farmers. Likewise, an accountant may be hired on a part-time basis. Custom hiring and leasing are also possible in some cases, as a means of making an otherwise discrete resource available on a divisible basis.

Divisible resources are usually fully utilized. Some may be obtained in the exact amount needed, as in the case of electricity, water, and custom-hired services. In the case of other divisible resources--gasoline or fertilizer, for instance--leftover quantities may be stored for future use, or returned to the dealer for credit. On the other hand, discrete resources are often underutilized, even by well-organized firms. For example, a tractor of a certain size may be underutilized with 640 acres but may not be able to handle 800 acres, while local practices may dictate that land is available only in increments of 160 acres. Many such instances exist in which the discrete resources do not "come out even," because they have different capacities.

4/ Lengthening the planning horizon does not necessarily imply an extension of time, as indicated earlier. The long run could occur in a single day.

In general, the smaller the incremental unit of a discrete resource relative to the total quantity used by the firm, the closer the firm can come to achieving full utilization of that resource and any other discrete resources with which it is jointly used. In the above example, suppose now that land is available in 40-acre increments instead of 160, and that the tractor would be fully utilized with 695 acres. The firm could move from 640 to 680 acres, and thus achieve a fuller utilization of the tractor.

If all resources or resource services were available in divisible quantities, then any underutilized resource could be replaced by a slightly smaller and (presumably) slightly cheaper resource, and full utilization of all resources could be achieved.5/

This whole matter of full utilization of a resource should now be placed in the broader context of the firm's actual behavior. Full utilization is a partial means of reducing average cost of production, as the cost of the resource is spread over more units of output. However, full utilization of one discrete resource may not be compatible with full utilization of certain others. Furthermore, reducing average cost of production is only a partial means of increasing profit, and, after all, profit is the motive force of the firm. Thus, a firm would not necessarily move from 640 to 680 acres to achieve full utilization of a resource. Considerations other than full utilization might be more important. For example, total profit might be higher with 640 acres than with 680. Or, perhaps some other resource such as the operator's labor or capital might be limited. Also, the operator might decide to allow a little excess machine capacity as a safeguard against losses due to untimeliness of operations resulting from unfavorable weather.

Problems of Uncertainty and Coordination

Most studies of the economies of farm size have shown that as farm size increases, average cost either (a) decreases, or (b) remains about the same, or (c) on very large farms, increases slightly but still is below average revenue, even for the largest farms observed. This implies that profit increases steadily as farm size increases, and that the largest farms are the most profitable. It would be expected, then, that farms would tend steadily toward the largest sizes, and that the size distribution of farms would be shifting accordingly. This does not seem to be so, however. In many areas and for many types of farming, the most rapid increase in number of farms is in the intermediate size classes, consisting chiefly of farms that can be operated by one or at most only a few full-time men, using modern technology and adequate capital. The number of very large farms seems to be increasing only gradually and, in some cases, to be decreasing.

5/ This seemingly utopian situation--perfectly divisible resources--is approximated when all resource services may be hired on a custom or contract basis, as in the Imperial Valley of California (20).

This is consistent with broad changes in U.S. agriculture generally. After detailed analysis of a special tabulation of census data, Nikolitch has identified three postwar trends:

> First, the very small units account for most of the net decrease in number of farms. Second, farm production, land and other resources are concentrated not in a smaller number of large farming organizations, but in a rapidly expanding number of adequate farms. Finally, the number of farms and farm production are increasing more rapidly among adequate family farms than among the larger-than-family farms (94). 6/

How can these trends be reconciled with the empirical findings indicating huge profit possibilities for very large firms? The approach used here is to refine the concepts underlying the traditional theory to allow for the treatment of uncertainty and difficulty of coordination as factors limiting indefinite expansion of farm size.

Definitions of Supervision, Coordination, and Entrepreneurship

Management is traditionally defined to include two components: Supervision and coordination (70). Entrepreneurship (uncertainty-bearing or risk-taking) is often considered as different from management because it is the unique function of the entrepreneur.

Entrepreneurship is an essential element in any firm. It is a specialized and personal attribute that cannot be bought on the market. Because men are unequal in entrepreneurial ability, the production function will vary from one person to another (136, p. 4). Entrepreneurship involves making major decisions such as hiring supervisors and plant managers, and making broad judgments regarding total resource use, choice of enterprises, technology employed, and disposition of products (104). Furthermore, it involves bearing the responsibility for the outcome of these decisions in terms of the financial success or failure of the firm. The farm operator usually serves three functions--labor, management (including coordination), and entrepreneurship. Additional supervision and coordination may be provided by hired managers, foremen, or boards of directors (22), but only the operator, the owner of the enterprise, can perform the entrepreneurial function.

Supervision is overseeing day-to-day operations of the firm, seeing that each task is performed correctly. Coordination involves determining the kinds of contracts to be entered into, seeing to it that the necessary resources are available for timely completion of individual tasks, and carrying out adjustments in response to

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6/ "Adequate family farm" is defined as a farm business with sufficient "resources and productivity to yield enough farm income to meet expenses for (a) family living; (b) farm expenses, including depreciation, maintenance of the livestock herd, equipment, land and buildings, and interest on borrowed capital; (c) enough capital growth for new farm investments required to keep in step with technological advance and rising levels of living."

uncertainty and changing conditions. The essential feature of coordination is that every decision must be made in the context of all the other decisions already made or likely to be made. This gives rise to the unitary character of coordination--all interrelated information must pass through a single brain. Boards of directors may be the coordinators, but each member is obliged to keep all the data concerning interdependent aspects of the firm's operation in his mind. Machines and computers can make coordination more efficient in some cases, but the loss of reality due to the coding and decoding of information sometimes leads to errors in judgment. Devices such as 2-way radios and closed-circuit television also increase the individual's effectiveness and capacity for coordination. But with a given state of technology, the quantity of resources other than coordination that can be advantageously added will be limited by management's degree of ability to coordinate the firm's activities (22).

Coordination and Supervision Problems Unique to Farm Firms

The firm's activities can be thought of as integrating and aggregating many different stages of production.7/ Conceptually, a stage consists of all the productive services, both durable and nondurable, that cooperate in a single major operation or group of closely related minor operations. The delineation of a stage will vary from one situation to another, depending on the importance of the operations involved and the way they fit into the time sequence of the production process.

One crucial difference between factory production and farm production is the relationship between stages. In a typical factory operation, the object being produced flows through a series of stages, all of which can proceed simultaneously at spatially separate points. In farm production, the stages typically are separated by waiting periods, but occur in the same areas. For example, many stages occur on an acre of corn--plowing, planting, cultivating, harvesting--but the stages are separated by waiting periods because the biological processes involved take time to complete.8/

This difference has important effects on the labor and management requirements of the two types of firms. Coordination of factory production poses unique problems not faced by most farms, because a large number of different stages are continuously being performed by many different persons at different places in the plant. Interpersonal communication and supervision problems tend to be more serious as the number of employees increases. In farming, the stages are spread out over a long period of time, so that relatively few operations must be coordinated, and only a few people employed, at any given time.

7/ An excellent formulation of this concept is given by French, Sammet, and Bressler (46).

8/ The author is indebted to John M. Brewster for pointing out this important distinction. For a more thorough discussion of this concept, see Brewster's paper, The Machine Process in Agriculture and Industry (15).

On the other hand, the farm manager's task is complicated by (1) the relatively large dispersion of workers in most types of farming, and (2) the necessity for regular farm laborers to shift repeatedly from one kind of work to another throughout the production season. These features lead to a considerably greater supervisory input per man in farming than in factory operations, where most workers perform essentially the same tasks throughout the production cycle.

Uncertainty and Coordination Problems as Factors Limiting Farm Size

Farm enlargement is frequently limited by uncertainty and the difficulty of coordinating larger farms. As the farming operation becomes larger and more complex, the number of unpredictable situations requiring unique decisions becomes burdensome, because the coordinator must relate each decision to all the other decisions that have been made or are going to be made. At this point, the amount of other resources that can be profitably added is limited by the ability of management to coordinate a larger operation. In cases where coordination is a limiting resource, the marginal value product of additional resources becomes less than their marginal cost. Consequently, the presence of a profit margin does not necessarily imply that additional resources will be drawn into production. Similarly, in cases where the high degree of uncertainty leads farm operators to place a high reservation price on their coordination and entrepreneurial abilities, the profit potential is not sufficient to attract new firms into production, or to induce existing firms to greatly expand their operations.

According to Knight, coordination is essentially a dynamic function--reacting to changes in the pecuniary and technical situation that occur under conditions of uncertainty (74). Thus, the need for coordination is a feature of uncertainty and disequilibrium, rather than of perfectly competitive static equilibrium. In Marshall's stationary state, no coordination would be needed. Management would be reduced to supervision. However, Kaldor points out that in the actual world the size of an individual firm may remain more or less limited because the inherent profit-maximizing tendency of the firm to expand will be continuously defeated by spontaneous changes in the pecuniary and technical situation (70).

Hicks is in general agreement with Kaldor on this point. He contends that we can perceive forces that might lead to a determinate size of firm even if changes in the quantity of the coordination factor were allowed. Under conditions of uncertainty, one of the obstacles to attainment of very large firm size is the increasing difficulty of management and control as the firm gets larger (62, p. 200).

This phenomenon could be viewed as a decreasing marginal productivity of the coordination factor, requiring the very large firm to make a greater than proportional increase in coordination as the levels of the other resources are increased to achieve higher levels of output. This would tend to force the average total cost curve to turn upward at some very large size of firm.

Hicks cites risk as another item in the list of phenomena that might inhibit the indefinite expansion of a firm. The effect of increased risk may be represented as a downward shift in the discounted average revenue curve for very large levels of output. The marginal revenue function would fall even more rapidly, and would eventually intersect the marginal cost curve. Beyond this point, discounted profits would decline with greater output. This point of intersection could occur even within the range of constant average cost, where the marginal and average cost curves coincide. Thus, Hicks concludes that in cases where risk increases with level of output, size of firm may be limited (62).

In this discussion, Hicks considered only the revenue-decreasing aspects of risk, ignoring the fact that sometimes risk also increases cost. For example, a sudden outbreak of a contagious disease may force a beef feedlot operator to incur an additional operating cost for medicine and veterinary service. Timely detection and treatment might be more difficult for large operations. Other examples are the use of frost-inhibiting devices and the hiring of custom harvesting to "beat the weather." In some instances, the cost-increasing effect of risk may be more serious as size of farm increases. In such cases, the downward-sloping discounted average revenue curve would be intersected (at an even smaller size of firm than Hicks indicated) by an upward-sloping "adjusted" marginal cost curve. In other instances, as Whitin and Peston have pointed out, the larger volume of resources available to bigger firms provides an advantage in meeting contingencies (138). For example, consider the volume of spare parts that a repair firm must hold in inventory to achieve a given probability of never running out of any specific item. As the size of the firm increases, the required volume of spare parts increases by a smaller proportion than the increase in the amount of repair work done. Another case in which larger firms might have an advantage in meeting risk is in providing backup machines to be used in case of breakdown or mechanical failure of one of the regular machines. It is reasonable to believe that the proportion of backup machines needed to provide a given probability of always being able to avoid breakdown delays would decrease as the size of firm and total number of machines increased. Cooper points out that this would be particularly important in operations such as harvesting truck crops, where untimeliness would cause considerable loss (27).

Despite these possible exceptions, most elements of uncertainty make coordination increasingly difficult as size of farm increases and lead eventually to a maximum feasible size of farm, for the reasons summarized below.

Management becomes more difficult as the complexity and uncertainty of the operations increase. Complexity is a function of the number of interdependent data the operator must simultaneously perceive, understand, and relate to the overall operation. Three aspects of farming greatly increase the difficulty of management: Lack of uniformity among resources, spatial dispersion of the operations, and unpredictable behavior of resources, environment, and the market.

(1) Uniformity of resources has an important bearing on both the coordination and supervision aspects of management. For example, a large farm with several different soil types is more difficult to manage than a similar size and kind of farm with highly uniform soil. Where the soils are extremely variable, some parts of the farm require more frequent irrigation or more thorough tillage than other parts. The operator often finds it easier to do the work himself than to be continuously advising a hired man who is less familiar with the soil characteristics, and, therefore, the way the different parts of a field must be irrigated or tilled. A uniform dairy herd is easier to manage and is more amenable to operation by hired men than a herd of diverse composition, where each cow must be handled in a special way known only to an experienced dairyman. A beef feedlot is easier to manage if the cattle are uniform in age, sex, appearance, and rate of gain because it requires fewer feeding

pens, fewer special rations, and less time and effort in separating the cattle for marketing. Difficulties associated with lack of uniformity of resources usually require special attention from the manager who must coordinate the operation. Some operators prefer to keep the size of their farms down to the acreage they can handle with little or no hired help. These farmers can expand their operations only by acquiring larger and higher capacity machines that allow them to cover more acreage, or by reducing the variability of their resources--for example, leveling and draining land or purchasing more uniform land requiring less coordination.

(2) Spatial dispersion, or distance, is another factor affecting management. When operations are going on simultaneously in widely separated parts of the farm, supervision is hampered by the need for frequent and prolonged travel back and forth to keep abreast of changing conditions. Coordination is also hampered by a lack of knowledge of what is happening in different places. Thus, communication problems and errors in reporting become important as size of operation increases, although they are less serious in intensive types of farming that occupy a relatively small area, such as poultry and beef feedlots.

(3) Lack of predictability also causes management difficulty. For example, in areas where market conditions are erratic or the weather is highly unpredictable, management problems are compounded. Unreliable laborers also add to management problems, increasing the amount of time management must devote to checking out and following up the tasks assigned to them. The same holds true for the other resource services the farmer hires. If experienced and competent family or hired foremen are available, or if a highly reputable and experienced service firm is hired to perform certain farm operations (spraying, fertilizing, harvesting, for example), then the farmer's coordination task becomes less complicated as part of the supervision is delegated to the family member or hired agent. Emergence of specialized service firms eases the farm-management burden, and opens up possibilities of farm expansion that would otherwise be impossible because of management problems during peak workloads.

Conditions That Foster Farm Enlargement

Despite the handicaps of and impediments to farm enlargement discussed above, in some areas and types of farming there has been a marked tendency toward larger farms. Considerable research must be done before we will understand all the preconditions and situations that tend to either favor or inhibit a widespread enlargement of farms. The following tentative generalizations may suggest additional areas of inquiry into the causal relationships underlying some of the important structural changes related to farm size.

To the extent that coordination is a limiting factor in the expansion of farm size, farms will tend to expand as management technologies become available and allow the operator to coordinate larger units. Improved roads, fast pickups, helicopters, and airplanes facilitate faster movement of management personnel. By reducing the need for movement of management personnel, telephones, two-way radios, and closed-circuit television allow management to keep up with developments in the firm, to make decisions, and to see that they are carried out properly. Physical arrangements can also reduce coordination problems. For example, a specialized beef feedlot occupies relatively little area. For this reason, it is easier for the manager to coordinate the activities of several men and handle thousands of cattle in a feedlot than on a beef cattle ranch that is spread out over several thousand acres. Availability of a large supply of experienced and reliable farm labor, and of timely and reliable custom services to replace work otherwise done by farm labor, can reduce the need for supervision and simplify coordination.

More rapid farm enlargement should be expected in areas and types of farming where resources and production conditions are homogeneous, and put less of a strain on coordination. For example, in areas where soils are homogeneous and production conditions are relatively predictable, coordination of larger farms is less complex than in areas where extreme variations in soil and weather necessitate frequent managerial reaction to unanticipated conditions. Likewise, when irrigation becomes available in a semiarid region, yield uncertainty is reduced because farmers no longer need to rely on unpredictable rainfall.

It is widely recognized that Government price-support programs have facilitated enlargement of farms producing price-supported commodities and closely related products. When price uncertainty is eliminated, farmers feel more confident of their debt-repayment ability. They are more likely to apply for, and creditors are more likely to give, the credit necessary to acquire the machines, land, and other resources necessary for farm expansion. Similarly, yield uncertainty is reduced as irrigation becomes available, as new disease-resistant varieties are developed, or as rapid mechanical harvesters are developed to replace an unsure seasonal labor force. As these devices or technologies become available and widespread, farmers tend to "charge" a lower reservation price for the entrepreneurial service of bearing the uncertainty inherent in operating a larger farm. This lower reservation price will inevitably lead a greater number of entrepreneurs into larger farm sizes, and shift the supply curve to the right. Hence, the balance between profit potential on one hand and the opportunity cost and reservation price of additional resources on the other hand is tipped in favor of farm enlargement.

The Residual Claimant and Profit

Total cost and profit are complementary terms, in that they always add up to gross income or revenue. However, neither term has any precise meaning without a complete specification of the residual claimant--the set of resources that absorbs the profit. Total cost is the sum of the direct cash costs plus the opportunity cost or reservation price (whichever is higher) of any resources excluded from the residual claimant.9/ Thus, as more resources are excluded from the residual claimant, total cost increases and the residual profit becomes correspondingly smaller. However, in the long run, profit must be at least large enough to compensate the factors

9/ Conceptually, opportunity cost is the highest return a resource can earn in any alternative employment currently available. In accounting, opportunity cost is usually approximated by the market rate of return, such as going wage rates for operator and family labor, foreman salary for management, and the market rate of interest on capital investment. Some resources do not have any effective opportunity cost, in the sense that the going rate of return is less than adequate to retain the resource in use. In these cases, the reservation price becomes relevant, as the lower limit of resource returns below which the resource will simply retire from use. The reservation price usually becomes the cost that applies to entrepreneurship.

in the residual claimant, or these resources will seek alternative employment or retire from use. Under conditions of uncertainty, profit must be sufficient to compensate the entrepreneur for bearing the uncertainty of the firm's financial outcome. Thus, entrepreneurship (uncertainty bearing or risk-taking) is an essential element of the residual claimant.

Alternative Profit Concepts

Many alternative profit concepts are employed in empirical studies. Each of these concepts depends on a different (and usually implicit) definition of the residual claimant. Below, several of the most widely used profit concepts are described in common accounting and farm management terms.

Net cash income is gross income minus cash costs. This quantity indicates the cash remaining from the business after payment of all cash expenses for the year. Unless this figure is positive, the operator will be forced to draw on savings or outside sources for funds to continue in business, even during a single season.

Net farm income is net cash income minus depreciation. This is approximately equal to taxable farm income as defined by the Internal Revenue Service. As long as this quantity is positive, the operator can remain solvent indefinitely. He can replace his equipment, pay all cash costs, and have cash left over. However, the remaining amount of cash may be so low that returns to the operator's labor, management, entrepreneurship, and capital are below market rates. If this happens year after year, the operator will often find some way to earn a higher return for his resources, such as reorganizing the farm or even liquidating and reinvesting.

Operator labor and management income[10/] or simply operator income, is net farm income minus interest on investment. This quantity represents what is left for the operator's personal services--labor, management, and entrepreneurship--after paying for all the other resources at market rates. If the operator has full equity in his land and equipment, then the interest on investment is not a cash cost, but rather an opportunity cost reflecting what the capital would earn if invested elsewhere at prevailing rates of return. If the operator owned less than 100 percent of his resources and therefore paid cash interest costs, both his net cash income and his net farm income would be lowered by the amount of the interest charged. Operator income would remain unchanged.

Further distillation of "profit" may be achieved by pricing parts of the operator's personal resource contribution, thus further reducing the elements included in the residual claimant. For example, operator management income (or, more precisely, operator management and entrepreneurship income) is operator income minus an opportunity cost charged for the operator's labor. This amount is a return to the operator for his services of coordinating and supervising, and for bearing the uncertainty of the business

10/ This term, as used in the literature, implicitly includes entrepreneurship, and could be stated more exactly as operator labor, management, and entrepreneurship income.

Finally, entrepreneurial income is defined as operator management income minus the opportunity cost for the operator's management (supervision and coordination). 11/ This value is a return to the operator for his entrepreneurial function, uncertainty-bearing. Thus, it is a "pure profit," as defined by Professor Knight (74). In businesses involving some degree of uncertainty, this quantity must be positive for the firm to continue operating indefinitely. All resources are paid for at their opportunity cost, including the operator's labor and his management services of supervision and coordination, which could conceivably be supplied by hired persons. The only remaining element of the operator's service is his entrepreneurial function of bearing the uncertainty of the business venture.

Proper interpretation of a profit or cost statistic depends on how the residual claimant is defined. Conversely, what is included in the residual claimant depends on the purpose of the analysis and how the analyst intends to interpret his cost and profit data. If the reader is to fully understand and reconstruct the accounting data, he must know what resources are included in the residual claimant, and how each of the other resources was priced. For example, table 1 shows five kinds of net income in a way that allows the reader to choose his preference, and this list of possible "profit" concepts is by no means complete.

Cost:revenue ratios are also shown in table 1, assuming four alternative residual claimants, so as to demonstrate two important principles. First, as additional resources are included in the residual claimant, the cost:revenue ratios become smaller. Second, one-man farms appear to have lower average costs in relation to larger farms when the residual claimant includes all the operator's personal services (labor, management, and risk-bearing) than when labor is excluded. These principles provide a clearer understanding of the cost:revenue ratios or average costs in the various studies discussed later in this report.

This demonstration of the extreme diversity of assumptions serves to illustrate an important source of misunderstanding and erroneous interpretation of cost analysis studies. An example of a study showing a net loss for all firms analyzed will clarify the meanings and interpretations of the various profit concepts. This was a study of Arizona cattle ranches (83). The principal source of data was a 1961 survey of 34 ranches throughout the southwestern portion of the State. Grazing land in this area typically has a very low carrying capacity, and each ranch has vast expanses of rangeland, with only a handful of cattle gleaning their existence from each square mile. A typical ranch was budgeted for each size class based on the sample data. All the resources were valued at current market rates or opportunity costs, including $5,000 per man-year for family labor, 5 percent interest on investment capital, and 6 percent interest on operating capital.

Average cost per hundredweight of beef produced declined sharply as ranch size was increased. For example, a 5,300-acre ranch carrying a herd of 100 animal units had an average total cost per hundredweight of $54.64, compared with $28.39

11/ The salary of a hired farm manager or foreman is sometimes used as an approximation of this opportunity cost.

Table 1.--Alternative net income formulations and cost:revenue ratios calculated for optimal organization of farms at selected points on an envelope curve

Item	Unit	Optimal farm organization		
Resources:				
a. Regular labor (including operator)	Man-year	1	3	5
b. Tractor and equipment, 6-row	Number	1	3	4
c. Farmland (90.9 percent cropland)	Acre	440	1,120	1,720
d. Irrigation wells	Number	4	10	15
e. Seasonal hired labor	Man-year	.4	.9	1.4
f. Investment (average value)	Dollar	294,347	748,087	1,147,086
Enterprise levels:				
j. Cotton	Acre	140	356	547
k. Grain sorghum	do.	121	306	470
l. Soybeans	do.	109	279	428
Costs:				
m. Operator management cost 1/	Dollar	2,974	7,634	11,732
n. Operator labor cost	do.	2,569	1,541	0
p. Interest on investment	do.	14,717	34,404	57,354
q. Interest on operating capital	do.	336	876	1,347
r. Depreciation	do.	4,449	11,370	17,307
Cash costs:				
Seasonal hired labor	do.	714	1,817	2,791
Hired regular labor	do.	0	5,138	10,276
Other cash costs	do.	19,300	50,091	78,003
s. Total cash costs	do.	20,014	57,046	91,070
t. Total cost	do.	42,085	108,237	167,078
Income:				
u. Gross income	do.	59,481	152,684	234,647
v. Net cash income = u - s	do.	39,467	95,638	143,577
w. Net farm income = v - r	do.	35,018	84,268	126,270
x. Operator labor and management income = w - p - q	do.	19,965	45,988	67,569
y. Operator management income = x - n	do.	17,396	44,447	67,569
z. Entrepreneurial income = y - m	do.	14,422	36,813	55,837
Cost:revenue ratio when residual claimant is--				
Operator risk-bearing = 1 - z/u	---	.758	.759	.762
Operator management and risk-bearing = 1 - y/u	---	.708	.709	.712
Operator's personal services (labor, management, and risk-bearing) = 1 - x/u	---	.664	.699	.712
Operator's personal services and capital = 1 - w/u	---	.411	.448	.462

1/ Assuming the opportunity cost or reservation price of operator management is 5 percent of gross income.

Source: (80).

for a ranch budgeted with about 43,000 acres of rangeland, carrying 800 animal units. Beyond this size only slight economies were attained. As ranch size increased to 90,000 acres of range with 1,680 animal units, average cost per hundredweight of beef produced declined only 55 cents, to $27.84.

These costs are well above the longrun projected beef prices for the area, and imply that the net return is not sufficient to meet the cash operating costs and depreciation, plus the opportunity cost of capital (interest on the investment) and the opportunity cost of the operator's labor and management. However, these opportunity cost items account for more than half of total cost. All of the composite ranches budgeted in the study were found to be capable of earning a positive net farm income, meeting all cash operating costs and depreciation, but not capable of meeting the opportunity cost on capital and the operator's personal services. A rancher having full equity in his operation could continue operating indefinitely, even though his resources failed to receive their opportunity cost. However, in a longrun planning situation such as that facing a prospective or new rancher or the heirs of a deceased rancher, it seems unlikely that the resources would be invested in an Arizona cattle ranch unless all opportunity costs were met. 12/

This line of reasoning is generally valid for cases involving stable or constant land prices. However, when land prices are generally rising, farmers and prospective investors may be encouraged to invest in farming even though current net income is not sufficient to meet the opportunity cost of all resources. Over a long period capital gains can be an important source of increase in net worth, particularly in view of the fact that realized capital gains are taxed at lower rates than income from the farming operation. Throughout all of the studies examined in the present report, land values are assumed to remain constant, thereby ignoring the possibility of capital gains. The transition from this assumed situation to real life can be easily made by applying the appropriate rates of capital appreciation.

Frequent Misinterpretations of Farm Cost and Profit Data

Most studies of economies of size show average total cost to be less than average revenue on the farms studied, leaving a profit which is sometimes rather large, particularly among very big farms. This leads to the idea that these very big farms are enjoying an exorbitant profit. The traditional formulation of the theory of the firm sometimes leads to concern over the existence of profit, for two reasons. First is the belief that if our competitive system is really functioning, entry of new firms or expanded production by existing firms will surely force output up and prices down. Second is the belief that as the price is forced down toward the equilibrium level (tangent to the low point of the average total cost curve), all smaller firms will be forced to either expand or drop out of production. This prospect is particularly distressing to those concerned about the future of the "small family farm."

12/ This would require either a more favorable set of resource costs and beef prices, or more efficient technologies than those currently used on the typical Southwest Arizona cattle ranch.

Another reason for concern is that when the results of several independent economies of size studies analyzing a given type of farming in different areas are compared, it appears that some areas are considerably more efficient than others. This may lead to the conclusion that the areas exhibiting relatively higher cost curves will give way to the more efficient producing areas. These concerns are frequently the result of erroneous interpretations of farm cost and profit data, as discussed below.

The contention that the existence of a profit margin will always attract new resources is a misinterpretation of the key concepts of profit, total cost, and residual claimant. Total cost, as calculated in economies of size studies, includes a return to all resources excluded from the residual claimant. Since profit is the return to the residual claimant, and the residual claimant usually includes operator management and entrepreneurship, profit includes a return to the operator for supervising and coordinating the operation and for bearing the risk and uncertainty of the firm's financial outcome. Under perfect competition, equilibrium of the firm requires that the average revenue (marginal revenue) curve is tangent to the minimum point of the envelope curve (average total cost curve). Each resource is paid just enough to keep it from being drawn into other uses, but not enough to attract additional resources into production.

One vital assumption of perfect competition is that perfect knowledge prevails--no uncertainty exists. This implies that the marginal value product of the uncertainty-bearing factor is zero. Hence, the firm does not need to earn a pure profit, or net return to uncertainty-bearing or entrepreneurship. There is no pure profit at equilibrium under perfect competition, because there is no uncertainty. Firms will maximize profit (at zero level) or minimize losses by gravitating toward the minimum point on the envelope curve, at output level Q in figure 1.

Now, if we relax one of the assumptions of the perfect competition model, and recognize that uncertainty prevails, then we view firms as tending toward an elusive equilibrium that does involve a profit; that is, a return to uncertainty-bearing or entrepreneurship. Thus, average revenue will not necessarily be forced down to the minimum point on the longrun average cost curve. Firms in equilibrium would maximize profits (at some positive level) by extending output beyond level Q. But the presence of uncertainty leads real firms to hold production below the profit-maximizing level.

Farms smaller than the size corresponding to the low point on the average cost curve will not necessarily be forced out of production, as long as their profit potential is sufficient to overcome the opportunity cost and reservation price of small-farm operators. Opportunity cost is likely to remain relatively low for a substantial number of farmers who lack the skills, education, and mobility to be attracted into off-farm employment. Farmers will probably continue to place lower reservation prices on their management for 1- or 2-man operations, and higher reservation prices for larger operations that require supervision of several hired men and coordination of a highly complex operation. Furthermore, farmers will probably also continue to place a relatively lower reservation price on their entrepreneurial function in an operation that can be operated profitably by one or a few full-time men, as compared with very large, complex farm businesses that have a high probability of failure.

Another misinterpretation of farm cost analysis concerns interregional competition. Certain types of farming will not necessarily disappear from areas that seem to have relatively high production costs, nor will production necessarily gravitate into other areas that seem to be capable of greater efficiency. For any commodity or type of farming, there are considerable differences in production costs between areas. This variation is partly real, reflecting true differences in efficiency, and partly methodological, resulting from differences in accounting procedures, definition of residual claimant, and other assumptions employed in the cost analysis. Even when the methodological effects are sifted out, leaving only the real differences in production cost, one is still not justified in predicting unequivocally that the less efficient areas will give way to the more efficient ones. Such conclusions are invalidated by the familiar principles of comparative advantage and by other concepts underlying interregional spatial equilibrium analysis.

Another concept needing clarification is the relation between stabilizing forces, average cost, and supply functions. When uncertainty is reduced, the reservation price farm operators charge for their entrepreneurial service is lowered. Consequently, the real average cost and marginal cost are reduced. This has the effect of shifting the supply curve to the right, so that a larger quantity will be produced at a given price. This line of reasoning is essential to an accurate anticipation of the production response that will result from a change in price-support policy. For example, when a commodity is first brought under price support, one initial effect is the elimination of, or great reduction of, price uncertainty. This in turn reduces one of the resource costs, namely, the reservation price of the uncertainty-bearing or entrepreneurial factor. The supply curve is thus shifted to the right by an amount depending on the degree of price uncertainty existing prior to enactment of the price support. Thus, if price-support levels are established on the basis of the supply function as it existed earlier, then the output is likely to be much greater than anticipated, even taking into account technological change and rising yields.

Misinterpretations often result from failure to recognize entrepreneurship as one of the factors of production. When the perfect-knowledge assumption is relaxed, the conventional classification of resources as land, labor, and capital should be extended to include entrepreneurship (risk-taking or uncertainty-bearing). Imputing residual returns to one of the usual factors such as labor or land or capital often leads to some peculiar findings, because entrepreneurship is not recognized as a permanent part of the residual claimant. An example taken from an analysis of irrigated cotton farms in the Texas High Plains will help to clarify this concept (80). Profit is defined in that study as the return to the farm operator for the management functions of coordination and supervision and for bearing the responsibility for a profit or loss from the farm's operation. In calculating total cost, each resource is priced at market rates on an annual cost basis, including an opportunity cost for the operator's labor.

Total profits earned by various sizes of farms analyzed are presented graphically in figure 2. The shortrun average cost curves are included to facilitate comparison of average costs and total profits per farm. The total profit scale is indicated on the right vertical axis, and the average cost scale (total cost per dollar of output) is indicated on the left vertical axis. When the two curves are considered simultaneously, several facts become evident. Average cost is almost constant over a wide range, from \$60,000 to \$235,000 of output, representing cotton farms of 440 acres to about 1,800 acres. Throughout this range, the cost:revenue ratio (ratio of

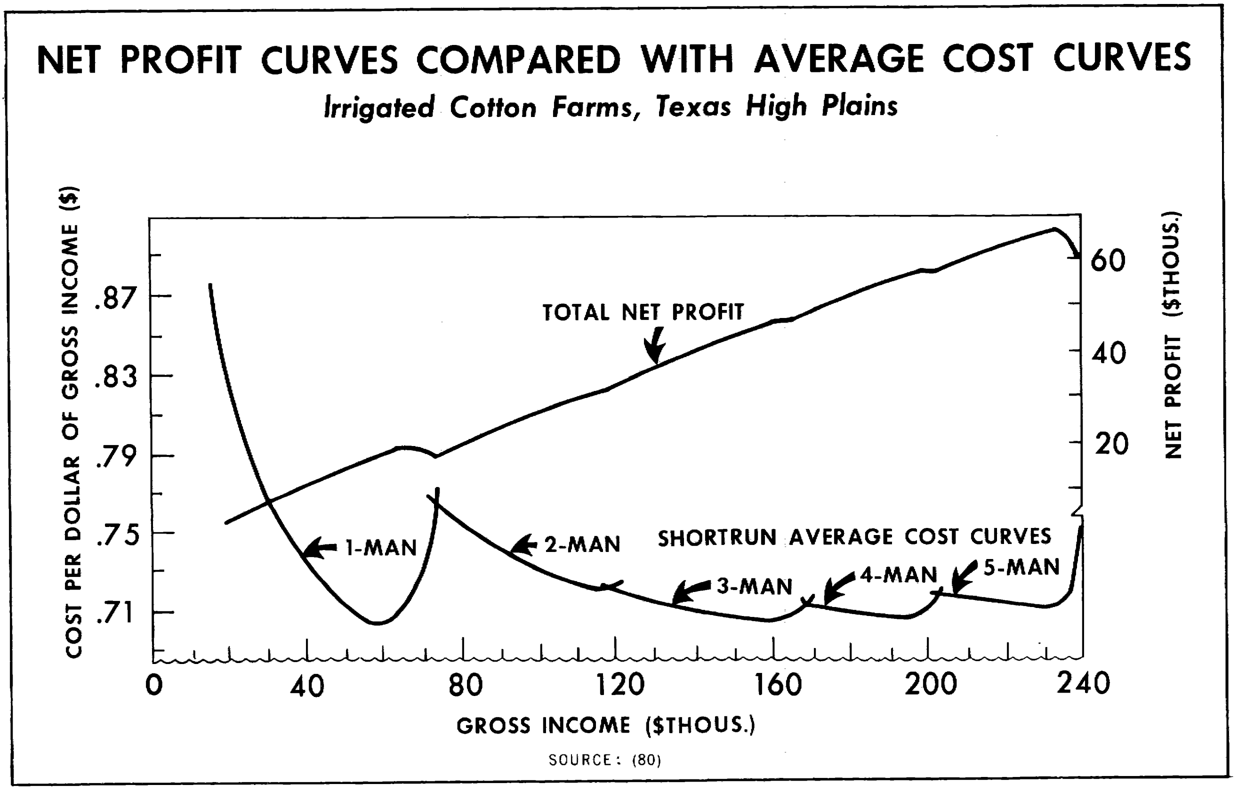

Figure 2

total cost to the income generated by incurring this cost) is less than 1.0. Therefore, the total profit curve has a rather constant upward slope along this range of output. The 1-man 440-acre farm with 6-row machinery achieves an average total cost as low as any of the larger farms. But the larger farms earn considerably higher profits, totaling more than $67,000 annually for a 5-man farm with more than 1,500 acres of cropland.

These results were based on 1967 projected prices and advanced technologies available at the time the analysis was done in 1962. Although profit potentials and size-efficiency relationships for earlier periods are not available, the relationships developed here probably apply in general to earlier years in that farming area. More specifically, it seems likely that during the period 1954 to 1959 farms with more than 1,000 acres of cropland were more profitable than similar type farms of smaller size.

During this period, the number of farms with 1,000 or more acres of cropland increased by 5 percent, while the number of farms with from 500 to 999 acres increased by 10 percent. Why did this profit potential not draw more firms into the largest size class? Perhaps this question can be answered partly in terms of the opportunity cost and reservation price concepts. No one but the individual farmer himself knows the opportunity cost or reservation price which he places on his labor, management, and entrepreneurship. Following Haavelmo (49), one can see that a possible reason why so few firms have expanded to very large size is that the promise of a greater profit potential is somewhat offset by the uncertainty and the difficulty of coordinating the operations of these large firms. In other words, the profit potential may be less than the sum of (a) the opportunity cost or reservation price farmers place on their labor and on their task of supervising and coordinating the efforts of several hired men, plus (b) the reservation price they place on their entrepreneurial services.

The Farm as a Goods-and-Services Firm

Now we turn to the other end of the size continuum, and examine ways in which the changing form of the farm firm has led to changes in the structure of agriculture in general, and particularly in the nature of small farms. The modifications of traditional theory offered here should also provide a framework for understanding size-efficiency relationships and for initiating research on the changing structure of U.S. agriculture.

The farm operator is usually envisioned as being engaged only in the production of goods, not of outside services, owning or otherwise controlling all the durable factors as fixed resources, and using these resources to provide services only for his own farm. A more realistic concept views the farm firm as (a) a producer not only of goods but also of various services, such as custom work and off-farm jobs, and as (b) having the possibility of hiring various resource services in the amounts needed, as well as owning and operating durable resources.

This broader range of economic activities allows the firm more possibilities for achieving harmonious organization of its operations. For example, when a farmer custom hires all or part of an operation whose succeeding stages tend to overlap, he can overcome peak workloads and can achieve greater harmony among the sequential stages. He can also obtain a larger output from each of the competing farm enterprises. Custom hiring allows the operator to expand an enterprise for which certain operations (such as harvesting of fresh vegetables) must be performed within rather narrow time limits, or an enterprise whose requirements for labor and machinery over the course of the production period would conflict with other enterprises.

Coordination is frequently the limiting resource that necessitates the hiring of custom services. If two or more simultaneous operations each require a considerable amount of coordination, the result may be higher cost or lower revenue because of improper or untimely execution of the operations.

On the other hand, a farmer who owns (or otherwise controls) a large, high-capacity machine is often able to perform certain operations so rapidly that he and his equipment are idle between sequential operations. This gives rise to excess labor and machine capacity that can be sold to other farmers as custom service. A part-time off-farm job can be viewed in a similar light, as a means of selling unused services of a fixed resource (in this case, the operator's labor) to another firm.

Under this concept, the output of a firm includes the income from custom work done plus wages from off-farm jobs in addition to gross income from the sale of farm products. Custom services hired are included in the direct or variable cost items. A farm viewed as a goods-and-services firm may have a lower average total cost than would the same farm viewed as a strictly goods-producing firm, since wages and income from custom work raise the gross income.

At one end of the goods-and-services spectrum are the farms whose sole source of income is the sale of farm products. At the other end of the spectrum are the specialized custom service firms. In between are farms whose income from the sale of farm products is supplemented by custom work or other services.

Emergence of Specialized Service Firms

Familiar examples of operations that are often performed by specialized custom service firms are grain harvesting and application of pesticides and fertilizers. Less familiar examples are seedbed preparation for vegetable crops, fruit-tree pruning, and artificial insemination. In fact, many stages previously performed as part of the farm operation emerged as processing or marketing functions when specialized firms took over their performance. Consider, for example, grading and packing of fruits and vegetables, transporting and slaughtering of livestock, and the separating and churning of cream. In some areas and for certain types of farms, contract or custom service firms are available to perform virtually every task involved in growing a crop, as is the case for vegetable farms in the Imperial Valley of California (20). In other farming areas, relatively few production operations have been assumed by such specialized service firms.

Custom operators and specialized service firms are often able to offer their services to farmers at cost-reducing rates. This is possible when there are important economies of size in the operations, and when the service firm can operate at or near full capacity. Under some circumstances, the farm operator can reduce his variable costs by hiring custom work done, even when custom rates are higher than the average variable cost at which he could perform the same service. For example, if the hiring of custom work relieves a bottleneck and allows expansion of enterprises that compete for limiting resources during a peak work period, and if the resulting increase in revenue is more than the cost of the custom work, then the firm's profit has been increased.

In general, specialized firms tend to emerge whenever they can take over the performance of a stage of production or series of stages and can earn a profit by doing so. Such a firm will succeed if it can perform a sufficiently large volume of service at a price high enough to overcome the high fixed cost of the specialized machinery and equipment. A relatively steady flow of business throughout the year is necessary to attain this volume. Some firms achieve this steady flow by migrating from one area to another to take advantage of differences in planting and harvesting dates. Custom wheat harvesting firms, for example, move northward through the Great Plains with the maturing date of wheat.

Rising Importance of Off-Farm Work

Viewing the farm as a goods-and-service firm also helps to explain the high and rising importance of off-farm jobs and custom work as sources of farm family income and profit. Farmers who employ increasingly productive machine technologies, but fail to make proportionate increases in the acreage they operate, often have unused labor available for sale to other firms in the form of hired labor, or they may be able to "sell" excess machine capacity by doing custom work. Pooling the income from all three sources--sale of farm products, custom work performed, and off-farm work done for hire--gives the gross income for a goods-and-services firm. The firm's costs are also increased by such items as operating costs and use-depreciation on the machines used for custom work, and transportation and other costs associated with the operator's off-farm job. But whenever the increase in cost is less than the increase in gross income, the firm's total profit is increased. From the efficiency point of view, whenever the increase in cost is less than proportionate to the increase in gross income, the firm's cost:revenue ratio or average total cost is decreased.

Off-farm jobs are an increasingly important source of income even among operators of farms producing \$10,000 or more worth of farm products annually. During the 1950's, the proportion of these farm operators who had off-farm jobs increased from 21 to 27 percent. The number working off their farms more than 100 days a year increased from 7 to 10 percent. Both off-farm jobs and custom work are important sources of net income to these farm operators; in 1959 they accounted for roughly \$90 and \$20, respectively, out of every \$1,000 of net income earned by farm-operator families in this class (128).

Persistence of a Large Number of Small Farms

An important principle of microeconomic theory underlying economies-of-size analysis is that average total cost must not exceed average revenue if a firm is to remain in production indefinitely. The usual conception of the small farm as a firm engaged only in the production of goods necessarily gives rise to an average cost curve with a steep downward slope, implying that small farms are inherently inefficient and therefore bound to disappear quite rapidly. The empirical studies presented later in this report indicate that in the long run the break-even point for average cost and average revenue per unit occurs well beyond \$10,000 of annual gross sales of farm products. On the basis of conventional microeconomic theory, this would lead one to expect farms producing less than \$10,000 of gross sales to disappear rapidly. However, small farms have continued to exist in rather large numbers. During the 1950's, the number of commercial farms with less than \$2,500 of gross sales (representing the main occupation and source of income to the operator) declined by 68 percent, leaving only 409,000 such farms by 1959. However, the number of farms with \$2,500 to \$10,000 of gross sales declined by only 20 percent, leaving 1.3 million such farms by 1959 (93, table 15). The continued existence of nearly 1.8 million commercial farms producing less than \$10,000 worth of gross sales seems to indicate a lack of consistency between theory and observed fact.

The persistence of a large number of small and part-time farms on the national scene becomes easier to explain when the farm is viewed as a goods-and-services firm, thus allowing for the broader range of economic activities that farm operators actually engage in. Empirical studies have shown that relatively small farms can achieve the ultimate in economies of size when sufficient custom service is available for timely performance of farming operations (20, 66). Furthermore, off-farm work is especially common among the operators of small farms. Among operators of farms with \$2,500 to \$9,999 of gross farm income in 1959, one out of three did some off-farm work during the year, and one-sixth worked off their farms more than 100 days (93, table 13).

METHODS OF ANALYZING ECONOMIES OF SIZE

A wide variety of analytical procedures has been employed in analyzing economies of size. This variation comes in part from the diversity of purposes for and situations in which these studies have been conducted. A slight difference in focus or in the nature of the production setting can greatly alter the appropriate procedures. Likewise, the analytical procedure will dictate the kinds of inferences that can be properly drawn from a study. No single analytical procedure is best for all economies-of-size studies. The optimal method depends on the specific situation involved--the nature of the production processes being considered, and the kinds of questions the study is supposed to answer. The purpose of this section is to discuss and compare the techniques most often employed.

The widely used concept "returns to scale" should be mentioned briefly. Economists frequently fit a least-squares Cobb-Douglas production function to input-output data and then examine the sum of the exponents (production elasticities). If this sum equals 1.0, this is taken as proof of constant returns to scale. Decreasing, constant, or increasing returns to scale are indicated if the sum is less than, equal to, or greater than unity, respectively. In the concept of constant returns to scale it is assumed that if all inputs are increased by a constant proportion, k, then output will be increased by the same proportion. By definition, returns to scale are decreasing if output increases by less than k and increasing if output increases by more than k.

Herein lies the first weakness of the returns-to-scale concept: It applies only to situations where all inputs are increased by the same proportion. Such situations seldom occur in the real world. Furthermore, the returns-to-scale concept applies only at the geometric means of the variables--that is, for the "average" size of firm observed. The sum of the elasticities gives no indication of the relative efficiency of larger or smaller size of firms.

Another weakness is that the results are strongly influenced by several rather arbitrary decisions regarding the number and form of the variables included in the equation, the range of sizes represented by the basic data, and the algebraic form of the equation fitted to the data. Thus, the results are not determinate in an objective sense.

Perhaps the most serious weakness of this approach is its inability to accommodate discontinuities such as those resulting from discrete increments of land. The production functions used in this approach assume that the resources and products are infinitely divisible (136, p. 2). Considering all these limitations, the concept of returns to scale is considerably less useful than the concept of economies of size of scale as used in this report.

The Survivorship Technique

A method presented by Stigler (122) and Saving (111, 112), called the survivorship technique, has the advantage of being both simple and direct. It also has several weaknesses. This technique is predicated on the idea that competition among firms will sift out the more efficient sizes. Size of firm is measured in terms of the firm's capacity as a percentage of industry capacity. Firms are stratified so that both the number of firms in each size class and the percentage of the industry's capacity represented by each size class may be tabulated. Tabulations are made for two or more points in time. Size classes that exhibit a declining proportion of the industry's capacity through time are deemed to be inefficient. Conversely, an increasing proportion of the industry's capacity in a larger size class is taken as prima facie evidence of efficiency and the attainment of economies of size.

Stigler provides examples of this method from many industries. His data for the petroleum refining industry show that in 1947 some 130 firms were in the size class representing less than one-tenth of 1 percent of the industry's capacity. Data for later years show that the number of firms in this smallest size class declined sharply; the percentage of the industry's total capacity found in this size class declined also. In contrast to this trend, an increase in relative importance was exhibited by the class of slightly larger firms, each of which had from 0.50 percent to 0.75 percent of the industry's capacity. All together, this size class had 3.04 percent of the industry's total capacity in 1947, and 5.05 percent in 1954. The class of largest firms (each having 10 to 15 percent of industry capacity) showed a slight decline in percentage of total industry capacity from year to year, slipping from 11.65 to 11.06 to 10.72 percent in 1947, 1950, and 1954, respectively. These and other data are offered as evidence that very small petroleum refining companies are not as efficient as the larger ones, and that the very large firms are no more efficient than middle-sized ones (122, p. 68).

This type of proof is not very informative or convincing, because it leaves several pertinent questions unanswered. First, did those very small firms disappear because they were inefficient? It seems entirely possible (although perhaps not likely) that many of the very small firms disappeared from the ranks of the very small size class by a process of growth, expanding their operations and being classified in a larger size class in the succeeding periods. Furthermore, conceivably these small, growing firms were producing more efficiently (that is, at lower average total cost) than any of the larger firms, and could even have experienced a decline in efficiency (rise in average total cost) as their size increased. This is a possibility when (a) the envelope curve reaches its absolute minimum at a very small size of firm, as is true for some types of farms, and (b) when the average revenue curve is not forced down to the point of tangency with the envelope curve at the low point of the latter. When the average revenue curve lies above the minimum point on the average cost curve, firms can achieve a higher profit by extending output beyond that minimum point, even though they experience higher average total cost than the smaller firms operating at the low point of the average cost curve. Thus, it is possible that firms could disappear from a small size class by shifting to larger and more profitable, but not necessarily more efficient, operations. This possibility raises questions as to the reliability of the survivorship technique as a means of pinpointing efficient sizes of firm. Findings developed using this technique would be more credible if they could be shown to agree with the results of more refined analysis of representative firms or synthetic firms of various sizes.

The size-efficiency relationships may be masked by other factors. Declining relative importance of a given size of firm might result from many factors other than the inherent inefficiency of that size of operation. Location, access to resources and markets, quality of management, productivity of labor, degree of utilization of plant capacity, and physical design of the plant could all vary among the observed plants.

Perhaps the most serious weakness of the survivorship technique lies in its measure of size: A firm's size is measured by its proportion of the industry's total productive capacity. The measure is highly elusive, particularly when the industry's capacity is changing. Furthermore, the results are of little meaning to planning entrepreneurs who seek the technical specifications of efficient and profitable plants. The findings give no hint as to whether the more efficient size firms are composed of a large number of small plants, or a few very large plants.

All these weaknesses of the survivorship technique would be largely alleviated if size of firm were measured in physical units, and if this technique were used in conjunction with the more incisive types of cost analysis discussed below. Standing on its own, this technique has little to recommend it as a method of analyzing economies of size. The only inferences that one is justified in drawing from a survivorship analysis are those regarding changes in the concentration of productive capacity in different size classes, where size of firm refers to the percentage of the industry's capacity found in the individual firm.

Direct Analysis of Actual Firm Records

Many researchers have attempted to determine economies of size directly from a sample of actual firm records. This procedure has the advantage of being rather quick and inexpensive if the farm records are readily available. To some people, the technique's direct connection with actual firms makes the results seem more reliable than the results of synthetic firm analysis, in which hypothetical plants are constructed on the basis of economic and engineering data reflecting advanced or better-than-average technologies. However, this direct accounting method has rather severe shortcomings, as illustrated by the following example.

Records of nonfeed costs were obtained from about half of the feedlots operating in Arizona during 1957 (91). In all, 94 feedlots were observed, representing 82.5 percent of all the cattle fed in the State that year. Average total cost per ton of feed fed was calculated for each of the sample feedlots. Size of feeding operation was measured in tons of feed fed during the year.

The largest class of feedlots fed an average of about 16,500 head per year. These large feedlots were found to have less than one-third as much nonfeed cost per ton of feed fed as did the smallest feeding operations. However, this size-efficiency relationship is confounded by two factors. First, other studies have shown that average cost declines sharply as percentage utilization of facilities is increased. In this study, larger feedlots were observed to be operating closer to full capacity than were the smaller operations. Therefore, much of the difference in average cost attributed to size of feedlot is actually the result of fuller utilization of facilities. Second, it is widely recognized that average cost varies with length of feeding period, classes of feeders fed, and the types and quantities of feed used. The observed feedlots varied widely in regard to all these factors.

Slightly different versions of this method have been applied in many other studies. In each case, the findings have been subject to similar limitations. As a result of these weaknesses, this procedure provides very little useful information about the effect of farm size per se on the average cost of production.

Composite Firm Budgets From Actual Firm Records

In a slightly modified approach, composite firm budgets are developed from actual farm records. The farm records are first separated into size classes. Within each size class a composite farm is developed using averages of the various recorded items (total acreage, investment, acres of each crop, yields, cash expenses, etc.). Then the average cost per unit of output of the composite farm in each size class is calculated, using assumed prices or observed averages. These results are then assumed to be "typical" of farms in the respective size classes. Comparison of these typical costs yields a size-efficiency relationship.

For example, Maier and Loftsgard (81) analyzed the costs and practices of potato producers in the Red River Valley of North Dakota. Data from 82 selected growers were separated into three size groups (based on potato acreage) to facilitate comparisons of costs and practices as potato acreage per farm increased. The average characterisitics, practices, and yields for each size group were used to form three composite farms to represent the three size groups. Fixed machine costs were allocated to the potato enterprise on the basis of the percentage of annual use devoted to that enterprise. Average cost was calculated as cost per hundredweight of potatoes. Operator and family labor were charged at local wage rates, and operator management was included in the residual claimant.

Farms in the largest size class, with 321 to 1,005 acres of potatoes, were found to have lower average costs than the smaller farms (table 2). However, these differences in cost were attributable not only to differences in size, but also to differences

Table 2.--Size-efficiency relationships for potato farms in North Dakota

Item	Unit	Small-size group	Medium-size group	Large-size group	All growers
Range in potato acreage	Acre	95-160	161-320	321-1,005	95-1,005
Average potato acreage	do.	122	235	517	287
Total costs per acre	Dollar	107.35	105.35	104.45	105.15
Average 1960 yields per acre	Cwt.	130	140	150	145
Total cost per hundredweight	Dollar	.83	.75	.70	.73

Source: (81).

in practices. For example, larger farms used more fertilizer and made more frequent chemical applications, and consequently achieved higher yields than the smaller farms. Although this study is very informative and useful for many purposes, it provides no indication of the potential efficiency attainable by farms in different size classes, in cases where all sizes use comparable technologies.

Studies of this kind differ considerably in the specific procedures and assumptions employed; however, they share several basic weaknesses. One is the possibility of inaccurate cost data. Different firms employ a variety of cost accounting procedures. Particularly troublesome are differences in handling resource inventories. In reporting purchases of certain inputs, a firm may not be accurately reporting the amounts actually used in production, because of changes in carryover inventory.

A more serious defect is that the composite farms do not accurately reflect the actual average cost of farms in their respective size classes. The class intervals are established subjectively so that the decision as to whether a specific farm is averaged in with a smaller or larger group is a matter of judgment, and the class averages are influenced by this judgment. Furthermore, as wider class intervals are used, the size-efficiency relationship is obscured. As narrower intervals are used, the number of farms in each interval is reduced, thereby making the results more vulnerable to minor fluctuations among farms as well as to errors in observation. Another source of inaccuracy is that, since several characteristics of individual farms are being averaged, the resulting composite firms have an aggregation bias, making them inaccurate replicas of the group of firms they represent.

Another basic fault of this method is that the composite farms do not accurately reflect the potential efficiency attainable by farms of various sizes. Many existing farms are using outdated machines and buildings, and practices that are grossly inefficient by modern standards. Some farms are operating at less than full capacity, or with inefficient combinations of enterprises. Averages calculated on the basis of data from these farms are not good indicators of the efficiency that a planning firm could expect to achieve with various sizes of operation.

Standardized or Adjusted Data From Actual Firms

Several techniques have been devised in an attempt to compensate for the limitations of cost data obtained from actual firms. In some cases, the data from actual firms can be adjusted to take account of such deficiencies as excess capacity or underutilization of facilities, and differences in method of reporting cost rates and prices in the firm records. For example, Carter and Dean (20) included a degree-of-utilization variable in their multiple regression model. This variable indicates the percentage of available machine capacity that is actually utilized. In calculating points for a cost curve, this utilization variable is set at 100 percent, so that each size of farm is evaluated on a somewhat comparable basis.

In another study, Dean and Carter (31) compared two alternative analytical procedures--a regression analysis using adjusted data from actual farm observations, and a synthetic-firm budgeting analysis. Sample data for the 1958 crop year from producers of cling peaches were adjusted to eliminate the effects of differences in proportions of bearing and nonbearing peach trees. Also, the interest rates and depreciation formulas used in the farm accounts were standardized to conform with the procedures used in the budgeting analysis. The main difference in the results of the two analyses is that the regression analysis of actual observations indicates greater reductions in average total cost as size increases. In part, this is probably a result of the mathematical form of the cost function fitted (the Cobb-Douglas). However, it also reflects the substantial overinvestment in (or underutilized capacity of) machinery evident on the small farms. In the synthesized-budget analysis, the machinery investment on the small farms was fitted more exactly to requirements than is often the case in practice. Therefore, it is apparent that the synthetic-firm analysis provides a more accurate comparison of the potential efficiency attainable by each size of farm, when all sizes are efficiently organized without excess capacity. The synthetic-firm analysis approach is now examined in detail.

The Economic-Engineering or Synthetic-Firm Approach

Synthetic-firm analysis is an appropriate technique when either of two research questions is asked: (1) What is the average cost per unit of output or profit that firms of various sizes could potentially achieve using modern or advanced technologies, or (2) what are the differences in average cost per unit of output attributable strictly to differences in size of firm, and not to differences in degree of plant underutilization, use of obsolete technologies, or substandard management practices.

In the synthetic-firm approach, budgets are developed for hypothetical firms, using the best available estimates of the technical coefficients--resource requirements and expected yields--and charging market prices or opportunity costs for all resources. Hypothetical firms are developed in much the same way that an architect or engineer bidding for a construction contract designs a proposed factory or bridge, and estimates the performance and cost of the finished product.

When the planning firm has few alternative choices, the synthetic firms can be constructed by using budgeting techniques.13/ However, when a large number of enterprises, or alternative technologies or levels of resources are considered, manual budgeting becomes burdensome and time consuming. Use of linear programming can greatly simplify the computations, particularly if a computer is used.14/ With a shift from manual budgeting to linear programming, each enterprise or firm activity budget is represented by a column in the linear programming tableau.

Every study of economies of size may require a unique model to reflect the peculiarities of the data involved. Several basic types of model have been employed. For comparison with other types, a basic cost-minimization model is first presented in detail. This model is designed for multiple-product firms allowing variable proportions of resources and products.15/ Specific plant sizes are recognized. Short-run economies are obtained through increasing utilization of a given plant, up to its

13/ This method is widely used. See for example Bressler (9). For a more recent example, see Hunter and Madden (65).
14/ Conventional procedures are discussed by Heady and Candler (55).
15/ This model is discussed in detail with the aid of an actual example by Davis and Madden (29).

full capacity. Determining the longrun economies that are obtained as plant size increases, with all resources variable, involves comparing the efficiency of various plant sizes. A specific plant is represented by a given level of the fixed resources. Various degrees of utilization for a given plant may be represented by different levels of gross income. Thus, it is possible to specify the plant size and level of gross income in a cost-minimizing linear programming model and to compute the least-cost combination of products and variable resources for that specific plant and level of gross income. Then by calculating the cost:revenue ratio (total cost[16] divided by gross income), one point on the shortrun cost curve is determined for the specific plant size being considered. Additional points on the shortrun cost curve are determined by setting the level of gross income at various levels representing different degrees of utilization of the plant, and computing additional linear programming solutions. When a shortrun average cost curve is plotted for this specific plant size, the level of gross income is shown on the horizontal axis and the cost:revenue ratio on the vertical axis, as in figure 1 (p. 3).

Shifting to the next shortrun curve, fixed resources are set at new levels defining the next plant to be considered. Then successive linear programming solutions are computed for each of several levels of gross income, each representing a different degree of plant utilization. This process is repeated until a shortrun average cost curve is determined for each plant size. Then the envelope curve is plotted as the tangency of the shortrun curves.

This model has been used for developing average cost curves in several studies of economies of size. It can be described symbolically as follows: The predetermined data include the technical input-output coefficients (a_{ij}), variable costs (c_j), average gross revenue for real activities (g_j), and resource constraint levels (b_i). The problem is to determine the activity levels (x_j), such that

$$\sum_{j=1}^{n} a_{ij} \; x_j \leq b_i, \quad \text{and}$$

$$\sum_{j=i}^{n} c_j \; x_j = \text{minimum},$$

subject to the following constraints:

1. $x_j \geq 0$, for all j.
2. $\sum_{j=1}^{n} x_j g_j = G$, a specified level of gross income.

16/ Total cost is calculated for each programming solution as the sum of the costs incurred in the objective function plus the lump sum of costs pertaining to the plant size being examined.

3. b_i = constant for the i's representing certain fixed resources and

   $b_i \geq 0$ for other resources involved in "buying" activities,

4. Levels of the fixed resources are set at different quantities representing the various plant sizes to be analyzed:

   a. There are type-of-farming constraints on source of gross income, assuring that at least a specified percentage of gross income is produced by the main enterprise.

   b. The current farm price support programs can influence the area of land available for certain crops, and prices received for supported commodities.

The programming analysis determines the least-cost method of producing specified levels of gross income with certain size-determining fixed resources. Therefore, it can be said that the optimizing criterion is minimum cost per dollar of gross income. 17/

Selection of appropriate gross income levels for a given plant size is accomplished largely by trial and error. However, a useful guide may be obtained using the unrestricted profit-maximization model described below, with the fixed resources set at appropriate levels to represent the specific plant sizes for which cost curves are to be derived. 18/ This model employs the same coefficient (a_{ij}), average gross revenue (g_j), and resource levels (b_i). In this case, we also define r_j as average net revenue of the activities. Then the problem is to determine the activity levels x_j such that

$$\sum_{j=1}^{n} a_{ij} \; x_j \leq b_i, \text{ and}$$

$$\sum_{j=1}^{n} r_j x_j = \text{maximum.}$$

The constraints used are the same as those stated above, except that in the second constraint, gross income is not held constant. Instead, the program determines the one level of gross income which gives the largest profit attainable with the specified levels of the fixed resources. At that specific level, this model gives exactly the same solution as the basic cost-minimization model. However, this unrestricted profit-maximization model is by definition irrelevant for more than

17/ In a special case of this model, one of the resources is kept at a predetermined level throughout the analysis. For example, in the model developed by Miller and Nauheim (87), land is fixed at 1, 600 acres (84).

18/ Miller and Nauheim also used this model (87).

one level of gross income. Only one point on a cost curve or revenue curve is determined. It is necessary to return to the basic cost-minimization model to determine other points needed to specify the cost curve.

The profit-maximizing level of gross income in the solution is useful in spotting the relevant range of gross income levels for each specific plant size. The profit-maximizing level of output will occur slightly to the right of the low point on the shortrun average cost curve in all cases where this low point lies below the average revenue curve. 19/ The profit-maximizing level of gross income represents a level of plant utilization on the upward sloping portion of the shortrun average cost curve. Other values of gross income slightly above this level and for a considerable range below this level may be selected. Each of these levels of gross income should be specified as an equality in the gross-income row of the basic cost-minimization model. A separate cost-minimizing solution is computed for each of these levels, to determine points on the shortrun average cost curve. Then the same steps as for the cost-minimization model are followed.

Another model sometimes used in research such as this calls for minimization of the acreage of land used. This model employs the same set of data as the previous models. Net income is specified to be at one or more levels:

$$\sum_{j=1}^{n} x_j r_j = \text{constant.}$$

Land requirements (L_j) are specified for all activities. Then the optimizing criterion is

$$\Sigma \quad x_j L_j = \text{minimum.}$$

Other constraints include the first and third, and sometimes the fourth and fifth given above for the basic cost-minimization model.

This land-minimization model is useful for determining the largest number of farms, each earning a specified minimum net income, that can operate in a given area (124). One advantage of this model is that land values are not specified, thus eliminating one possible source of imputation error in the analysis. However, this does not provide for the simultaneous minimization of the cost of more than one resource, unless a resource price ratio is assumed, making this model a special case of the more general cost-minimizing model.

Several ingenious variations have been built into programming models to allow for the specific assumptions appropriate to the individual studies. One technique commonly employed is to specify rotations (such as corn-oats-meadow) and allow each vector to represent a specific rotation and a variation in some related technology (such as irrigation versus no irrigation). The programming model selects the

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19/ In general, the maximum profit is achieved where the marginal cost curve intersects the marginal revenue curve from below. For the firm in atomistic competition, the marginal revenue curve is a horizontal price line. When price is above the low point of the average cost curve, the marginal cost curve passing through this low point intersects the marginal revenue curve somewhere to the right.

optimum number of acres for each rotation and related technology alternative. This allows variable proportions among products and resources (3), although these can be specified a priori if desired (36).

Numerous automatic programming techniques have been incorporated into economies-of-size models. For example, Carter and Dean (19) used variable capital programming and calculated the maximum gross income per dollar of capital for various levels of investment. Although it is not an economies-of-size analysis, a study by Heady and Loftsgard of farm planning for Northeast Iowa (58) is an excellent example of the use of variable resource programming techniques. Barker (2) successfully combined variable resource and variable pricing techniques to derive average cost curves. Mixed integer programming seems to hold considerable promise for economies-of-size analysis. For example, Madden and Davis (80) achieved integer values for irrigation wells, complements of machinery, and 40-acre increments of land, using successive approximations with a conventional linear programming code. Mixed integer programming codes are now available at some computer installations. With these and other improvements in programming technology becoming increasingly available, future economies-of-size analysis will become computationally easier and cheaper, and less abstract models will become feasible.

Point Versus Interval Estimates of Cost Curve

The typical approach used in economies-of-size analyses is to develop point estimates of the average cost curves. That is, the relationship between average cost and output is presented as a single curve. This procedure indicates a single average cost for each level of output, based on specific assumptions regarding prices, yields, and other technical relationships.

As an alternative approach, several different cost curves may be developed, each representing a specific combination of high or low product and resource prices and different yield assumptions. This approach gives rise to an entire family of point-estimated cost curves, and the relationship between output and average total cost can be represented as a curved band, rather than a curved line. The width of this band at any given level of output indicates the range of likely outcomes of average cost under the different combinations of price and yield assumptions.

This type of presentation is useful in that it warns the reader how high or low the average cost could be in any given situation. Such warnings should be taken into account by firms in their planning stages--particularly those most vulnerable to an unfavorable outcome. In many cases, entrepreneurs would choose an alternative with relatively lower expected net revenue and lower likelihood of failure, in preference to an alternative offering higher expected earnings but also higher likelihood of failure.

A useful refinement of this interval estimation approach is to develop probability confidence intervals to indicate the expected variation in average cost for given levels of output. This approach assumes that one or more of the important resource or product prices or yields is subject to some degree of random variation. Thus, the variance of prices and yields, and consequently the variance in income and average total costs, is taken into account. 20/

EMPIRICAL STUDIES OF ECONOMIES OF FARM SIZE

The foregoing theoretical and procedural discussions have set the stage for analysis of a selected group of empirical studies of crop farms, beef feedlots, and dairy farms. The discussion is designed to clarify the theoretical treatment, presented earlier, and to give the reader a more adequate basis for interpreting such studies. It is hoped that researchers will gain insight into the advantages and disadvantages of the various analytical procedures as an aid in planning future studies of economies of size.

A six-point frame of reference is used in discussing each of the studies.

1. Study area, type of farming, and date of study. An empirical study is usually applicable only to the area and type of farming for which it was conducted. Production techniques, yields, and costs change rapidly. Thus, it is important to recognize that empirical results are time-dated, being based on production practices and technologies employed during a specific period in time.

2. Range of farm sizes examined. In many of the studies, only the smaller sizes of farms were examined; a few studies extended to very large sizes. Proper interpretation of the resulting size-efficiency relationship requires that the size range examined be explicitly stated.

3. Method of analysis and key assumptions. As indicated earlier, the size-efficiency relationships indicated by study results are strongly influenced by the choice of analytical procedures and assumptions. One of the most crucial decisions regarding procedure is whether an actual-firm or synthetic-firm (economic-engineering) approach is selected, and whether current practices or advanced technologies are assumed. Also, the interpretation of the cost and profit data depends on the choice of residual claimant, and on the rates of return assumed for the operator's labor, management, and capital if these resources are excluded from the residual claimant. As mentioned earlier, the average costs per unit of production,

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20/ Examples of this approach are given by Carter and Dean (18) and Moore (89). In Moore's study, average total cost is represented by the cost:revenue ratio. Variance of average total cost is then calculated by assuming that the numerator (total cost) is constant and that the denominator (gross income) varies. This simplifying assumption leads to a slight understatement of the true variance of average cost. If both the numerator and denominator of this ratio are considered as variables subject to random variation, then the variance of average cost is the variance of a ratio of two variates. This concept is discussed by M. G. Kendall in his discussion of the distribution of a ratio (71, p. 248).

or the cost:revenue ratios, are made smaller for all farm sizes by inclusion of additional factors in the residual claimant. And the left-hand portion of the envelope curve, representing the average cost for smaller farms, is lower when the residual claimant includes all the operator's personal services (labor, management, and risk-bearing) than when operator labor is excluded.

4. Size-efficiency relationship. Results of the studies are examined for their findings on (1) how large a farm must be to achieve the utmost efficiency and (2) whether the longrun average cost curve continues to decline throughout the size range, or reaches a minimum at a relatively small size of operation and remains more or less constant through the very large size range. With very few exceptions, the latter seems to be the typical size-efficiency relationship.

5. Size-profit relationship. Results of the studies are further analyzed for indications of the relative profitability of the various sizes of farms and of how large a farm must become to be profitable. Most studies show that even a 1-man or 2-man operation that is well organized can be quite profitable if prices do not sink to abnormally low levels and if modern technologies are used.

6. Changing size distribution of farms. Another point sometimes noted in discussing each study is the changing size distribution of the farms studied. When the available data permit, the size ranges that seem to be attracting additional farmers are compared with those that appear to be efficient and profitable according to the empirical studies. (This last step is a refinement of Stigler's survivorship technique, discussed earlier.)

Crop Production

This section contains a discussion of economies of size in a number of different crop farming situations. Seven types of crop farms in five States are examined. The acreage that can be operated with a given labor supply varies widely from one farming situation to another--from the highly intensive peach orchards of California to the extensive wheat farms of Oregon. Capital requirements also vary considerably. In most of the farming situations examined, a modern and fully mechanized 1-man or 2-man operation can produce efficiently and profitably, achieving all or nearly all of the economies of size.

Cling Peach Production in California

In 1963 Dean and Carter analyzed the economies of size in cling peach production in the Yuba City-Marysville area of California (31). The size range of peach farms examined extended from 8 acres producing less than 100 tons to more than 400 acres producing over 5,000 tons of peaches annually. Synthetic-firm budgeting techniques were used to determine how the size efficiency relationships were influenced by changes in wage rates and the introduction of mechanized methods of pruning, thinning, and harvesting. The farm operator's personal services (labor, management, and risk-taking) were included in the residual claimant.

The basic synthetic-firm analysis showed that with the prevailing nonmechanized production practices, average total cost per ton of peaches declined as farm size increased up to about 60 acres--marketing about 715 tons of peaches (fig. 3). Beyond that size, slight reductions in harvesting costs and machinery investment per acre were realized, but these were offset by increases in costs of hired supervision (foremen). Therefore, average total cost with prevailing practices was essentially constant beyond 60 acres.

When mechanized practices were used, average cost declined up to a farm size of between 90 and 110 acres--basically a one-man operation. Mechanized methods gave lower costs than present methods for large farms. The break-even point between current and mechanized practices occurred at 55 acres. When 25 percent higher wage rates were assumed, the break-even point between present and mechanized methods occurred at a smaller size--25 to 30 acres. When assumed wages were increased by 50 percent, the break-even point was 18 to 20 acres.

Both average cost and profit were found to be strongly influenced by the level of yields. For budgeted operations of efficient size, average cost was about 40 percent higher with low yields than with high yields. Furthermore, orchards with low yields showed net losses for a very wide range of peach prices and orchard sizes. In fact, profit margins were found to be so low as to make selling the business a serious alternative for growers with low yields, regardless of orchard size. On the other hand, orchards of only 20 acres were found to be profitable with high yields. Assuming the average 1957-61 price of $62 per ton, a 20-acre operation earned $2,400 return to the operator's personal services. Net return on a 50-acre operation was $10,000, while the operators of 100-acre and 300-acre orchards earned $20,000 and $60,000, respectively.

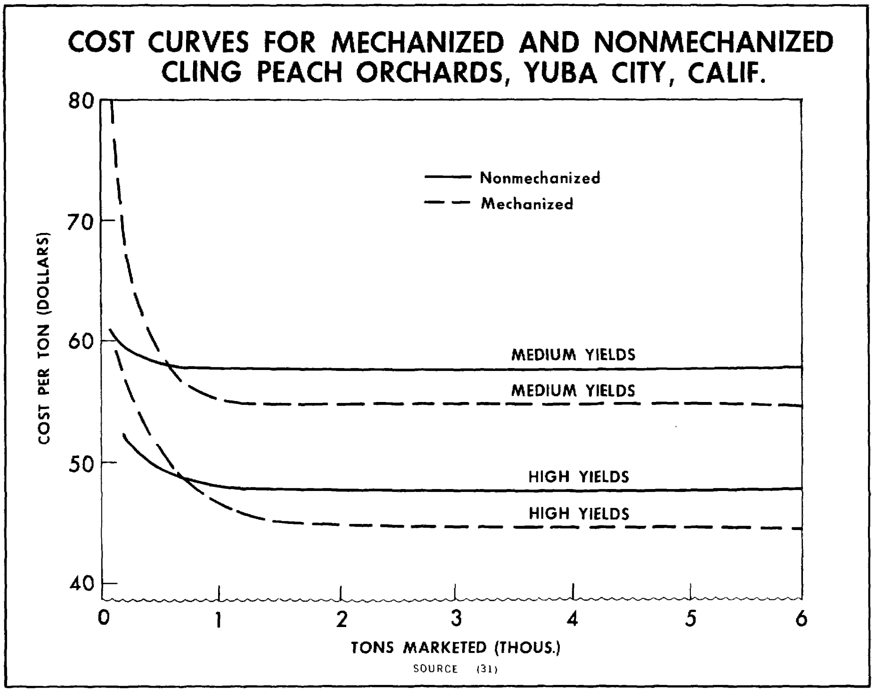

Figure 3

Possibilities for combining off-farm jobs with cling peach production were also examined. It was found that a farmer could handle 20 acres of peaches while holding down a full-time job, or 40 acres while working year-round at a half-time job. The analysis showed that off-farm work could greatly increase the income of small farmers. However, it was pointed out that the operator of a small farm could profitably sell his farm and revert to a full-time job, if he had a lucrative off-farm job opportunity.

Iowa Cash Grain and Crop-Livestock Farms

The two studies discussed below dealt with separate farming areas, but both used similar analytical procedures. The findings were limited to the economies of size on 1-man and 2-man farms.

Southern Iowa

In 1960, Ihnen and Heady analyzed the economies of size for farms in nine southern Iowa counties (66). Synthetic-firm budgeting methods were used, with emphasis on choice of least-cost machinery combinations for various farm sizes. The enterprises considered included corn, oats, meadow, soybeans, and a beef-cow herd producing feeder calves. Operator management, risk-taking, and land were included in the residual claimant, so costs included a charge for operator and family labor, but not for land. Crop losses due to untimeliness of operations were also included as costs. (In most of the other studies, crop losses were treated only as a reduction in gross income, not as a cost.) Full ownership of most machinery items was assumed, initially, but for some operations custom hiring was considered for comparison. The budgeting analysis was conducted first under the assumption that only crop enterprises were used, and second, using both crop and livestock enterprises.

Farms with three different classes of topography--hilly, upland, and average--were considered in this study. The hilly mixture or hilly farm consisted primarily of rolling land with relatively little bottomland. The upland mixture or upland farm was composed predominantly of level to undulating upland soils. The average mixture or average farm consisted largely of rolling upland with smaller amounts of hilly and level upland.

The results were quite different in these three situations. On the hilly and average farms, the crop-livestock combination resulted in a lower cost:revenue ratio than crops only. For the hilly farms, average cost per unit of production declined to its minimum with a farm size of 320 to 360 acres, representing a 2-man operation with a 2-plow and a 3-plow tractor. The cost:revenue ratio was 0.95 at this point (fig. 4). One-man farms were shown to be incapable of meeting total costs in this area, under the basic assumptions allowing no custom hiring.

Similar results were obtained for the average farms, with a cost:revenue ratio of 0.90 occurring in the minimum average total cost range of 320 to 480 acres. In this case, however, a 1-man, 240-acre farm with a 3-plow tractor could break even. The cost:revenue ratio at this point was 0.97.

Entirely different results were obtained for the upland farms. First, farms budgeted with only crop enterprises achieved lower average costs than the farms budgeted with both crops and livestock. Second, the 1-man upland farms were

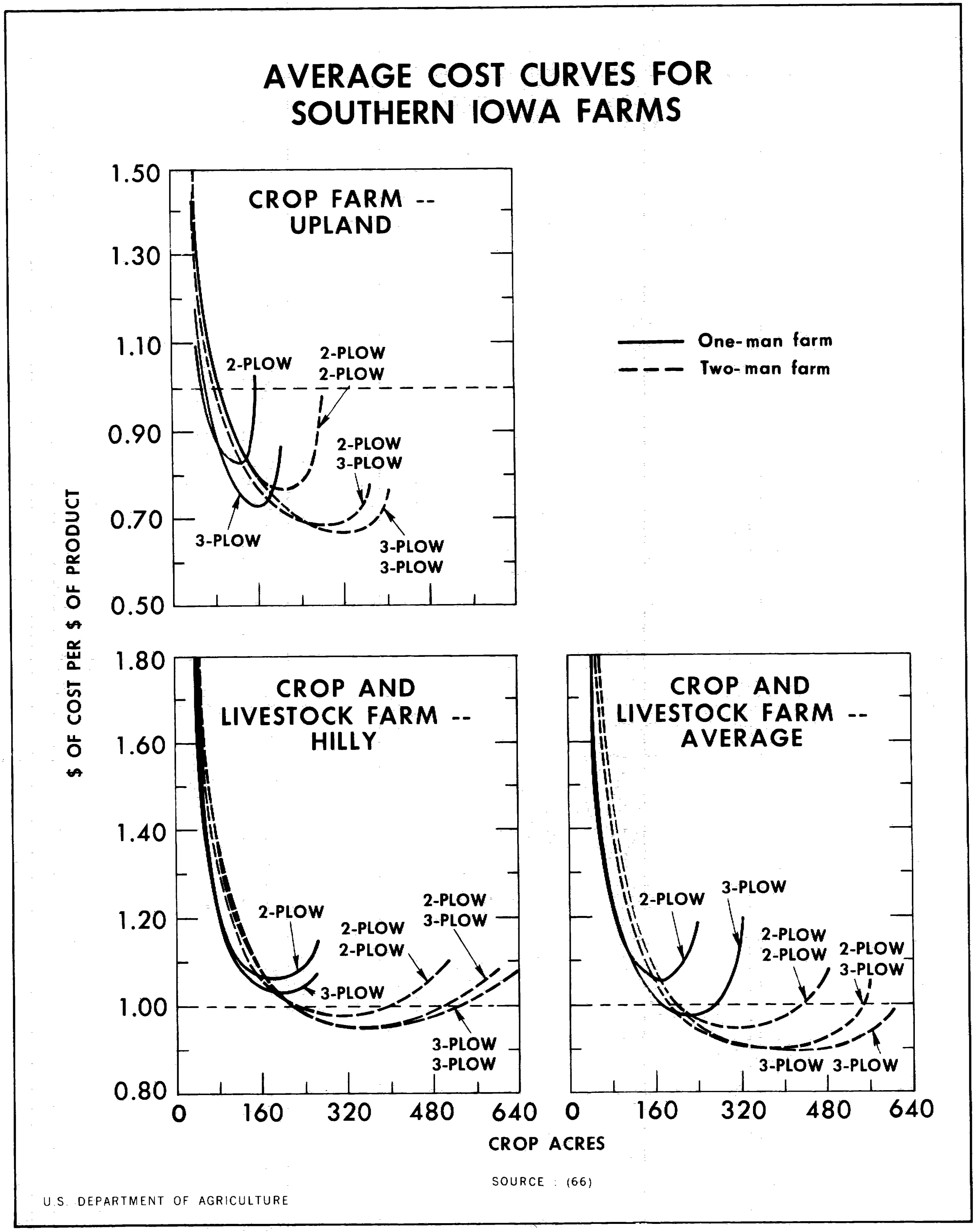
AVERAGE COST CURVES FOR
SOUTHERN IOWA FARMS
CROP FARM --
UPLAND
1.50
1.30
1.10
0.90
0.70
0.50
2-PLOW
2-PLOW
2-PLOW
2-PLOW
3-PLOW
3-PLOW
3-PLOW
3-PLOW
One-man farm
Two-man farm
$ OF COST PER $ OF PRODUCT
CROP AND
LIVESTOCK FARM --
HILLY
1.80
1.60
1.40
1.20
1.00
0.80
2-PLOW
2-PLOW
2-PLOW
2-PLOW
3-PLOW
3-PLOW
3-PLOW
3-PLOW
CROP AND
LIVESTOCK FARM --
AVERAGE
2-PLOW
3-PLOW
2-PLOW
2-PLOW
2-PLOW
3-PLOW
3-PLOW 3-PLOW
0
160
320
480
640
CROP ACRES
SOURCE : (66)
U.S. DEPARTMENT OF AGRICULTURE

Figure 4

considerably more efficient than the 1-man hilly or average farms. Using a 3-plow tractor, a 1-man upland crop farm of 160 acres achieved a cost:revenue ratio of 0.62, which allowed a sizable profit margin for land and operator management and risk-taking. Two-man farms were slightly more efficient; a cost:revenue ratio of 0.57 was achieved with a 320-acre farm using two 3-plow tractors.

When custom corn picking and hay baling were allowed in the budgeting analysis, the 1-man farms were able to achieve considerably lower average costs than they could have without custom hiring. For example, the 1-man crop farm with 240 acres of average land achieved a cost:revenue ratio of 1.02 when all machinery was owned by the farmer. But when custom corn picking and hay baling were allowed, the cost: revenue ratio declined to 0.91. Custom hiring of these tasks greatly augments the timeliness of the farm operations, thereby reducing crop losses. In this case, custom hiring brought the ratio average cost below the 1.0 break-even line, making the difference between a net loss and a positive net return to operator management and land.

Custom operations reduced by 25 percent the acreage required to achieve minimum average total cost. In fact, the budgeting results indicate that on the average-soils farms most of the cost economies available in crop production could be achieved with (a) a 1-man, 1-tractor combination with 150 to 290 acres of cropland, or (b) a 2-man, 2-tractor combination with 290 or more acres of cropland. However, the cost reductions associated with custom operations would not be realized if there were extensive waiting periods for custom services. Thus, an adequate supply of competent and reliable custom service is essential to efficient operation on relatively small farms of this type.

Calculations of profit per farm for various sizes of operation were not presented in this study. The residual claimant was initially defined as operator management, risk-taking, and land. When land was removed from the residual claimant (thereby adding a land rent to total cost) the cost:revenue ratio rose above 1.0 for all 1-man farms, and was only slightly below 1.0 for the 2-man farms. This implies that the net return to operator management and risk-taking was negative for the 1-man farms, and very small even for the 2-man farms.

As with all cost analyses that assume a constant product mix, the cost curves obtained are suboptimal, because optimum resource combinations were not determined. Because of this, the resulting size-efficiency relationships do not reflect the maximum efficiency attainable by different sizes of farms. A more sophisticated analysis with a model that allows variable enterprise proportions would have given somewhat more accurate results, and consequently the cost curves would have been lower in some cases than the ones derived in this study.

Western and Northeastern Iowa

Using budgeting techniques similar to those used in the southern Iowa study discussed above, Heady and Krenz (57) calculated average cost curves for the Carrington-Clyde soils area in the northeast quarter of Iowa, and the Ida-Monona soils area in the west. As in the southern Iowa study, a constant product mix was assumed, and primary emphasis was given to selection of optimum machinery combinations. Two rotations were considered--a rotation based on current practices and a 5-year rotation of corn-corn-oats-meadow-meadow. Continuous corn was also considered in the budgeting analysis for comparison with the rotations in calculating total cost. No charge was made for the interest on land investment. Thus, the residual claimant was composed of land and operator management and risk-taking, as in the southern Iowa study.

For northeastern Iowa, the major reductions in average cost were attained at 280 crop acres with the continuous-corn program. The cost:revenue ratio was 0.42 at this size. The lowest cost:revenue ratio was attained at 320 acres under the 5-year rotation and at 400 acres under the current cropping program, with a cost: revenue ratio of 0.46 in each case.

A smaller machinery investment was required for the continuous-corn program than for the other two cropping programs. Average costs per dollar of output were slightly less for continuous corn, mainly because corn produces a greater gross income per acre than do oats, soybeans, or meadow.

Cost curves developed for western Iowa were considerably higher than those for the northeastern area (fig. 5). Most of the cost economies from acreage expansion were attained at 320 crop acres, as in the northeastern area, but average cost in this area was roughly 20 cents higher per dollar of gross income. This difference is partly due to lower yields and less intensive row cropping in the western area. However, if a land charge (interest on land investment) were included in the calculations of total cost, this difference would be partly or entirely eliminated because of differences in the price of land, and hence, in the interest charge on land investment.

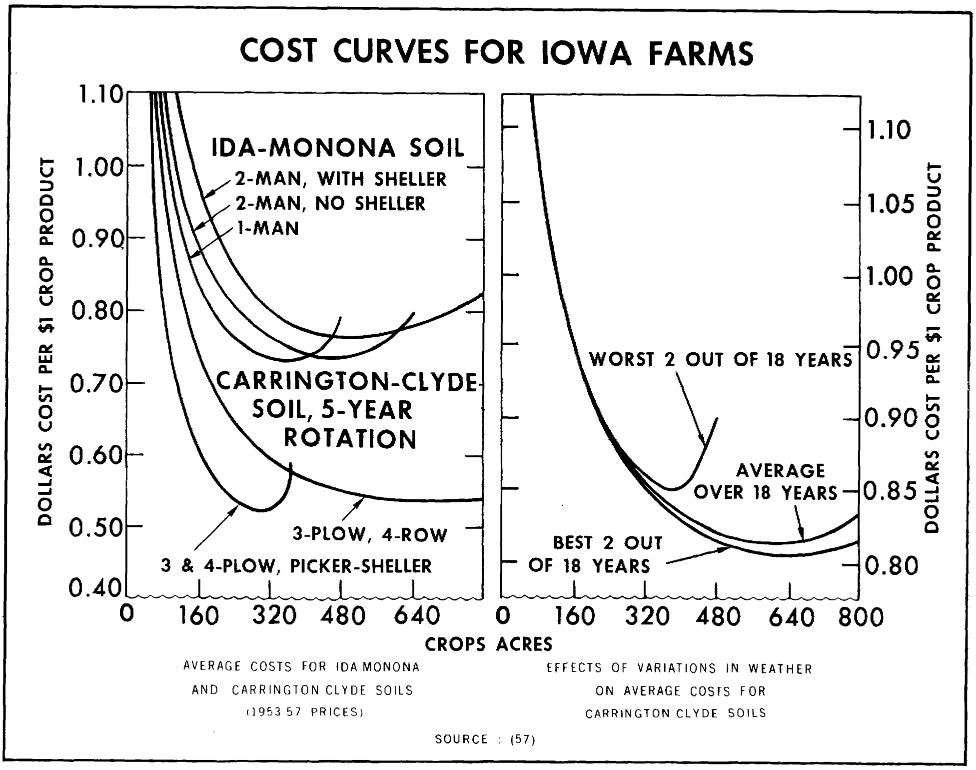

Figure 5

Another factor contributing to the differences in average cost was that losses from delays in hay harvesting were more severe in the western area. With more meadow (hay) in the rotations, expanding acreage led to untimeliness of operations, and consequently hay losses became more serious than in the northeastern area. Thus, the acreage attaining lowest average cost was smaller in the western area, particularly for the 2-man farms.

The effect of weather variations on the average cost curves was examined for the northeastern area. Under unfavorable weather conditions, average costs were generally higher, and the cost curves turned up at smaller sizes (fig. 5). These differences resulted from crop losses due to untimely operations.

One of the prominent conclusions of this study is that the longrun average cost curve is relatively flat over a wide range. For example, average cost was found to vary only 2 cents per dollar of gross sales on farms in the northeastern area with between 400 and 800 crop-acres. This small difference in average cost over such a wide acreage range would allow survival of farms of many sizes.

While this conclusion is probably correct in general, it must be pointed out that in the long run the profit margin (distance between the average cost curve and the price or average revenue line) must be large enough to prevent the residual claimant from being drawn into other uses. Presumably, the reservation price on management and uncertainty-bearing would increase as the size of farm increased from 400 to 800 acres, because of the more stringent demands on management and the greater uncertainty. In this case, we should expect fewer management and uncertainty-bearing resources (that is, fewer farm operators) to be drawn into 800-acre farms than into 400-acre farms when prices are low and profit margins thin.

However, with relatively high and stable prices, profits would tend to exceed the farmer's reservation price on management and uncertainty-bearing, and consequently a considerable increase in the number of larger farms would be expected. This seems to be precisely what happened during the late fifties. Assuming that roughly one-fourth of the cropland would be devoted to corn, farms with 800 acres of cropland would have about 200 acres of corn. Between 1954 and 1959, the number of Iowa farms that harvested in excess of 200 acres of corn more than tripled (130).

Irrigated Cotton Farms in Texas and California

Economies of size have been analyzed for irrigated cotton farms in Texas and California, using the synthetic-firm (economic-engineering) approach. A separate study was conducted in each area, but the methods used were essentially the same. Each study used a linear programming model to determine the least-cost enterprise combination and resource combination for each level of output. Output was measured in terms of gross income, because multiple-product firms were involved. The programming models used in these studies were variations of the basic cost-minimization model discussed on pages 29-33. Certain modifications of this basic model were made to provide for the peculiarities of the study areas involved.

Texas High Plains

In the Texas study (80), irrigated cotton farms ranging from 120 to more than 1,700 acres, using from 1 to 5 man-years of labor, were analyzed. Cotton acreage ranged from 40 to 570 acres. Basic data from a sample survey of farms in the Texas High Plains were used to determine certain resource requirements and practices. Prices were projected to 1968, and input-output coefficients were projected assuming use of advanced technology. Such technology included practices already used by the more progressive operators in the study area, or new practices whose workability and economic feasibility had been tested either by farmers or by agricultural experiment stations. It was assumed that eventually most farmers will adopt this advanced technology.

The programming model selected the enterprise combination--quantity of land, number of irrigation wells, and number of irrigations applied to each crop--required to produce each level of gross income at least cost. Then, using as its optimizing criterion the minimum cost per dollar of gross income, this analysis determined the optimum number of regular laborers and the number of tractors and complements of 4-row or 6-row equipment for each level of output. Land was considered to be available in discrete increments of 40 acres. Irrigation wells, regular laborers, tractors, and complements of equipment were also considered to be available only in discrete quantities.21/

The results of this study show cost data based on a variety of residual claimants. Data underlying the average cost curves reflect an assumption that operator management and risk-taking constitute the residual claimant. It was assumed, on the basis of survey data, that the operator would be required to devote an increasing amount of time to supervision and coordination as additional regular laborers were hired and as farm size increased. Thus, the amount of time the operator devoted to labor, and consequently the charge for operator labor, declined with larger farm size. In fact, the 5-man farm analyzed here was spread out over nearly 3 square miles, thus requiring the operator to devote full time to supervision and coordination. The labor cost for the 5-man farm thus included the wages of only the four regular laborers. The return to the fifth man was the profit, or return to operator management and risk-taking.

The findings show that the 1-man farm with adequate capital could be as efficient as any of the larger farms (table 3). In fact, a 440-acre farm with 102 acres of cotton, operated by one man with a set of 6-row machinery, could achieve an average cost of less than 71 cents per dollar of gross income (table 3). None of the larger farms could achieve lower average costs than the 1-man farm (fig. 6).

With the average cost curve remaining nearly constant at slightly above 70 cents per dollar of gross income over a wide range of sizes, total profit increased steadily with larger farm sizes. Thus, while the 1-man, 440-acre farm achieved the ultimate in efficiency and earned more than a $17,000 return to management, larger farms were more profitable. For example, on the 5-man farm, operator management and risk-taking earned more than $67,000 profit. Gross income on such a large farm would be nearly $235,000. More than $1 million of investment (average value) would be required, including some 1,720 acres of farmland with 15 irrigation wells.

21/ These resources were integerized by a process of successive approximations using a regular linear programming code (LP/90), which did not contain a mixed integer programming feature at the time the computing was done.

Table 3.--Irrigated cotton farms, Texas High Plains: Range in output and acreage, with lowest average cost for each size

Range in acreage	Output range 1/	Size of farm and minimum points on average total cost curves for each size group					
		Regular laborers	Complements of equipment: 4-row	Complements of equipment: 6-row	Output 1/	Farmland	cost: revenue ratio 2/
Acres	1,000 dollars	Number	Number	Number	Dollars	Acres	
120 to 240	17 to 33	1	1	---	43,600	320	0.732
240 to 680	33 to 75	1	---	1	59,500	440	.708
560 to 920	75 to 119	2	---	2	118,800	920	.730
880 to 1,280	119 to 166	3	---	3	152,700	1,120	.709
1,200 to 1,520	166 to 200	4	---	4	197,400	1,480	.711
1,480 to 1,800	200 to 239	5	---	4	234,600	1,720	.712

1/ Output is measured as gross income.
2/ Lowest cost:revenue ratio for given levels of output, with land variable.

Source: (80).

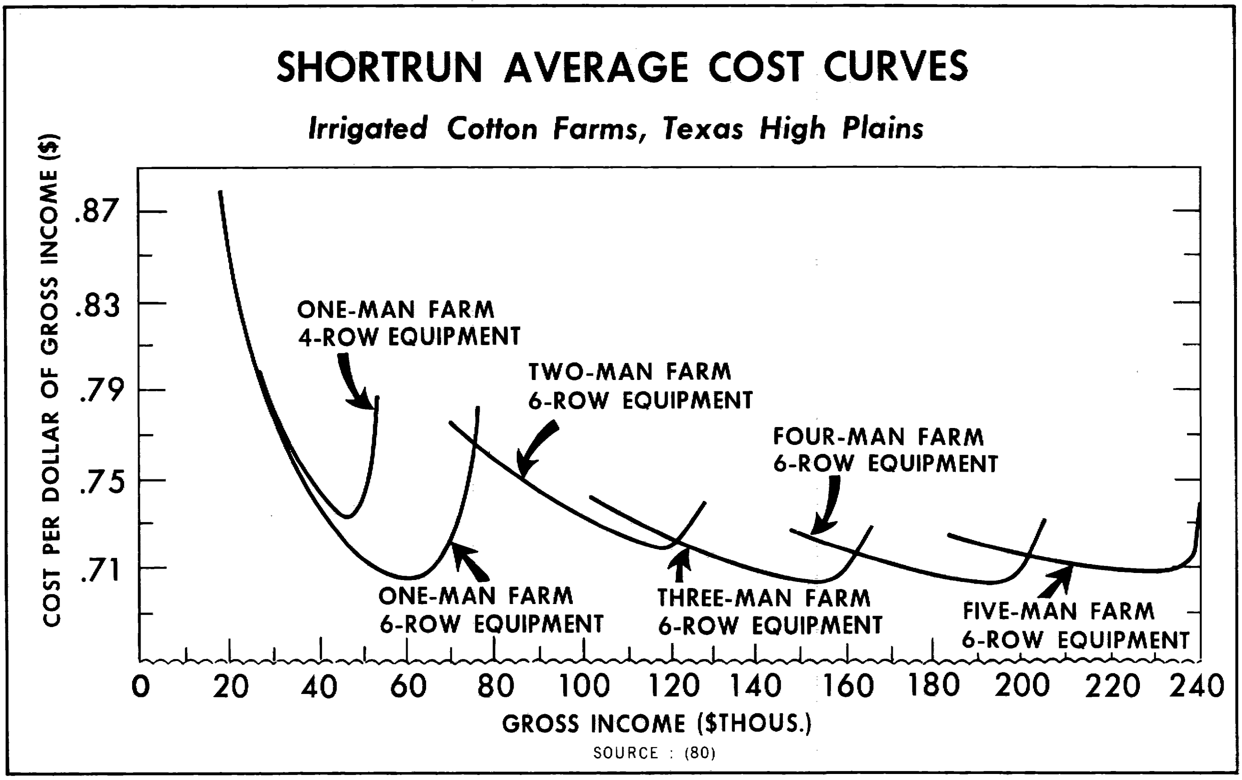

Figure 6

Despite this extremely high profit potential, the very large farms are not increasing in number as rapidly as are the intermediate sizes. During 1954-59, the number of farms in the Texas High Plains with more than 1,000 acres increased by only 5 percent, and the number of farms with less than 500 acres decreased. During the same period, there was an increase of 10 percent in the number of farms with 500 to 1,000 acres--1-man or 2-man farms.

Fresno County, Calif.

The area covered in Moore's analysis of Fresno County cotton farms (89) has two major soil types, one light and the other heavy, separated by the Fresno Slough. To the west of the slough lie the medium- to heavy-textured soils of the recent alluvial fans. Light, sandy soils characterize the area east of the slough. The resource requirements, yields, and practices were so different for farms in these two soil types that two separate cost analyses were conducted. Year-round labor supply was the primary measure of farm size in this study. The four sizes analyzed were 1-man, 2-man, 4-man, and 8-man farms. Amounts of farmland in the model farms extended beyond 2,000 acres. This study was completed in 1965, using prices projected to 1968 as in the preceding study.

For each farm size, both custom harvesting and the use of farmer-owned harvest machinery combinations were evaluated and were compared with regard to average total cost for producing specified gross incomes. Least-cost combinations of land, labor, and machinery were determined for each farm size for at least five levels of gross income. Heavy tillage equipment units were held constant for any given farm size. This procedure permitted the evaluation of each machine in terms of the cost per unit when used at different capacities, but more important, it took into account the returns from labor released by labor-saving equipment. In other words, the analysis evaluated each piece of equipment by noting its impact on the overall farming operation, not as an isolated item operating independently.

Figure 7 shows the envelope curves for the heavy soils and light soils areas, respectively. These curves are bordered by approximate confidence boundaries, indicating plus and minus one standard deviation of the cost:revenue ratio. The variance and standard deviation of the cost:revenue ratio were calculated under the assumption that the numerator, total cost, was a constant. As points on the upper confidence limit of the average cost curve were calculated, total cost was divided by the quantity, gross income minus one standard deviation of gross income. The lower bound was calculated by dividing total cost by the quantity, gross income plus one standard deviation of gross income.

Considerable reductions in average cost were achieved as farm size was extended up to four men, representing more than 1,400 acres in the heavy soils area, and 700 acres in the light soils area. Table 4 compares the efficiency of farms of similar size as shown in the Texas High Plains study and the Fresno County study, assuming operator management and risk-bearing are the residual claimant. Strictly speaking, the average costs derived in the two studies are not directly comparable because of the different assumptions regarding management requirements and other procedural matters. However, the overall effects of these differences are minor.

Table 4.--Comparison of acreage and average cost for optimal farm plans for irrigated cotton farms in Texas High Plains and in California

Study area	Acres		Cost:revenue ratio	
	1-man farm	4-man farm	1-man farm	4-man farm
Texas High Plains	440	1,480	0.71	0.71
Fresno County, Calif.:				
Heavy-soils area	270	1,134	.91	.85
Light-soils area	193	710	.83	.76

Source: (80, 89).

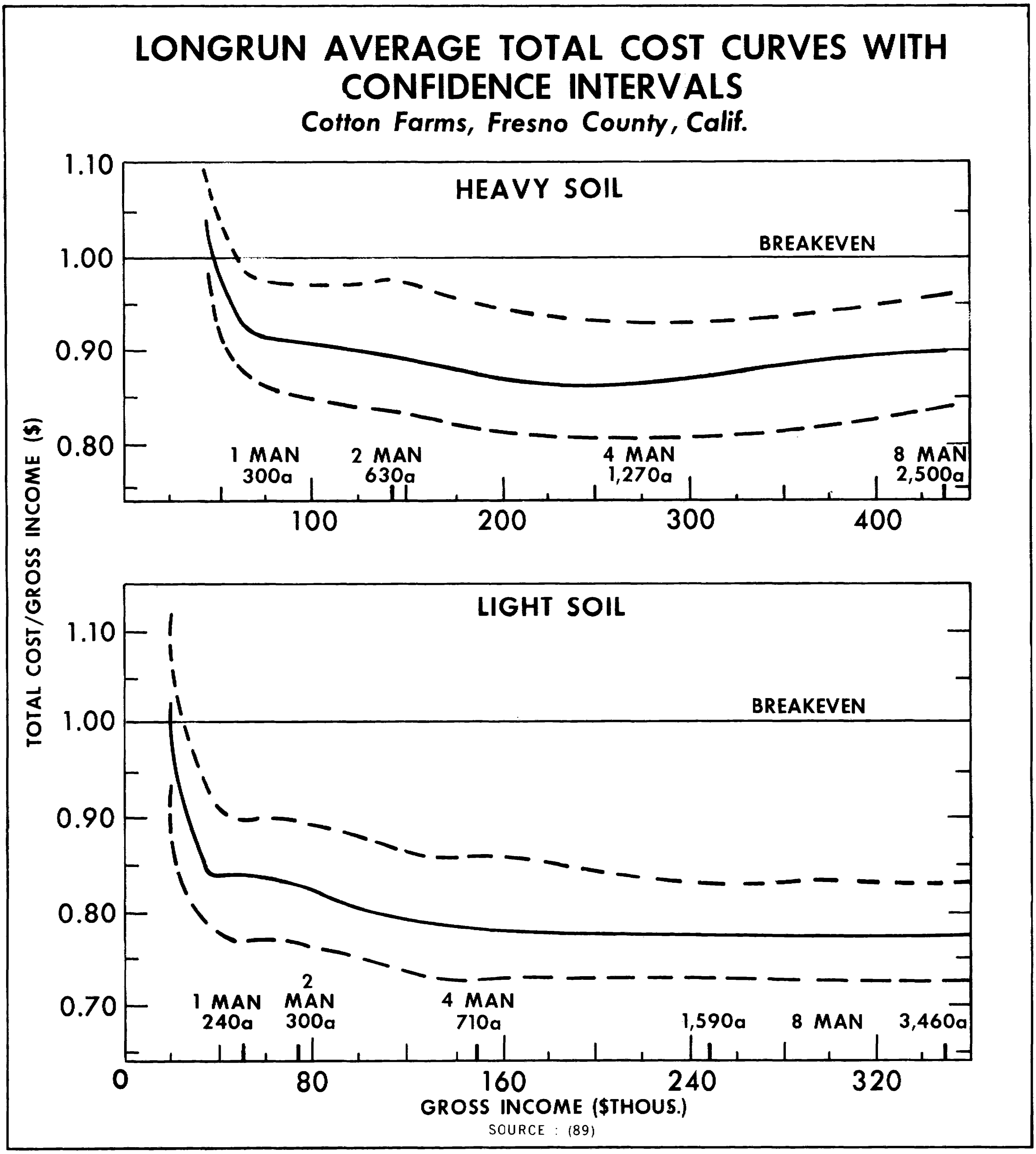
LONGRUN AVERAGE TOTAL COST CURVES WITH CONFIDENCE INTERVALS
Cotton Farms, Fresno County, Calif.
HEAVY SOIL
BREAKEVEN
1.10
1.00
0.90
0.80
1 MAN 300a
2 MAN 630a
4 MAN 1,270a
8 MAN 2,500a
100
200
300
400
TOTAL COST/GROSS INCOME ($)
LIGHT SOIL
BREAKEVEN
1.10
1.00
0.90
0.80
0.70
1 MAN 240a
2 MAN 300a
4 MAN 710a
1,590a
8 MAN
3,460a
0
80
160
240
320
GROSS INCOME ($THOUS.)
SOURCE : (89)

Figure 7

Moore assumed that the opportunity cost for operator labor used in the direct operation of the farm was the wage rate for tractor drivers. The portion of the operator's time spent in supervision was charged at the higher rate paid to foremen. Table 5 indicates the annual fixed cost charged to each farm size. Supervision requirements and consequently supervisory costs were assumed to be constant at $720 per man for all four farm sizes.

Table 5.--Fresno County, California: Annual fixed labor costs by farm size, irrigated cotton farms

Item	1-man farm	2-man farm	4-man farm	8-man farm
	Dollars	Dollars	Dollars	Dollars
Direct labor	4,380	8,760	17,520	35,040
Supervision	720	1,440	2,880	5,760
Total	5,100	10,200	20,400	40,800

The operator's time devoted to supervision was not subtracted from the labor supply available for farmwork. For example, the 4-man farm was assumed to have 4 man-years of regular labor available for farmwork. The operator was assumed to devote roughly half his time to management duties, providing about one-half a man-year of regular farm labor. The other 3.5 man-years were assumed to be provided by regular hired labor. The other farm sizes involved a comparable mixture of hired and operator labor, with hired labor replacing the portion of the operator's time devoted to management duties. Thus, regular hired labor was not assumed to be available in 1-man increments on a full-time basis, as it was in the Texas study. This difference alters the interpretation of results slightly, in that the analysis was predicated on the assumption that part-time hired laborers were as productive and required as little supervision per man-year as the full-time regular employees.

The proportion of cropland having a cotton allotment was found to decline with larger farm size. This is a result of institutional factors and historical landownership patterns. Moore allowed for this varying proportion of cotton allotment land in his investment requirements and in calculating the land price and the annual interest charge on land.

Another minor procedural difference between the Texas and California studies is that the residual claimant was smaller in the latter study: Only coordination and risk-bearing were included. Supervision was included with operator labor, hired labor, capital, and all the other resources in calculating total cost and the cost:revenue ratios underlying the cost curves. In the Texas study, supervision was included in the residual claimant. Since total costs and consequently the cost:revenue ratio are larger when more elements are excluded from the residual claimant, this procedural difference has the effect of slightly raising Moore's average cost curves--by about 1 or 2 cents per dollar of gross income for all farm sizes. The cost data from the California study can be converted to the same basis as the Texas data, using operator management and risk-bearing as the residual claimant, by subtracting the supervision charge (table 5) from the total cost. This was done in calculating the cost:revenue ratios for table 4.

California Cash Crop Farms

Yolo County Cash Crop Farms

In 1960, Dean and Carter (30) analyzed the economies of size for cash crop farms in Yolo County, Calif., near Woodland. They employed a linear programming model similar to that used in the Texas study described above. The main crops grown in the study area were sugarbeets, tomatoes, milo, barley, alfalfa, and safflower. The linear programming model selected the optimum (least cost per dollar of gross income) combination of enterprise levels for each level of output.

A wide range of farm sizes was considered. Because of institutional and rotational considerations, the sugarbeet acreage allotment did not increase proportionately with size. The envelope curve (fig. 8) was therefore "u"-shaped, declining sharply to about $0.70 at $100,000 output, falling to a minimum of $0.65 at $240,000 output, and then increasing gradually to about $0.72 at an output of $440,000. Thus, farms with output beyond $240,000 (roughly 1,400 acres) began to experience rising average costs. The authors emphasize the fact that the "u" shape of their envelope curve might be directly attributed to resource and institutional restrictions which change with size, forcing changes in input combinations and output mix. Nonetheless,

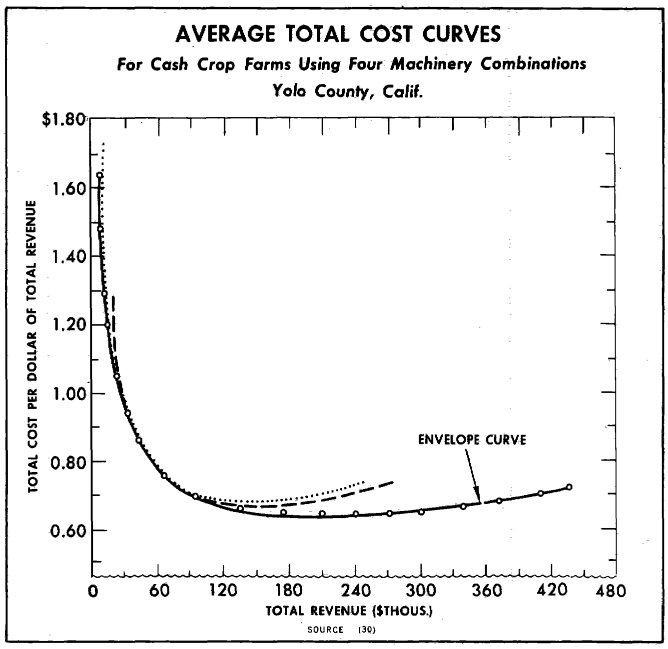

Figure 8

the planning curve did correspond to a realistic path of expansion for farms in the study area, and the analysis revealed definite economic reasons for the trend toward consolidation and expansion of smaller units in Yolo County.

On the other hand, the analysis did not indicate a strong economic incentive for expansion to extremely large size; farms of about 600 to 800 acres appeared able to compete on a unit-cost basis with much larger farms. And with unit costs approximately constant over a wide range, this 1960 study suggested that a continuation of a wide variation in farm sizes could be expected, with little tendency for a concentration at one optimum size. Dean and Carter suggest that this relationship may help to explain the relatively small number of farms actually operating in the extremely high output ranges.

Another important factor in the determination of farm size was the risk and uncertainty inherent in farming. Expansion in size ordinarily requires borrowed capital; as more borrowed capital is employed the risk of losing equity accumulated over time increases. Thus, farmers who have achieved an efficient size of unit and satisfactory incomes tend to "play it safe" in order to protect their current position. High income taxes for large farmers may also reduce the incentive to expand farm size.

This analysis assumed no pecuniary economies in purchasing inputs (discounts on large purchases) or in marketing products in large quantities. Neither were diseconomies due to inefficient labor use, coördination problems, or "red tape" considered. Therefore, the shapes of the cost functions presented arise entirely from other sources of economies and diseconomies.

Imperial Valley Field Crop Farms and Vegetable Crop Farms

In 1962, Carter and Dean (20) examined the economies of size for field crop farms and vegetable crop farms in the Imperial Valley of California. They used synthetic-firm budgeting procedures, assuming a fixed combination of crop enterprises for all farm sizes.

Five size classes of farms were examined in the budgeting analysis, the largest including farms of more than 2,400 acres. Custom hiring and contracting were considered as alternatives to the owning and operating of machines. The machinery combination developed for each size class represented a reasonably efficient setup, with some excess capacity to take care of unusual situations.

Field crop farms and vegetable farms were considered in separate analyses. Shortrun average cost curves developed for the five size classes are shown in figure 9. Because a fixed product mix was assumed, the output and average cost data may be expressed in terms of either acreage or gross income. The curve for the smallest size class, farms with less than 320 acres, is horizontal because all the operations were conducted on a variable cost basis, using custom hiring or contract operations rather than farm-owned equipment. Shortrun average cost curves for larger size classes exhibit the usual downward-sloping shape, a result of fuller utilization of farm-owned machines.

The envelope curve for field crop farms declines steadily to about 1,500 to 2,000 acres (total revenue of $300,000 to $400,000) and declines only slightly thereafter.

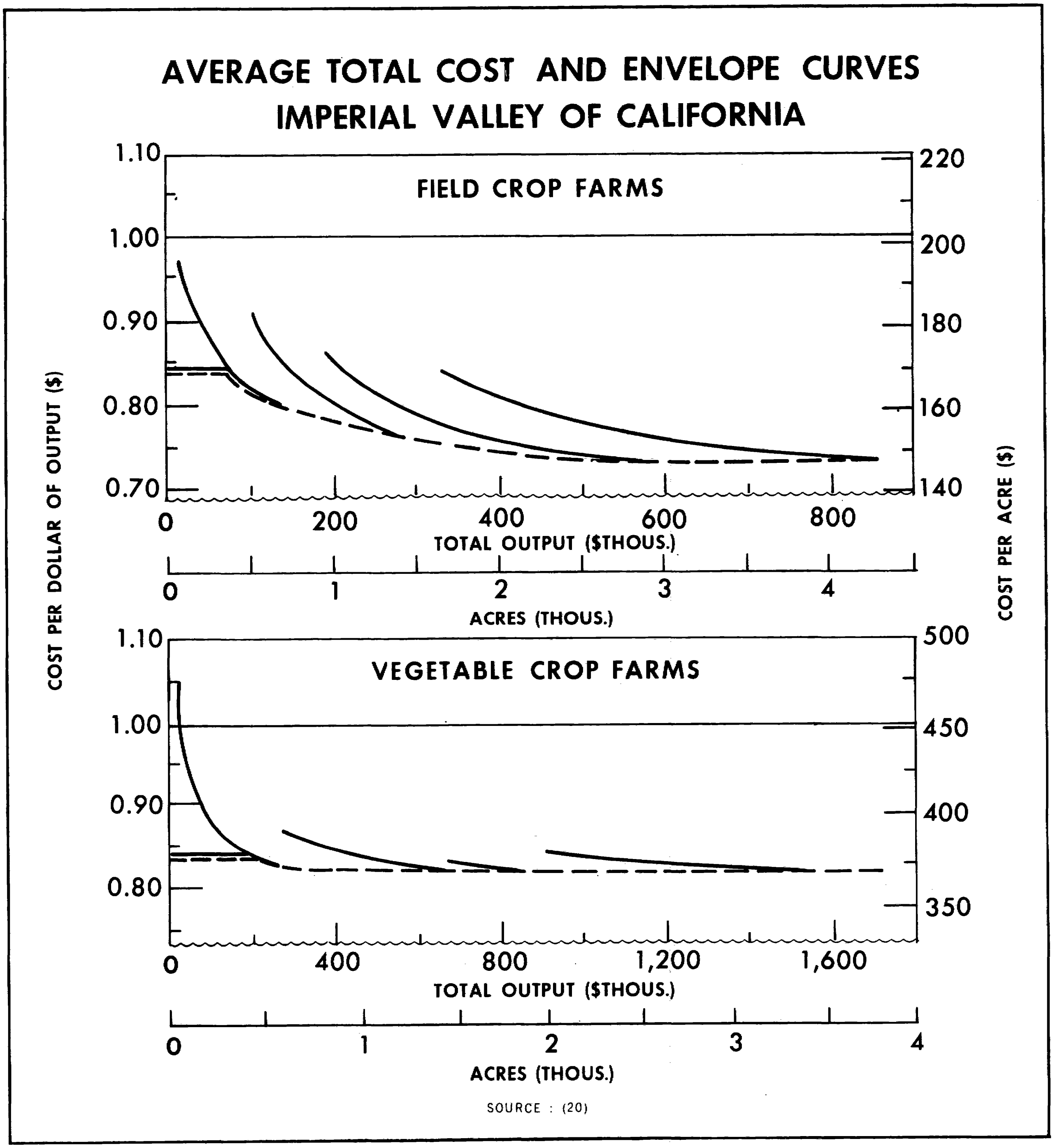
AVERAGE TOTAL COST AND ENVELOPE CURVES
IMPERIAL VALLEY OF CALIFORNIA
FIELD CROP FARMS
1.10
1.00
0.90
0.80
0.70
220
200
180
160
140
0
200
400
600
800
TOTAL OUTPUT ($THOUS.)
0
1
2
3
4
ACRES (THOUS.)
VEGETABLE CROP FARMS
1.10
1.00
0.90
0.80
500
450
400
350
0
400
800
1,200
1,600
TOTAL OUTPUT ($THOUS.)
0
1
2
3
4
ACRES (THOUS.)
COST PER DOLLAR OF OUTPUT ($)
COST PER ACRE ($)
SOURCE : (20)

Figure 9

For each size group, minimum cost per dollar of total revenue (or per acre) was achieved with fixed resources (machinery and managerial labor) used to maximum capacity.

These cost curves emphasize three points: (1) Significant cost advantages accrue to increased size of field crop farm operations up to a size of about 1,500 to 2,000 acres; thereafter, the costs per unit of production decline only slightly and eventually level out; (2) if farms that are highly mechanized and otherwise set up to operate large acreages underutilize this capacity, they may have higher unit costs than smaller operations more fully utilizing their fixed resources; and (3) farms of any size could operate efficiently and make reasonable profits under the conditions prevailing in 1959. On the basis of cost per dollar of output, the envelope curve declines from about 84 cents at low output levels to about 73 cents for output in excess of $500,000. Thus, the net return to operator labor and management before income tax varies from 16 cents to 27 cents per dollar of output over the corresponding range in output.

Similar procedures were used in analyzing vegetable crop farms. The results show that if competent and timely contract services are available for the smaller vegetable farms (up to 640 acres, producing around $100,000 of total crop revenue annually), the longrun average costs for vegetable production are essentially constant throughout the size range, from very small farms to those with more than 2,400 acres of farmland (fig. 9). Results of the study indicate that when competent and timely contract services are available at current rates, the Imperial Valley vegetable farmer achieves little or no cost advantage by owning equipment. In fact, the very large vegetable farms that are equipped to operate on a large scale, but use their machinery at less than full capacity, actually have higher average cost than farms that use only contract services for all the farm operations. In a situation where contract work is not readily available, considerable cost economies occur with increasing size up to about 640 acres.

The apparent lack of any economies of size on vegetable crop farms relates in part to the high proportion of variable costs, especially for contract harvesting, incurred in vegetable crop production. Lettuce and cabbage, which together comprise 50 percent of the cropping system analyzed, account for about 75 percent of the total variable costs associated with harvesting. Harvesting lettuce and cabbage is a highly labor-intensive operation with relatively minor machine costs, under present technologies. Thus, only slight economies of size are attainable on these operations.

Kern County Cash Crop Farms

In 1963, Faris and Armstrong (36) analyzed the economies of size for cash crop farms in Kern County, Calif. They used a combination of linear programming and budgeting to determine the least-cost machinery combination and irrigation system for each farm size. The model and assumptions employed in this study are very similar to those employed in Moore's study of irrigated cotton farms in Fresno County, Calif. (89).

Three different cropping programs were considered. The cotton-alfalfa-barley-milo farms achieved slightly lower average total cost per dollar of revenue than either the cotton-alfalfa-potato farms or the cotton-alfalfa farms. Results were similar for each of these three cropping programs (table 6). Lowest average total was achieved by the 640-acre farm, with about 90 cents total cost per dollar of gross income. The 160-acre and 320-acre farms were shown to be almost as efficient, each achieving a cost per dollar of revenue within 5 cents of the minimum in each cropping program. The 1,280-acre and 3,200-acre farms were slightly less efficient than the 640-acre farms, having costs 2 to 4 cents higher than the minimum in each case.

Table 6.--Cash crop farms, Kern County, California: Total cost per dollar of crop revenue for three cropping programs

Farm size (acres)	Cost:revenue ratio for--		
	Cotton-alfalfa farms	Cotton-alfalfa-potato farms	Cotton-alfalfa-barley-milo farms
80	1.06	1.06	1.00
160	.96	.94	.93
320	.92	.91	.91
640	.91	.89	.89
1,280	.94	.93	.91
3,200	.96	.93	.92

Source: Calculated from data in Faris and Armstrong (36, table 26).

Wheat Farms in the Columbia Basin of Oregon

In a study conducted by Stippler and Castle in 1961 (123), dryland wheat-summer fallow farms in the Columbia Basin of Oregon were examined using the synthetic-firm budgeting technique. Four farm sizes representing specific labor-machinery combinations were analyzed. Three levels of machine utilization were considered in each of the four labor-machinery size groups. In each case, the lowest average cost was obtained when the machines were fully utilized; that is, were being used on as many acres as possible on a 10-hour-day basis.

Table 7 shows the average cost attained by each of these full-utilization farm plans. The 1-man wheat farms achieved lower average costs than either the 2-man or 3-man farms. The 1-man farm with a 50- to 60-horsepower tractor had a cost: revenue ratio of 0.86, and earned a $5,629 return to operator labor, management, and risk-taking. The 2-man and 3-man farm sizes had costs in excess of 90 cents per dollar of gross income, and earned less than $5,500 of net operator earnings.

This study used highly simplified procedures and assumptions. Only a narrow range of production and resource acquisition alternatives were considered. However, it appears that the size-efficiency relationships developed are a generally accurate representation of the economies of size for wheat-summer fallow farms in the Columbia Basin.

Table 7.--Columbia Basin wheat farms: Average cost and operator earnings for selected farm plans using the moldboard fallow operation

Farm size	Basic resources		Full-utilization farm plan			
	Men	Tractors	Acres	Gross farm income	Operator income	Cost:revenue ratio
Small----------	1	One 30 to 40 HP	1,000	$24,572	$3,669	0.85
Medium---------	1	One 50 to 60 HP	1,600	39,317	5,629	.86
Medium-large---	2	Two 50 to 60 HP	2,500	61,420	5,429	.91
Large----------	3	Two 50 to 60 HP, one 25 to 35 HP	3,600	88,462	5,252	.94

Source: (123, table 5).

The size-efficiency relationships vary widely among the 14 crop-farming situations discussed here. Although much of this variation results from differences in the assumptions and procedures used, some useful comparisons and generalizations can be made.

In the production of cling peaches in California, average cost reached a minimum with an orchard size of 90 to 110 acres when mechanized practices were used. This size of operation required one full-time man plus seasonal hired labor.

The two studies of crop farms and crop-livestock farms in Iowa showed that when full ownership of all machinery was assumed, 2-man farms were more efficient than 1-man operations. When custom hiring of certain field operations was introduced into the analysis, the cost curves for the smaller farms were lowered by about 25 percent, making the 1-man farm nearly as efficient as the 2-man farm. However, these cost reductions were attained only when the custom services were available when needed, so that crop losses were avoided. These two studies examined only a limited range of sizes: 1-man and 2-man operations. Consequently, they provided no insights into the comparative efficiency of larger farm sizes operated by three or more full-time men.

Similar results were found in the analysis of field-crop farms and vegetable farms in the Imperial Valley of California. Farm sizes extending beyond 2,400 acres were examined. Vegetable farms of less than 640 acres could produce almost as efficiently as any larger size by hiring custom work for all or most of their field operations. Among the smaller field-crop farms, custom hiring was also found to greatly reduce the average costs, but additional economies of size were found to occur up to about 1,500 to 2,000 acres.

Analysis of cash-crop farms in Yolo County, Calif., producing sugarbeets, tomatoes, milo, barley, alfalfa, and safflower showed that all the economies of size were attained at a farm size of about 600 to 800 acres. Because of institutional and crop rotation considerations, farms beyond 1,400 acres were found to experience rising average costs.

Farms producing cotton, alfalfa, milo, and barley in Kern County, Calif., were found to achieve lowest average cost at about 640 acres. Larger farms extending beyond 3,000 acres were slightly less efficient.

In the analysis of irrigated cotton farms in Fresno County, Calif., 1-man, 2-man, and 8-man operations were found to be less efficient than 4-man farms representing about 700 acres in the heavy-soils area and 1,400 acres in the light-soils area.

In two studies, larger farms were found to be no more efficient than highly mechanized 1-man farms. These 1-man farms were a 440-acre irrigated cotton farm in Texas and a 1,600-acre wheat-summer fallow farm in Oregon.

In most of these studies, all of the economies of size could be attained by modern and fully mechanized 1-man or 2-man farms. But it is often possible to increase total profit by extending beyond the most efficient size. In these cases, the incentive for expansion to very large farm sizes is higher total profit, rather than lower average cost.

Partially counteracting the profit incentive to farm enlargement is the increasing uncertainty and difficulty of managing a larger and more complex farm. As farm size increases, complexity and management problems become particularly serious in types of farming and areas where (1) distances between workers are great, (2) land quality is uneven, (3) growing conditions and prices are unpredictable and require frequent revisions in management plans.

Beef Feedlots

Beef enterprises occur on a wide variety of types and sizes of farms. On crop-livestock farms, the beef herds range in size and relative importance from small supplementary enterprises using idle off-season labor and unsalable crop residues to large enterprises in which the beef herds provide the main source of revenue and in which crops are produced mainly as a source of feed. At the extreme end of the continuum are the highly specialized drylot beef feeding businesses that utilize very little land area and buy all their feed inputs. These specialized feeding businesses account for a large and rising proportion of the Nation's beef production. Four reports of empirical studies of specialized beef feedlots are discussed in this section.

Model Feedlots of 500-, 2,000-, and 5,000-Head Capacity in Eastern Oregon

Three levels of feedlot capacity were examined in a 1964 study by Richards and Korzan (101). This was intended primarily as a feasibility study, rather than as an analysis of economies of size. However, because of the procedures used and the feedlot sizes considered, the findings shed some light on the size-efficiency possibilities available to farmers considering initiation of a beef feeding operation.

Lots capable of holding 500, 2,000, or 5,000 head of feeder steers were included in the study. The results show that even though a 2,000-head feedlot operation is not as efficient as larger sizes, a considerable amount of net profit can usually be expected under price conditions such as those existing in eastern Oregon from 1956 to 1963.

The authors assumed an initial weight of 650 pounds and a finishing weight of 1,062.5 pounds (before shrinkage). A 150-day feeding period and a 2.75-pound average gain per day were assumed. Synthetic-firm budgeting procedures were employed, and operator management and risk-taking were used as the residual claimant. Nonfeed cost per pound of gain was the measure of average total cost. The 500-head feedlot had an average nonfeed cost of \$5.38 per hundredweight of gain, compared with \$4.13 and \$3.32 for the 2,000- and 5,000-head operations, respectively.

Potential profits for the 2,000-head feedlot were calculated for each year from 1956 to 1963 on the basis of average prices received each year for slaughter steers. Returns to management and risk-taking ranged from a \$50,000 loss (in 1963) to a \$115,000 net return (in 1958). In 6 of the 8 years, profits were above \$36,000.

The average annual return to management and risk-taking during the 8-year period was about $43,000.

Actual and Synthetic Feedlots in California

Hopkin analyzed the economies of size in California beef feedlots in 1958, calculating average cost curves both from actual firm records and from synthetic-firm budgets (64). Basic data were obtained from a random sample of 77 feedlots widely distributed around the State. The sample data were separated into six size classes, according to feedlot capacity.

In the actual-firm analysis, a quadratic least-squares regression curve was fitted to the observations for all the firms in each size class. This equation expressed nonfeed cost per head per day as a function of the feeding ratio.

For the synthetic-firm analysis, a model feedlot was designed to represent each size class. The average characteristics of all the observed firms in each size class were used as if they were the actual record of a single firm with capacity set at the group average. The feeding ratio was then allowed to vary from one budget to another, from one-third to full utilization of the facilities. One point on the synthetic firm's shortrun cost curve was derived from each budget. A curve was then drawn approximately through the plotted points. A 120-day feeding period was assumed, and each lot was assumed to operate continuously and at the same capacity throughout the year.

The shortrun average cost curves obtained from actual firm records and from synthetic-firm budgets are quite similar, indicating that with a given size of plant the average nonfeed cost declines sharply as the feeding ratio, or degree of plant utilization, is increased. Both the synthetic-firm analysis and the actual-firm analysis provide evidence of a downward-sloping longrun average cost curve.

Average cost was measured as nonfeed cost per head per day, less a credit of 0.88 cents for manure. For the smallest class of feedlots, those with less than 1,200-head capacity, average cost was 11.77 cents nonfeed cost per head per day. These small feedlots fed an average of less than 800 head per year. Average cost was found to decline steadily as feedlot size increased. The largest size class included feedlots with more than 14,000 head capacity, feeding an average of more than 35,000 head per year. These large feeding operations achieved an average cost of only 7.69 cents, roughly one-third less than the average cost of the smallest class.

The synthetic-budgeting results showed approximately the same size-efficiency relationship as the actual-firm analysis because average or typical plant characteristics were budgeted. If the budgets had been based on advanced technologies and above-average practices, the two relationships would probably have been quite different.

Model Feedlots With More Than 3,000-Head Capacity, Imperial Valley, Calif.

Cost analyses can be conducted using various degrees of abstraction of actual-firm characteristics. At one extreme are studies such as the preceding one by Hopkin in which firms are synthesized to reflect every detail of the average or typical plants found in various size classes. This procedure produces size-efficiency relationships that are geared to presently existing practices and facilities, many of which were initiated long ago and have become outdated. At the other extreme are studies using the economic-engineering approach (73). In this approach, various firm sizes are budgeted with no regard for average or typical situations, except to assure that the arrangements are feasible and realistic. This method produces results that are relevant to the firm in its planning stage, when the entrepreneur seeks the specifications of various plant sizes, and is interested in a comparison of the efficiency and profit attainable with each size. Presumably the planning entrepreneur is concerned with the most efficient and profitable plant designs in each size class, rather than typical or average situations based partly on outdated technology. King's 1962 study of feedlots in the Imperial Valley, Calif., is an excellent example of the economic-engineering (synthetic-firm) type of budgeting analysis (73).

Average nonfeed cost was found to decline from 7.19 to 5.57 cents per head per day as the number of cattle on feed at one time increased from about 11,000 to 68,000 head (fig. 10). During a 120-day feeding period, this cost reduction would result in a savings of nearly $2 for each steer fed. These average cost figures are based on full utilization of the feeding facilities, with all the pens filled to capacity during three 120-day feeding periods each year. Alternatively, if these model feedlots are operated throughout the year with pens partly empty, average costs rise sharply. For example, if the largest of the model feedlots is operated all year with the pens only 60 percent full, average nonfeed cost rises from 5.57 to 6.79 cents per head per day (table 8). This amounts to a difference of nearly $1.50 per head for a 120-day feeding period.

King also examined another kind of plant underutilization, in which the pens are kept full only part of the year and the operation is closed down during the remainder of the year. This kind of underutilization also increases average cost per unit. For example, consider a feedlot designed for 6,000-head capacity. If this plant were fully utilized throughout the year using a 120-day feeding period, approximately three batches of feeder cattle could be fed and the average nonfeed cost per head per day would be 6.8 cents. But if the operation were closed down after the first batch, average cost would nearly double, rising to 12.6 cents. Thus, the benefits of large scale operation may be offset if the facilities are operated at less than full capacity.

Each of the five model feeding operations was organized to provide full utilization of a specific size of mill; the five mill sizes had rated capacities of 5, 10, 15, 20, and 30 tons per hour. Five model feedlots with designed capacities of 3,760, 7,520, 11,278, 15,038, and 22,556 head, respectively, were synthesized on the basis of data from a sample of feedlots and from other sources. Mill construction costs and specifications were obtained from a feed mill construction firm. Cost rates for electricity, labor, and other inputs were set at locally prevailing rates and checked for consistency against the feedlot sample data. A sample of 12 large feedlots in the Imperial Valley of California provided information regarding requirements for equipment, labor, veterinarian's services, medicine, and various other input data.

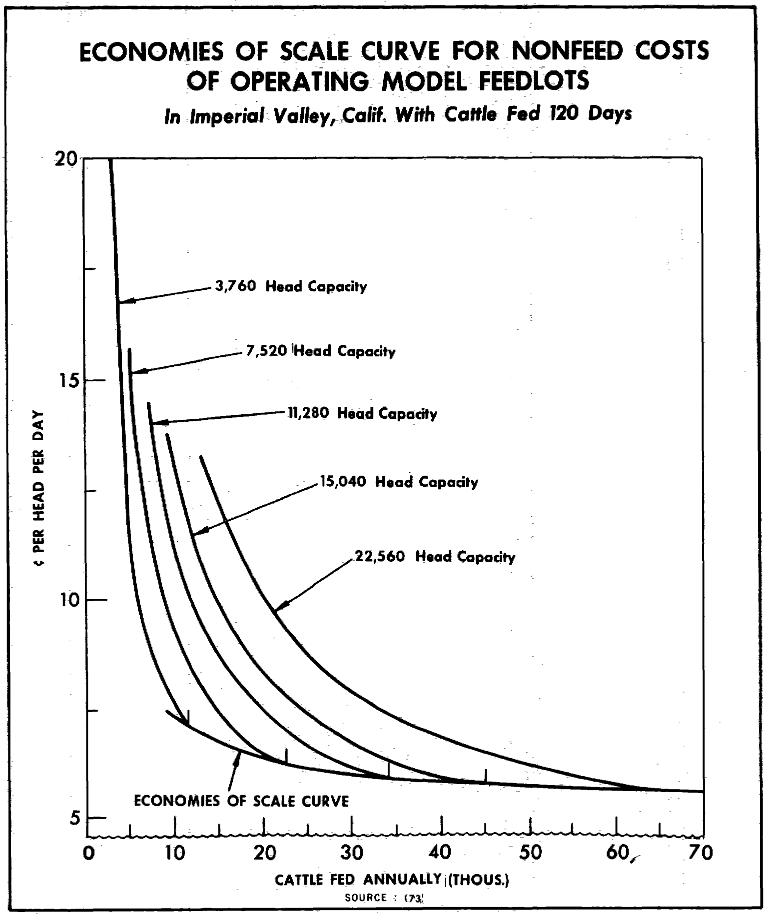

Figure 10

The costs of fixed items such as taxes, insurance, depreciation, interest, management, and office expenses were tabulated separately as a series of lump sums. Cost items that varied with the number of head fed or the tonnage of feed fed were treated as variable costs. These included electricity, equipment repairs, gas and oil, telephone, death loss, veterinarian's services, medicine, and labor other than management and office staff. Total annual cost of each variable resource was calculated as a linear function of either the number of animal days (number of days of operation per year times average number of head on feed at a given time), or the total tonnage of feed fed. Since the amount of feed fed per head per day was assumed to be constant in this analysis, it was possible to convert these linear cost functions from one form to the other. In this way, average cost could be presented as a function of either animal days or tonnage of feed fed.

The costs derived in this study are lower than those derived in the Hopkin study by about 1.5 cents per head per day. The model feedlots were assumed to operate at 80 percent of maximum capacity for this comparison. This cost difference results primarily from the fact that King's budgets reflect better-than-average or advanced technology and practices, while Hopkin's budgets are based on average or typical situations.

Table 8.--Nonfeed cost per head per day for model feedlots operating at full capacity and at 60 percent of capacity in the Imperial Valley of California

Feedlot capacity, head on feed at one time	Feed-mill capacity per hour	When operated at various percentages of maximum annual outputs			
		Cattle fed per year 1/		Average cost 2/	
		100 percent	60 percent	100 percent	60 percent
	Tons	Number	Number	Dollars	Dollars
3,760-----------	5	11,280	6,768	7.19	9.33
7,520-----------	10	22,560	13,536	6.18	7.75
11,280----------	15	33,840	20,304	5.92	7.35
15,040----------	20	45,120	27,072	5.75	7.08
22,560----------	30	67,680	40,608	5.57	6.79

1/ Assuming a 120-day feeding period and 3 lots per year.
2/ Cents per head per day.

Source: (73, tables 9 and 10).

Model Feedlots in Colorado

A study of feedlots in Colorado completed by Hunter and this writer in 1965 employed essentially the same analytical techniques as King's study, with some modifications and extensions. Feedlot capacities ranging from 135 to 15,300 head were examined (65).

When all resources including the operator's labor were charged at going market rates, the model feedlots effected important savings by owning a feed mill of a size appropriate to the scale of the operation. For example, for a feedlot with a 3,150-head capacity feeding operation, a 15-ton-per-day feed mill provided lower average cost than equipment combinations having no feed mill or than any of the larger sizes of mill considered (65, fig. 6). Even with a very small feedlot designed with only 135-head capacity, an 8-ton mill provided lower average nonfeed cost than any of the nonmill equipment combinations considered. As more feeding space was added and more cattle were fed with this 8-ton mill, average cost dropped sharply, reaching a minimum at 1,500-head capacity. Beyond 1,700-head capacity, feeding operations that used this small feed mill had higher average nonfeed cost than operations using the larger mills (fig. 11).

The size of feed mill that provided the lowest possible average cost per head fed per day and per hundredweight of gain is shown for various feedlot sizes in table 9. It was assumed that each steer gained an average of 2.57 pounds per day during a 169-day feeding period, and that the feedlots were kept essentially full throughout the year. These cost data indicate the average cost of owning and operating various sizes of feeding operations, excluding the cost of feed and feeders, which are assumed to be constant and, therefore, not to affect economies of size.

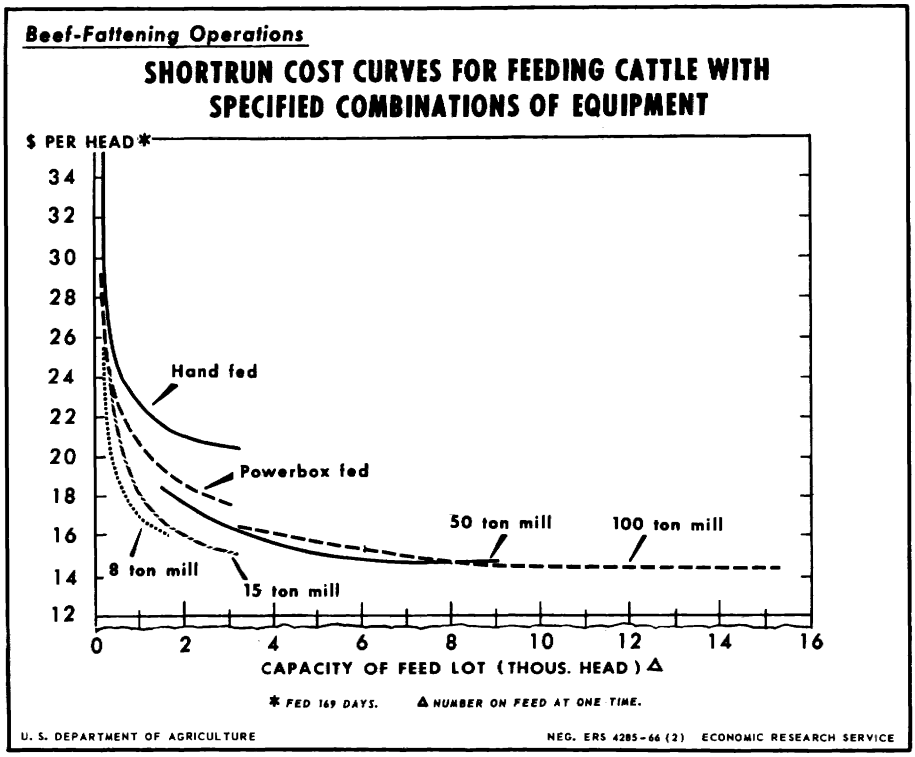

Figure 11

Table 9.--Economies of size in feeding yearling steers in Colorado

Size of feedlot (head on feed at one time)	Size of least-cost feed mill per 8-hour day 1/	Least-cost point: Feedlot size	Average total cost: Per head fed: 169 days	Per head fed: Per day	Per pound of gain
	Tons	Head	Dollars	Cents	Cents
135 to 1,700------	8	1,500	16.37	9.7	3.8
1,700 to 4,000----	15	3,500	15.15	9.0	3.5
4,000 to 9,000----	50	8,100	14.66	8.7	3.4
9,000 to 15,300---	100	15,300	14.10	8.3	3.2

1/ Each of the least-cost equipment combinations includes powerboxes rather than hand-scoop shovels for distributing the feed into the feed bunks.

Source: (65).

The small model feedlots with a capacity for 135 to 1,700 head on feed at one time operated most efficiently using an 8-ton feed mill and powerboxes to distribute the feed into the bunks. Feedlots in this size range were designed to be operated by one or two men. The average cost for a 1,500-head feeding operation was 3.8 cents per pound of beef gain. For larger feedlots having between 1,700 and 4,000 head on feed at a time, the 15-ton feed mill was most efficient; in the 4,000- to 9,000-head size range, the 50-ton mill was most efficient. Beyond 9,000-head capacity, the 100-ton mill was most efficient, providing an average cost of only 3.2 cents per pound of gain for a feedlot with 15,300 yearling steers on feed at a time. This was only slightly more efficient than the 1,500-head operation using an 8-ton mill--a difference of only 0.6 cent per pound of gain. These findings indicate that the technical economies of size attained by feedlots feeding over 1,500 head are too small to have any appreciable effect on the average cost of producing beef or, consequently, on the wholesale and retail prices of beef. A slight variation in the purchase price of feed or of feeder cattle, or in the sale price of fat cattle, could exert a considerably stronger effect on average cost and the profit margin.

However, the slight gain in efficiency attributable to economies of size is quite significant in terms of the overall cost and profit of a large feeding operation. For example, because of this 0.6 cent difference in average cost, a feeding operation handling 15,000 head of steers at a time would have considerably lower total costs--a savings of more than $70,000 annually--using a single feedlot with a 100-ton feed mill instead of ten 1,500-head feedlots each using an 8-ton mill.

When prices are favorable, large feeding operations realize very high profits. But when prices are unfavorable, they incur sizable losses.

The model feedlots were also analyzed for operation at less than full capacity. The results indicate clearly that the advantages of large-scale operations are attained only when the facilities are fully utilized. Excess capacity in the mill or feedlot facilities greatly increased average total cost.

The basic data were obtained chiefly from a sample survey of feedlots and from feed mill construction firms. Four mill sizes were considered, with rated capacities of 8, 15, 50, and 100 tons of feed per 8-hour day, according to manufacturer's specifications. For each mill size, various levels of feeding space and the associated facilities were examined, ranging from a relatively small feeding capacity to sizes that required using the mill beyond its rated capacity. In cases involving overutilization, additional use-depreciation and overtime pay were assumed to occur.

Some of the smaller feedlots were designed without feed mills, and it was assumed that commercial feed mills would process and mix all the grain and concentrates fed to the cattle. These small feedlots were designed with two alternative equipment systems. Both systems used tractor loaders and grain augers for loading the feed trucks. But one system used hand-scoop shovels for unloading the feed trucks into the feed bunks, and the other used powerboxes (self-mixing, self-unloading feed units mounted on trucks). Four other equipment combinations were designed, each having a specific size of operator-owned feed mill to process, mix, and load the grains and supplements into the feed trucks. All four of these mill combinations used trucks with powerboxes to distribute the feed into the feed bunks. Feedlot areas with capacities ranging from 135 to 15,300 head of yearling steers were analyzed in conjunction with the six specific equipment combinations. Several realistic combinations of feedlot area and complements of equipment were analyzed.

Throughout the entire range of feedlot sizes analyzed here, least-cost operation was achieved by the operator owning an appropriate size of feed mill, rather than hiring the concentrate mixing done by a commercial mill, and using powerboxes rather than hand scoops to distribute the feed into the feed bunks.

In the basic analysis, the feeding area was assumed to be fully utilized throughout the year. The feed mill was allowed to operate at less than full capacity in cases where the assumed pen capacity was less than mill capacity. Herein lies one of the basic differences between this study and King's study. King viewed the fixed plant as being both the mill and the feeding facilities, whereas we assumed a slightly longer planning horizon, considering only the mill as fixed and allowing the quantity of feedlot area and feeding facilities to vary. In both studies, points on the shortrun cost curves represent various degrees of utilization of the fixed plant. In each study, a smaller number of cattle fed per year implies a lesser degree of utilization. However, as King reduced the number of cattle fed, he held pen capacity constant, at the level corresponding to the largest potential feeding capacity of the mill. This amounted to varying the feeding ratio--the number of head fed per year for each 1-head unit of feeding space, assuming a given length of feeding period. In our Colorado study, as the number of cattle fed was reduced, the feeding area was reduced accordingly, with mill size held fixed. Thus, the feeding ratio was held constant.

This divergence in procedures and assumptions alters the shape of the shortrun average cost curves. King's curves are steeper than ours, because his concept of underutilization allowed excess capacity in both the mill and the feeding facilities; in our procedure only the mill was allowed to operate at less than full capacity. Both procedures are correct for their respective planning horizons. In the longrun setting, where all resources are allowed to vary, both procedures give identical results. An envelope curve drawn tangent to the shortrun average cost curves will have the same shape and height, regardless of the planning horizon selected for examination of shortrun situations.

Results of the Four Feedlot Studies

One general conclusion can be drawn from these studies. For feedlots above a moderate size, say 1,500- to 5,000-head capacity, the technical economies of size attainable are relatively unimportant--only $1 to $2 per head fed. These relatively small savings can be easily surpassed by a small difference in the price of feed or feeder cattle. A feedlot operator whose operation is small enough to allow him to "shop around" and save a dollar a ton on his hay price, for example, or 50 cents a hundredweight on his feeder cattle, can often realize much greater savings in this way than are attainable through the technical economies of size. Thus, the possible pecuniary (buying and selling) economies and diseconomies of size may be very important in explaining changes in the beef feeding industry.

Dairy Farms

The emergence of new forage production technologies, milking parlor systems, and housing arrangements in recent years has opened up new possibilities of economies of size in dairying. Availability of these new and efficient techniques and the increase in wage rates have augmented the interest of dairy farmers and others in the question of economies of size. Changes in the size distribution of dairy farms have led to concern over concentration of production and its effect on the survival of small dairy farms. For the country as a whole, the number of dairy farms having fewer than 20 milk cows decreased sharply during the 1950's. Meanwhile, the number of dairy farms with 30 to 99 milk cows increased by more than 90 percent, and the number with 100 milk cows or more increased by 82 percent (table 10). Thus, the strongest percentage increases occurred among the herds of medium size--30 to 99 head--while the very large dairy herds remained few in number.

These facts raise a question concerning the economies of size in dairying. Four economies of size studies for dairy farming are summarized and interpreted here.

Table 10.--Changes in sizes of dairy farms, United States, 1950-59

Number of milk cows	Farms having specified number of milk cows		
	1950	1959	Percentage change
	Number	Number	Percent
1 to 19	3,465,526	1,571,496	-54.7
20 to 29	119,259	140,714	+18.1
30 to 49	46,799	89,315	+90.8
50 to 74	10,209	22,336	+118.8
75 to 99	2,871	5,604	+95.2
100 or more	3,593	6,551	+82.3
Total	3,648,257	1,836,121	-49.7
500 to 999	N.A.	177	N.A.
1,000 or more	N.A.	34	N.A.

Source: (130, table 26).

New England Dairies

A study conducted by Fellows, Frick, and Weeks in 1952 was designed partly as a means of testing the synthetic-firm budgeting technique in examining economies of size (39).

Model New England dairy farms with 35 or more milk cows were found to have significantly lower average total cost per unit of output than the smaller dairy farms, under the prices and technologies applicable in 1952. The average cost curve was approximately flat from the 1-man, 35-cow farm to the 3-man, 105-cow farm. These results are consistent with the broad changes in the size distribution of New England dairy farms during the 1950's. The number of farms in that area having less than 20 milk cows decreased steadily during the decade. Number of farms with 20 to 29 cows declined only slightly. Farms with 30 to 49 cows increased by nearly 50 percent, and farms with 50 cows or more doubled in number (128, pp. 528-529).

This study provides a good example of budgeting analysis employing a variety of assumptions about the residual claimant and the cost of the operator's labor and management. Three alternative forage harvesting techniques were considered, along with two alternative wage levels ($1,500 and $2,000) for regular hired labor. The residual claimant was initially assumed to be entrepreneurship. Operator labor and management were initially valued at $2,000 per year, but this value was also set at levels varying from zero to $4,000 for purposes of comparison. Figure 12 shows the resulting average total cost curves using alternative schedules for the cost of the operator's labor and management.

Curve 1 shows how average cost varies with size of dairy farm when the cost of the operator's labor and management are held constant at $2,000 per year for all sizes. The left-hand portion of the curve is quite high, because the fixed costs are spread over relatively few units of output. As the size of firm increases, the curve falls sharply, reaching a minimum of $2.64 per hundredweight of milk on the 2-man farm with 70 milk cows.

Curve 2 shows that when the opportunity cost of the operator's labor and management increases with farm size, the 1-man, 34-cow dairy achieves an average total cost that is within a few cents per hundredweight of that achieved by larger

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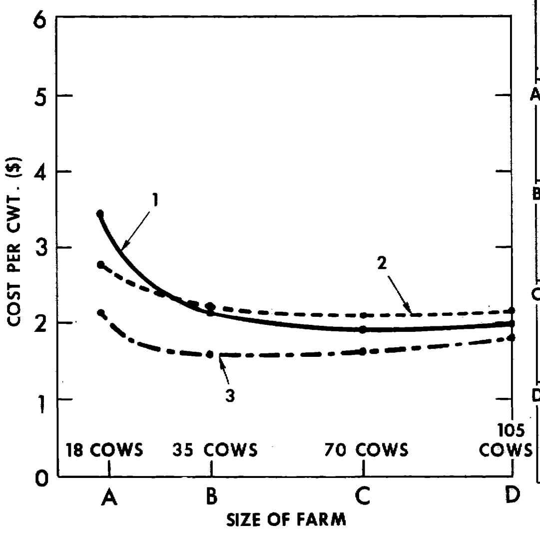
New England Dairy Farms Harvesting Field Chopped Hay and Grass Silage



SIZE OF FARM	ASSUMED RETURN TO OPERATOR LABOR AND MANAGEMENT		
	1	2	3
A ONE MAN (PARTIALLY EMPLOYED)	$2,000	$1,000	NONE
B ONE MAN (FULLY EMPLOYED)	$2,000	$2,000	NONE
C TWO MEN (FULLY EMPLOYED)	$2,000	$3,000	NONE
D THREE MEN (FULLY EMPLOYED)	$2,000	$4,000	NONE

SOURCE : (39)

Figure 12

farms. The budget costs underlying curve 2 are identical to those of curve 1, except that the opportunity cost of the operator's labor and management is varied from $1,000 to $4,000 as the size of firm increases. Implicit in this cost schedule is the assumption that (a) a farmer who operates a large dairy has a higher opportunity cost or reservation price than one who operates a smaller dairy, or (b) an operator places a higher reservation price on his management services for coordinating and supervising a large dairy than for operating a small one. The average cost curve (curve 2) resulting from this assumption is considerably flatter than curve I, where the cost of the operator's service is kept constant at $2,000.

Curve 3 is based on the operator's personal services valued at zero, implying that the residual claimant now includes operator labor and management as well as risk-taking. This is the shortrun cost curve as viewed by a dairyman who places no reservation price on his own labor and management and considers his opportunity cost to be zero because of limited employment possibilities. This is also the relevant average shortrun cost curve for a person with a full-time off-farm job, who uses the dairy enterprise as a supplementary source of income. In this case, the operator would correctly value his personal services at zero in calculating the average total cost of producing milk, if he places no reservation on the time he spends on the dairy enterprise. Curve 3 reaches its minimum point of $2.21 per hundredweight of milk with the 1-man, 35-cow dairy farm. The farmer could remain in production indefinitely, meeting all out-of-pocket costs and depreciation, if the price remained at this level. But he would receive no return for his labor, management, and risk-taking. Family living expenses and debt repayment would have to be met from the return to owned capital and from other sources.

Iowa Dairy-Cash Grain Farms

A study conducted by Barker and Heady in 1960 considered 1- and 2-man farms in Iowa producing milk and cash-grain crops (3). Herd sizes up to 64 cows were analyzed using linear programming to select the optimum crop rotation. Technologies analyzed included the stanchion barn system and four parlor systems: 4-abreast, stanchion parlor, 3-stall, 6-stall, and herringbone. The residual claimant included operator management and risk-taking. It was found that, on a 1-man farm with 14 cows, 156 acres of corn-corn-oats-meadow rotation, and $77,000 of capital (including livestock), gross income would just cover all costs--including the opportunity cost of the operator's labor valued at $2,500 per year, plus 5 percent interest charged for fixed capital and 7 percent for operating capital. With this size of farm, the operator would be fully employed, and expansion in farm size would require hiring another full-time worker. The wages of a hired man were assumed to be $2,500 a year.

The 2-man farm achieved the break-even point at a herd size of 24 cows, with 300 acres of cropland and more than $100,000 of investment. Beyond this size, average cost continues to decline sharply until a herd size of 32 cows is reached (fig. 13). At this size, the cost:revenue ratio is slightly over 0.90, and most of the cost economies have been attained. Only a slight reduction in the cost:revenue ratio is experienced as farm size is expanded to 58 cows, 470 acres of cropland, and $192,000 of capital. Beyond this size, with the labor supply held at 2.25 man-years, the average cost curve for the Iowa dairy-cash grain farm turns upward.

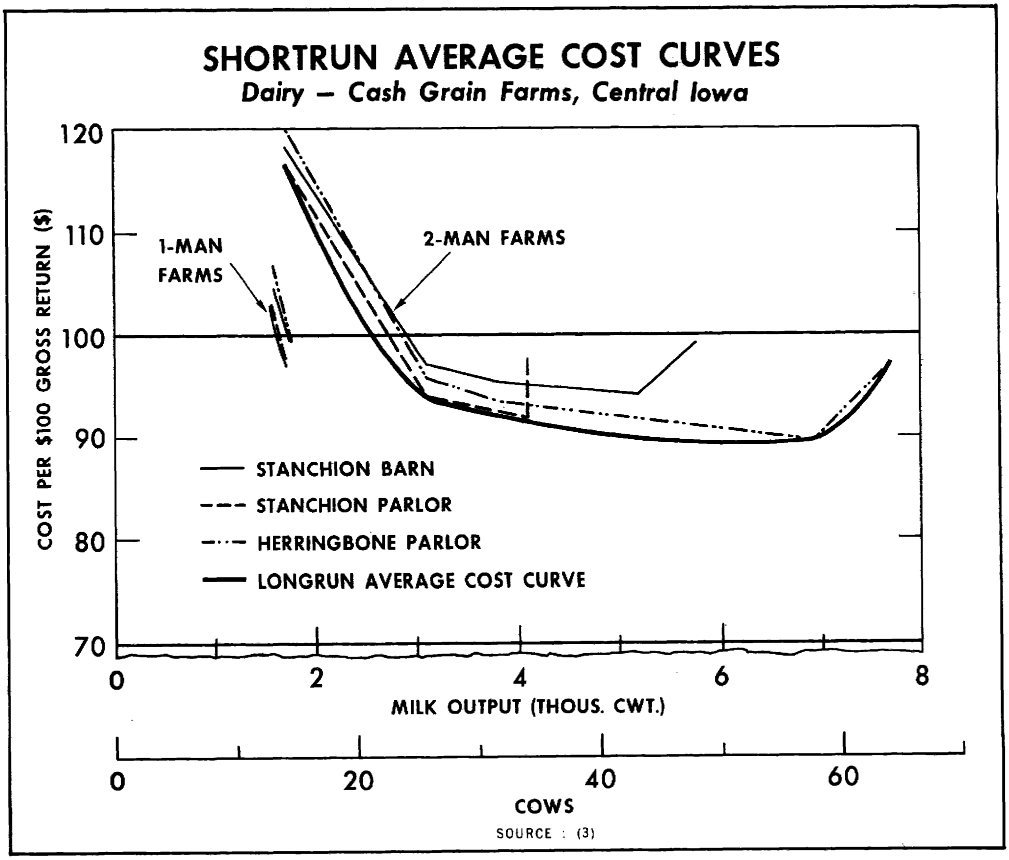


Figure 13

Very small farm sizes are depicted as being quite inefficient. This is partly because the firm is viewed in the conventional way, as simply a producer of farm products. Consequently, the cost of the operator's labor ($2, 500) and the cost of the other fixed resources are spread over relatively few units of output, leading to a high average total cost. This formulation is correct for farmers who operate small farms and have no other source of income. But in real life, the operators of many such small dairy farms also engage in some custom work or have off-farm jobs. If the small dairy farm is viewed as a goods-and-services firm, not all of the annual cost of the operator's labor would be necessarily charged against the farm enterprises.

Taking all these income sources together, the small dairy farm in real life probably is not as inefficient as the sharply sloping envelope curve would imply. Nonetheless, the number of Iowa farms with fewer than 30 milk cows decreased sharply during the 1950's, while the number with 30 to 74 milk cows nearly tripled. Large dairies (75 cows or more) increased by only 38 percent during the decade (128, pp. 528-529).

Martin and Hill in a 1962 study attempted to provide an insight into the nature of the right-hand portions of the envelope curve for dairies (84). Dairy farms ranging in size from 30 to 611 cows, with a labor supply of from 1 to 13 men, were surveyed.

Initially, average costs were calculated for synthetic dairy firms, assuming management and production per cow typical of each size group. Figure 14 shows that the average costs (curve 5) declined sharply up to a herd size of about 150 head, falling gradually to a minimum of $4.86 per hundredweight of milk for a herd size of 250 to 350 head, and then rose to $5.27 per hundredweight as herd size approached 600 head.

For comparison, the budgets were recalculated, assuming above-average management and holding production at 12,000 pounds per cow, but still using the barn system typical of each size group. The resulting average cost curve (curve 4) was considerably lower and flatter than with typical management and production, reaching approximately minimum average cost of $4.68 per hundredweight at a herd size of 150 head, with a 3-man labor force. Average cost was found to be nearly constant over a wide range of farm sizes, from 150 cows to the largest size analyzed (600 cows), with the labor supply varying from 3 to 12 men, and with value of investment rising from about $100,000 to more than $350,000.

To establish the characteristics of the synthetic firms, a total of 37 carefully selected dairies were arranged in six size groups, depending on each dairy's milk

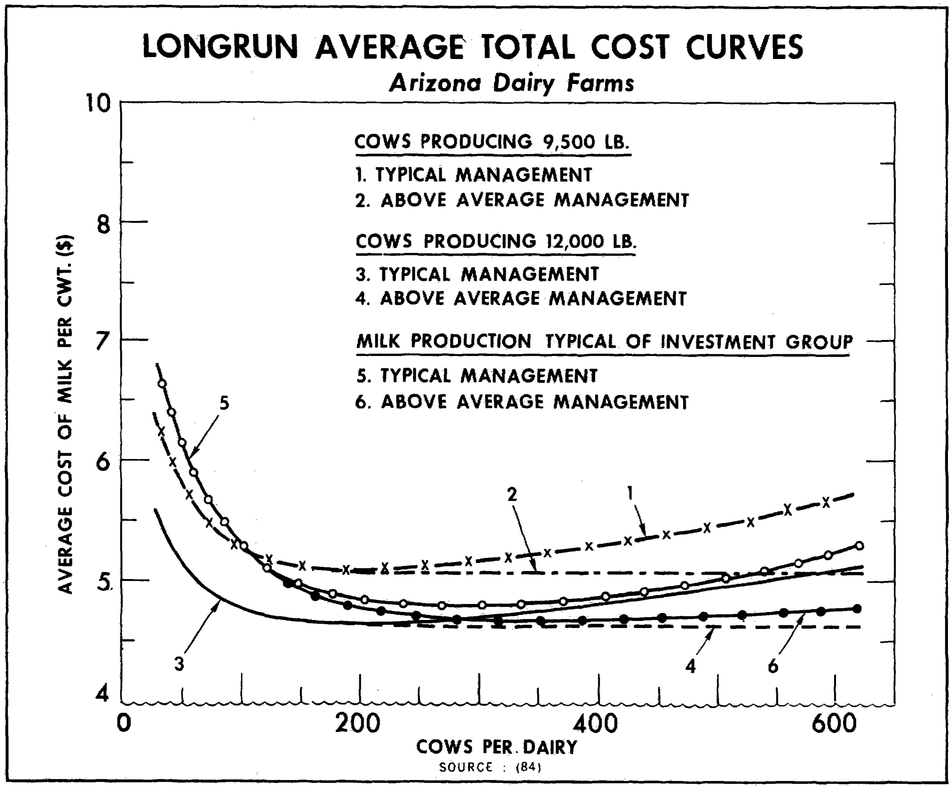


Figure 14

base (quota). Typical combinations of land, improvements, and dairy equipment were used to form a "representative" dairy farm for each of the six size categories. Each typical situation was adjusted to eliminate excess capacity, based on the carrying capacity of the milk barn and bulk tank. Investment costs used in calculating interest, depreciation, taxes, and insurance were based on current replacement costs. Yearly salary for hired labor was calculated at $4,800, including perquisites of about $725. Operator labor and management were included with risk-taking in the residual claimant.

Production per cow and cow prices were found to vary with herd size. A variety of assumptions were employed in the budgeting analysis to indicate cost curves with high-producing versus low-producing cows.

Survey data indicated that management difficulties typically began occurring near a herd size of 150 to 175 cows. This problem was manifested in three ways: (1) Feed waste increased with herd size; (2) it became difficult to vary the level of grain feeding relative to each cow's production as additional cows were added, because of the variation among cows, and (3) the manager's supervision and coordination duties became so difficult as the herd size and labor force increased that he had no time to look for savings in purchasing feeds. This seems to be an example of diseconomies of size. However, if the herd sizes and resource situations examined in this study had included the possibility of hiring additional management services and specialized purchasing personnel, some of these management problems might have been overcome, though probably with some rise in management costs. Type of milking barn on the survey farm varied with herd size. Stanchion barns were typical of dairies with fewer than 100 cows. Bucket-type milking machines were used on dairies ranging from 30 to 60 cows. Dairies with 60 to 100 cows used pipeline instead of bucket milkers. Milking parlors were typically found only on farms with more than 100 cows. The 3-stall, side-opening parlor was commonly used by 100- to 150-cow dairies. Walk-through parlors were used by most of the dairies with from 150 to over 600 cows. These typical milking barn systems were assumed in constructing the budgets for the different dairy sizes.

The analysis did not consider alternative milking-barn technologies for each size group. The herringbone parlor was not considered for any size group. Results of other studies indicate that even for dairies as small as 40 cows the milking parlor is considerably more efficient in the long run than the stanchion barn, and that the herringbone parlor is more efficient than other parlor systems in many cases (<u>17</u>, <u>3</u>). Therefore, the envelope curve which the planning firm in Arizona should consider is probably lower and flatter than suggested by the curves presented here, which reflect "typical" barn technologies for each size group. Employing advanced technology, the Arizona dairy farmer could probably achieve highly efficient production and realize most of the economies of size at a much smaller herd size than the 150-cow size indicated in this study.

Even so, the cost-efficiency relationships derived in this study are consistent with trends shown in the 1959 Census of Agriculture (<u>128</u>). The number of Arizona farms having less than 75 milk cows declined sharply during the 1950's, the number of farms with 75 to 99 cows remained stable, and dairies with 100 head or more tripled in number, rising from 40 to 126 farms. In 1959, five Arizona dairies had more than 500 cows.

Buxton conducted a completely synthetic analysis of Minnesota dairy farms in 1964, using linear programming to select the least-cost complement of machinery and the optimal farm plans for herd sizes up to 90 cows (17). 22/ Alternative farm enterprises considered were hogs, corn, and soybeans. The dairy enterprise accounted for at least 60 percent of gross income on the synthesized dairy farms. Several alternative housing and milking arrangements were considered. One-man systems included stanchion barns and three sizes of herringbone parlors (double-4, double-5, and double-6). The only 2-man system analyzed was a double-8 herringbone parlor. Operator labor and management were included with risk-taking in the residual claimant.

Virtually all the economies of size were achieved by a 1-man, 48-cow dairy, using a double-6 herringbone milking parlor (fig. 15). The farm plan called for more than $160,000 of investment capital, including 290 acres of land and a 3-plow tractor and complement of machinery. Average total cost per dollar of gross income was about $0.84 at this point, with a total return to the operator's personal services of almost $5,600.

The 2-man dairy achieved a slightly lower cost:revenue ratio of 0.82 with an 87-cow, 490-acre dairy farm. Net operator income was about $11,000 and resource requirements included more than $260,000 of investment capital.

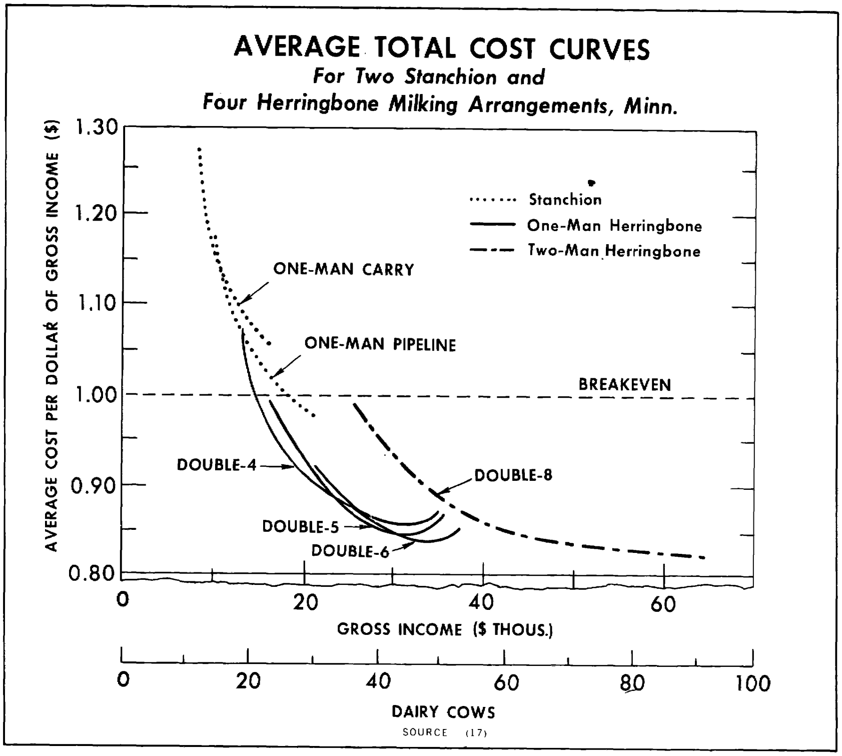


Figure 15

22/ Buxton is currently examining larger dairies--over 90 cows.

These results are relevant to the planning dairyman, because the analysis considered the highly efficient new milking-parlor technologies. The 1-man dairy can achieve considerable reductions in average cost by expanding herd size to about 48 cows. Only slight reductions are achieved as herd size is doubled and a regular laborer is hired. But because of larger volume, the total profit accruing to the 2-man dairy is about double that accruing to the 1-man unit.

During the 1950's, the number of Minnesota farms with fewer than 20 milk cows declined sharply. Number of farms with 20 to 29 head nearly doubled, and those having 30 to 99 milk cows quadrupled. The number of very large dairies remained small: in 1959, there were only 49 Minnesota farms with 100 or more milk cows, compared with 25 farms in 1950. Thus, it appears that although many Minnesota dairy farms are tending toward the more efficient and more profitable herd sizes, very few are venturing beyond the 100-cow size.

Results of the Four Dairy Studies

Results of the four studies discussed in this section are not directly comparable. First, the assumptions and procedures varied from one study to the next. Different depreciation schedules, salvage values, interest rates, and other input prices were used, and the studies varied as to whether operator labor and management were included in the residual claimant. Second, no common measure of average total cost is available. The cost per hundredweight of milk as presented in the New England and Arizona studies is not directly comparable with the cost:revenue ratio of the multiple product farms analyzed in the Iowa and Minnesota studies. Calculating the cost per hundredweight of milk for a multiple-product farm (as in the Iowa study) involves an arbitrary allocation of fixed costs to the dairy enterprise. Several alternative (and equally valid) criteria for allocating fixed costs are available, and each may give a slightly different answer. This difference in procedure further confounds the comparisons.

A third and more serious reason why the results of these four studies cannot be directly compared is that they differed in the degree to which the synthetic-firm economic-engineering approach was used. The Iowa and Minnesota studies considered modern milking parlor arrangements for all dairy sizes, not limiting the resource combinations to those found on existing farms. The Arizona study considered only the typical barn technologies for each size group as they were observed in the sample dairies. Likewise, the New England study considered only those technologies in use at the time (about 1950); these results are not applicable to today's planning firm.

The Iowa and Minnesota studies examined 1-man and 2-man dairies with herd sizes of less than 100 cows. Most of the economies of size were found to be attainable by a 40- to 50-cow dairy farm, provided the operator had sufficient management ability and could gain control of more than $150,000 of investment capital. The Minnesota study indicated that the 1-man dairy farm could realize little, if any, increase in efficiency by doubling farm size and hiring an additional worker, but the increase in volume would give rise to considerably higher profit.

In examining larger dairy farms, the Arizona study showed that resource variability became troublesome with a herd size of about 150 head, as it became difficult for the manager to see that each cow was fed according to her production. Also, as the supervision and coordination problems increased with the size of herd and the labor force, management experienced increasing difficulty in coping with feed price uncertainty, because there was not enough time for "shopping around" in buying feed. Thus, the larger Arizona dairies show how resource variability and uncertainty lead to serious problems for the limited coordination and supervision resources in the individual firm.

None of the empirical studies considered the possibility of hiring additional management resources. Nor did they consider the use of modern milking and housing systems for very large dairy farms. We do not yet know whether the increased complexity of a large, modern, well-organized dairy farm would require disproportionate increases in management inputs and costs. However, the 1959 Census of Agriculture (128) shows that the number of 30- to 100-cow dairies is increasing more rapidly than the number of larger dairies, and that relatively few firms are attaining the very large herd sizes. Thus, the survivorship principle (that only the most efficient sizes survive in the long run) suggests that very large dairies are not inherently more efficient than medium-sized dairies.

SELECTED REFERENCES

(1) Armstrong, David L., and J. Edwin Faris.
1964. Farm Machinery: Costs, Performance Rates, and Combinations, Southern San Joaquin Valley, California. Calif. Agr. Expt. Sta., Giannini Found. Res. Rpt. 273, Mar.

(2) Barker, Randolph.
1960. A Derivation of Average Cost Curves by Linear Programming. U.S. Dept. Agr., Agr. Econ. Res. 12(1): 6-12.

(3) ________, and Earl O. Heady.
1960. Economy of Innovations in Dairy Farming and Adjustments to Increase Resource Returns. Iowa Agr. and Home Econ. Expt. Sta. Res. Bul. 478, May.

(4) Blanchard, W. H., Glynn McBride, and A. L. Rippen.
1962. A Cost Analysis of Fluid Milk Packaging Operations. Mich. Agr. Expt. Sta. Tech. Bul. 285, Mar.

(5) Boles, James N.
1958. Economies of Scale for Evaporated Milk Plants in California. Calif. Agr. Expt. Sta., Hilgardia 27(21): 621-722.

(6) Boulding, Kenneth E.
1955. Economic Analysis. 3d ed. Harper, New York.

(7) Brems, Hans.
1952. A Discontinuous Cost Function. Amer. Econ. Rev. 42(4): 577-586.

(8) Bressler, Raymond G.
1942. Economies of Scale in the Operation of Country Milk Plants With Special Reference to New England. New England Research Council on Marketing and Food Supply, Boston.

(9) ________
1945. Research Determination of Economies of Scale. Jour. Farm Econ. 27(3): 526-539.

(10) ________
1950. Efficiency in the Production of Marketing Services. Univ. Chicago, Soc. Sci. Council Proj. in Agr. Econ., Econ. Efficiency Ser. Paper No. 6.

(11) ________
1952. City Milk Distribution. Harvard Econ. Studies, v. 91, Harvard Univ. Press, Cambridge.

(12) ________
1952. Efficiency in Fruit Marketing: Marketing Costs for Deciduous Fruits. Calif. Agr. Expt. Sta., Giannini Found. Agr. Econ. Mimeo. Rpt. 127, May.

(13) Bressler, Raymond G., and Benjamin C. French.
1952. Efficiency in Fruit Marketing: Grading Costs for Apples and Pears. Calif. Agr. Expt. Sta., Giannini Found. Agr. Econ. Mimeo. Rpt. 128, June.

(14) ________, and D. O. Hammerberg.
1942. Efficiency of Milk Marketing in Connecticut. 3. Economics of the Assembly of Milk. Conn. Agr. Expt. Sta. Bul. 239.

(15) Brewster, John M.
1950. The Machine Process in Agriculture and Industry. Jour. Farm Econ. 32(1): 69-81, Feb.

(16) ________
1954. Comparative Economies of Different Types of Cottonseed Oil Mills and Their Effects on Oil Supplies, Prices, and Returns to Growers. U.S. Dept. Agr., Agr. Mktg. Serv., Mktg. Res. Rpt. 54, Feb.

(17) Buxton, Boyd M.
1964. Economies of Size in Dairy Farming. Univ. Minn., St. Paul. Farm Business Notes 467, Nov.

(18) Carter, Harold O., and Gerald W. Dean.
1960. Income, Price, and Yield Variability for Principal California Crops and Cropping Systems. Calif. Agr. Expt. Sta., Hilgardia 30(6): 175-218.

(19) ________, and Gerald W. Dean.
1961. Cost-Size Relationships for Cash Crop Farms in a Highly Commercialized Agriculture. Jour. Farm Econ. 43(2): 264-277.

(20) ________, and Gerald W. Dean.
1962. Cost-Size Relationships for Cash Crop Farms in Imperial Valley, California. Calif. Agr. Expt. Sta., Giannini Found. Res. Rpt. 253, May.

(21) Chamberlin, Edward H.
1936. The Theory of Monopolistic Competition: A Re-orientation of the Theory of Value. Appendix B: The Cost Curve of the Individual Producer. 2d ed. Harvard Univ. Press, Cambridge.

(22) ________
1948. Proportionality, Divisibility, and Economies of Scale. Quart. Jour. Econ. 62(2): 229-262, Feb.

(23) Chenery, Hollis B.
1949. Engineering Production Functions. Quart. Jour. Econ. 63(4): 507-531.

(24) ________
1953. Process and Production Functions From Engineering Data. In Leontief, Wassily, and others, Studies in the Structure of the American Economy: Theoretical and Empirical Explorations in Input-Output Analysis, pp. 297-325. Oxford Univ. Press, New York.

(25) Clapham, J. H.
1922. Of Empty Economic Boxes. Econ. Jour. 32(127): 305-314.

(26) ________
1922. The Economic Boxes: A Rejoinder. Econ. Jour. 32(128): 560-563.

(27) Cooper, Martin R.
1953. That Extra Machine May Pay in the Long Run. U.S. Dept. Agr., Agr. Situation 37(4): 7-8, 16, April.

(28) Cooper, W. W., and A. Charnes.
1954. Silhouette Functions of Short-Run Cost Behavior. Quart. Jour. Econ. 68(1): 131-150.

(29) Davis, Bob, and J. Patrick Madden.
1965. Theory and Procedures for Studying Economies of Size on Irrigated Cotton Farms of the Texas High Plains. Tex. Agr. Expt. Sta., MP-780, Aug.

(30) Dean, Gerald W., and Harold O. Carter.
1960. Cost-Size Relationships for Cash Crop Farms in Yolo County, California. Calif. Agr. Expt. Sta., Giannini Found. Agr. Econ. Mimeo. Rpt. 238, Dec.

(31) ________, and Harold O. Carter.
1963. Economies of Scale in California Cling Peach Production. Calif. Agr. Expt. Sta. Bul. 793, Feb.

(32) Dean, Joel.
1941. The Relation of Cost to Output for a Leather Belt Shop. Natl. Bur. Econ. Res., New York. Tech. Paper No. 2, Dec.

(33) Dennis, Carleton C.
1963. Long-Run Equilibrium in Tart Cherry Production. Mich. Agr. Expt. Sta. Tech. Bul. 291.

(34) Donald, James R., and Charles E. Bishop.
1957. Broiler Processing Costs: A Study of Economies to Scale in the Processing of Broilers. N.C. Agr. Expt. Sta., A. E. Inform. Ser. 59, June.

(35) Eidman, V. R.
1965. Optimum Production Plans for California Turkey Growers With Change-constrained Programming. Univ. Calif., Berkeley, unpublished Ph. D. thesis.

(36) Faris, J. Edwin, and David L. Armstrong.
1963. Economies Associated With Size, Kern County Cash-Crop Farms, California. Calif. Agr. Expt. Sta., Giannini Found. Res. Rpt. 269, Dec.

(37) Farrell, M. J.
1957. The Measurement of Productive Efficiency. Roy. Statis. Soc. Jour., Ser. A (General), v. 120, part 3, 253-281, London.

(38) Farrish, R. O. P., and S. K. Seaver.
1959. Factors Affecting the Output, Size, Costs and Location of Poultry Plants in Southern New England. 1. Costs, Efficiency and Economies of Scale in Broiler Processing Plants. Conn. Agr. Expt. Sta. Bul. 342, Sept.

(39) Fellows, I. F., G. E. Frick, and S. B. Weeks.
1952. Production Efficiency on New England Dairy Farms. 2. Economies of Scale in Dairying--An Exploration in Farm Management Research Methodology. Conn. Agr. Expt. Sta. Bul. 285, Feb.

(40) Ferguson, Allen R.
1950. Empirical Determination of a Multidimensional Marginal Cost Function. Econometrica 18(3): 217-235, July.

(41) French, Benjamin C.
1952. Packing Costs for California Apples and Pears. Calif. Agr. Expt. Sta., Giannini Found. Agr. Econ. Mimeo. Rpt. 138, Oct.

(42) ________
1953. Efficiency in Fruit Marketing: Costs of Lidding Packed Fruit Boxes Influenced by Type of Equipment, Size of Plant, Length of Season. Calif. Agr. 7(1): 10-12, Jan.

(43) ________
1953. Economic Efficiency in California Pear Packing Plants. Unpublished doctoral dissertation, Univ. Calif., Berkeley.

(44) ________, and D. G. Gillette.
1959. Cost of Assembling and Packing Apples as Related to Scale of Operation. Mich. Agr. Expt. Sta. Tech. Bul. 272, Aug.

(45) ________, and L. L. Sammet.
1954. Efficiency in Fruit Marketing: Wage Plans and Efficiency in Grape Packing. Calif. Agr. Expt. Sta., Giannini Found. Agr. Econ. Mimeo. Rpt. 173, Oct.

(46) ________, L. L. Sammet, and R. G. Bressler.
1956. Economic Efficiency in Plant Operations With Special Reference to the Marketing of California Pears. Calif. Agr. Expt. Sta., Hilgardia 24(19): 543-721.

(47) Giaever, Harald, and James Seagraves.
1960. Linear Programming and Economies of Size. Jour. Farm Econ. 42(1): 103-117, Feb.

(48) Gottlieb, Manuel.
1960. On the Short-Run Cost Functions. Jour. Indus. Econ. 8(3): 241-248.

(49) Haavelmo, Trygve.
1960. The Number of Firms Problem. In A Study in the Theory of Investment, pp. 309-314. Univ. Chicago Press, Chicago.

(50) Hart, Albert G.
1942. Risk, Uncertainty, and the Unprofitability of Compounding Probabilities. In Lange, Oscar Richard, and others, eds., Studies in Mathematical Economics and Econometrics, Univ. Chicago Press, Chicago.

(51) Heady, Earl O.
1952. Economics of Agricultural Production and Resource Use. Prentice-Hall, Inc., New York.

(52) ________
1953. Technical Scale Relationships and Farm Size Policy. South. Econ. Jour. 19(3): 353-364.

(53) ________
1956. Budgeting and Linear Programming in Estimating Resource Productivity and Cost Relationships. In Heady, Earl O., Glenn L. Johnson, and Lowell S. Hardin, eds., Resource Productivity, Returns to Scale, and Farm Size, pp. 67-81. Iowa State Col. Press, Ames.

(54) ________
1956. Relationship of Scale Analysis to Productivity Analysis. In Heady, Earl O., Glenn L. Johnson, and Lowell S. Hardin, eds., Resource Productivity, Returns to Scale, and Farm Size, pp. 82-89. Iowa State Col. Press, Ames.

(55) ________, and Wilfred Candler.
1958. Linear Programming Methods. Iowa State Col. Press, Ames.

(56) ________, Glenn L. Johnson, and Lowell S. Hardin.
1956. Resource Productivity, Returns to Scale, and Farm Size. Iowa State Col. Press, Ames.

(57) ________, and Ronald D. Krenz.
1962. Farm Size and Cost Relationships in Relation to Recent Machine Technology. Iowa Agr. and Home Econ. Expt. Sta. Res. Bul. 504, May.

(58) ________, and Laurel D. Loftsgard.
1957. Farm Planning for Maximum Profits on the Cresco-Clyde Soils in Northeast Iowa, and Comparison of Farm and Nonfarm Incomes for Beginning Farmers. Iowa Agr. Expt. Sta. Res. Bul. 450, Apr.

(59) ________, Dean E. McKee, and C. B. Haver.
1955. Farm Size Adjustments in Iowa and Cost Economies in Crop Production for Farms of Different Sizes. Iowa Agr. Expt. Sta. Res. Bul. 428, May.

(60) Henderson, John S.
1953. Marginal Productivity Analysis--A Defect and a Remedy. Econometrica 21(1): 155-168.

(61) Henry, W. F.
1961. Effects of Farm Size on Costs in Assembly and Processing of Broilers. Unpublished doctoral dissertation, Harvard Univ., Cambridge.

(62) Hicks, John R.
1946. Value and Capital: An Inquiry Into Some Fundamental Principles of Economic Theory. 2d ed. Clarendon Press, Oxford.

(63) Hole, Erling, and James Vermeer.
1963. Wheat Growers' Machinery Costs, by Size of Farm, in Central North Dakota. U.S. Dept. Agr., Agr. Econ. Rpt. 24, Feb.

(64) Hopkin, John A.
1958. Economies of Size in the Cattle-Feeding Industry of California. Jour. Farm Econ. 40(2): 417-429.

(65) Hunter, Elmer C., and J. Patrick Madden.
1966. Economies of Size for Specialized Beef Feedlots in Colorado. U.S. Dept. Agr., Agr. Econ. Rpt. 91, May.

(66) Ihnen, Loren, and Earl O. Heady.
1964. Cost Functions in Relation to Farm Size and Machinery Technology in Southern Iowa. Iowa Agr. and Home Econ. Expt. Sta. Res. Bul. 527, May.

(67) Jantzen, Ivar.
1939. Basic Principles of Business Economics and National Calculation. G. E. C. Gad, Copenhagen.

(68) ________
1948. Laws of Production Costs. Report of the Washington Meeting, Sept. 6-8, 1947. Econometrica 16(1): 44-48.

(69) Johnson, Glenn L.
1956. Problems in Studying Resource Productivity and Size of Business Arising From Managerial Processes. In Heady, Earl O., Glenn L. Johnson, and Lowell S. Hardin, eds., Resource Productivity, Returns to Scale, and Farm Size, pp. 16-23. Iowa State Col. Press, Ames.

(70) Kaldor, Nicholas.
1934. The Equilibrium of the Firm. Econ. Jour. 44(173): 60-76.

(71) Kendall, M. G.
1947. The Advanced Theory of Statistics. Griffin & Co., London.

(72) Kimball, N. D., and G. A. Peterson.
1964. Economic Evaluation of Alternatives for Developing Large Dairy Farms in Wisconsin. Wis. Agr. Expt. Sta. Bul. 571, July.

(73) King, Gordon A.
1962. Economies of Scale in Large Commercial Feedlots. Calif. Agr. Expt. Sta., Giannini Found. Res. Rpt. 251, Mar.

(74) Knight, Frank.
1921. Risk, Uncertainty, and Profit. Houghton Mifflin Co., Boston and New York.

(75) Kohout, J. C., and J. C. Headley.
1962. The Relation of Cost and Farm Size on Western Illinois Livestock Farms. Ill. Agr. Econ. 2(2): 16-22.

(76) Lee, Deane.
1962. Large Dairy Farms in Massachusetts. Mass. Agr. Expt. Sta., Agr. and Food Econ. Prog. Rpt. on Res., Dept. Ser. 1.

(77) Loftsgard, Laurel D., and Earl O. Heady.
1959. Application of Dynamic Programming Models for Optimum Farm and Home Plans. Jour. Farm Econ. 41(1): 51-62.

(78) Logan, Samuel H., and Gordon A. King.
1962. Economies of Scale in Beef Slaughter Plants. Calif. Agr. Expt. Sta., Giannini Found. Res. Rpt. 260, Dec.

(79) MacFarlane, David L.
1950. Notes on the Scale of the Firm: Its Meaning, Measurement, and Usefulness in Research. Univ. Chicago, Soc. Sci. Res. Council Proj. in Agr. Econ., Econ. Efficiency Ser. Paper No. 11.

(80) Madden, J. Patrick, and Bob Davis.
1965. Economies of Size on Irrigated Cotton Farms of the Texas High Plains. Tex. Agr. Expt. Sta. Bul. B-1037, June.

(81) Maier, Melvin G., and Laurel D. Loftsgard.
1964. Potato Production Costs and Practices in the Red River Valley. N. Dak. Agr. Expt. Sta. Bul. 451, Sept.

(82) Markowitz, Harry M., and Alan S. Manne.
1957. On the Solution of Discrete Programming Problems. Econometrica 25(1): 84-87.

(83) Martin, William E., and William K. Goss.
1963. Cost-Size Relationships for Southwestern Arizona Cattle Ranches. Ariz. Agr. Expt. Sta. Tech. Bul. 155, Nov.

(84) ________, and James S. Hill.
1962. Cost-Size Relationships for Central Arizona Dairies. Ariz. Agr. Expt. Sta. Tech. Bul. 149, Sept.

(85) Mayer, Leo V., Earl O. Heady, and Loren Ihnen.
1963. Why the Rapid Farm Adjustments in Southern Iowa? Iowa Farm Sci. 18(5): 575-578.

(86) McCorkle, Chester O., Jr.
1953. Northern Kern County Cotton-Potato Farms. 2. Costs, Returns, and Scale of Operation. Calif. Agr. Expt. Sta., Giannini Found. Agr. Econ. Mimeo. Rpt. 143, Jan.

(87) Miller, Thomas A., and Charles W. Nauheim.
1964. Linear Programming Applied to Cost Minimizing Farm Management Strategies. Jour. Farm Econ. 46(3): 556-566.

(88) Moore, Charles V.
1965. Income Variability and Farm Size. U.S. Dept. Agr., Agr. Econ. Res. 17(4): 108-115.

(89) ________
1965. Economies Associated With Size, Fresno County Cotton Farms. Calif. Agr. Expt. Sta., Giannini Found. Res. Rpt. 285, Nov.

(90) ________, and Trimble R. Hedges.
1963. Economics of On-Farm Irrigation Water Availability and Costs and Related Farm Adjustments. 2. Farm Size in Relation to Resource Use, Earnings, and Adjustments on the San Joaquin Valley Eastside. Calif. Agr. Expt. Sta., Giannini Found. Res. Rpt. 263, June.

(91) Moran, Leo J.
1959. Nonfeed Costs of Arizona Cattle Feeding. Ariz. Agr. Expt. Sta. Tech. Bul. 138, Dec.

(92) Mueller, Allan G.
1964. How Many Acres for a One-Man Grain Farm? Univ. Ill. Coop. Ext. Serv. Farm Mangt. Facts and Opinions to Help You, No. 64-14, July.

(93) Nikolitch, Radoje.
1965. The Expanding and the Contracting Sectors of American Agriculture. U.S. Dept. Agr., Agr. Econ. Rpt. 74, May.

(94) ________
1965. The Adequate Family Farm--Mainstay of the Farm Economy. U.S. Dept. Agr., Agr. Econ. Res. 17(3): 84-89.

(95) Pawson, Walter W.
1964. Emerging Patterns of Feedlot Management in the Southwest, and Interregional Competition in the Location of Cattle Feeding. Talk prepared for delivery at Cattle Feeding Research Workshop, Denver, Colo., Mar. 16-18, 1964. Published by U.S. Dept. Agr., Econ. Res. Serv., Mktg. Econ. Div., Washington, D.C.

(96) Petit, James A., Jr., and Gerald W. Dean.
1964. Economics of Farm Feedlots in the Rice Area of the Sacremento Valley. Calif. Agr. Expt. Sta. Bul. 800, May.

(97) Pigou, A. C.
1922. Empty Economic Boxes: A Reply. Econ. Jour. 32(128): 458-465.

(98) ________
1927. The Laws of Diminishing and Increasing Cost. Econ. Jour. 37(146): 188-197.

(99) Reed, Robert H.
1959. Economic Efficiency in Assembly and Processing Lima Beans for Freezing. Calif. Agr. Expt. Sta., Giannini Found. Agr. Econ. Mimeo. Rpt. 219, June.

(100) ________, and L. L. Sammet.
1963. Multiple-Product Processing of California Frozen Vegetables. Part A: Analysis of Operations and Costs. Part B: Supplement. Labor and Equipment Standards and Requirements for Preparation and Packaging. Calif. Agr. Expt. Sta., Giannini Found. Res. Rpt. 264, July.

(101) Richards, Jack A., and Gerald E. Korzan.
1964. Beef Cattle Feedlots in Oregon--A Feasibility Study. Oreg. Agr. Expt. Sta. Spec. Rpt. 170, Mar.

(102) Robertson, D. H.
1924. Those Empty Boxes. Econ. Jour. 34(133): 16-31.

(103) ________
1930. Increasing Returns and the Representative Firm: A Symposium. Econ. Jour. 40(157): 79-116.

(104) Robinson, Austin.
1934. The Problem of Management and the Size of Firms. Econ. Jour. 44(174): 242-257.

(105) Robinson, Joan.
1934. Euler's Theorem and the Problem of Distribution. Econ. Jour. 44(175): 398-414.

(106) Rogers, George B., and Earl H. Rinear.
1963. Costs and Economies of Scale in Turkey Processing Plants. U.S. Dept. Agr. Mktg. Res. Rpt. 627, Sept.

(107) Rowe, Gordon A.
1952. Economics of Cheese Manufacturing in Tillamook County, Oregon. Oreg. Agr. Expt. Sta. Bul. 529, Dec.

(108) Sammet, L. L.
1953. Efficiency in Fruit Marketing: In-Plant Transportation Costs as Related to Materials Handling Methods--Apple and Pear Packing. Calif. Agr. Expt. Sta., Giannini Found. Agr. Econ. Mimeo. Rpt. 142, Jan.

(109) ________
1958. Economic and Engineering Factors in Agricultural Processing Plant Design. Unpublished doctoral dissertation, Univ. Calif., Davis.

(110) ________, and I. F. Davis.
1952. Efficiency in Fruit Marketing--Building and Equipment Costs, Apple and Pear Packing. Calif. Agr. Expt. Sta., Giannini Found. Agr. Econ. Mimeo. Rpt. 141, Dec.

(111) Saving, Thomas R.
1961. Estimation of Optimum Size of Plant by the Survivor Technique. Quart. Jour. Econ. 75(4): 569-607.

(112) ________
1962. The Estimation of the Optimum Scale of Enterprise. Unpublished doctoral dissertation, Univ. Chicago, Chicago.

(113) Schumpeter, Joseph.
1928. The Instability of Capitalism. Econ. Jour. 38(151): 361-386.

(114) Scoville, Orlin J.
1951. Relationship Between Size of Farm and Utilization of Machinery, Equipment and Labor on Nebraska Corn-Livestock Farms. U.S. Dept. Agr. Tech. Bul. 1037, Sept.

(115) Sorenson, V. L., and C. D. Keyes.
1962. Cost Relationships in Grain Plants. Mich. Agr. Expt. Sta. Tech. Bul. 292, East Lansing.

(116) Smith, Caleb A.
1942. The Cost-Output Relation for the U.S. Steel Corporation. Rev. Econ. Statis. 24(4): 166-174.

(117) Sraffa, Piero.
1926. The Laws of Returns Under Competitive Conditions. Econ. Jour. 36(144): 535-550.

(118) ________
1930. Increasing Returns and the Representative Firm--A Symposium. Econ. Jour. 40(157): 79-116.

(119) Staehle, Hans.
1942. The Measurement of Statistical Cost Functions: An Appraisal of Some Recent Contributions. Amer. Econ. Rev. 32(2): 321-333.

(120) Stigler, George J.
1939. Production and Distribution in the Short-Run. Jour. Polit. Econ 47: 305-327.

(121) ________
1952. The Theory of Price. Rev. ed. Macmillan, New York.

(122) ________
1958. The Economies of Scale. Jour. Law and Econ. 1(1): 54-71.

(123) Stippler, Henry H., and Emery N. Castle.
1961. Wheat Farming in the Columbia Basin of Oregon. Part 2. Costs and Returns on Specialized Wheat-Summerfallow Farms. Oreg. Agr. Expt. Sta. Bul. 578, Mar.

(124) Strickland, Percy L., Jr., James S. Plaxico, and William F. Lagrone.
1963. Minimum Land Requirements and Adjustments for Specified Income Levels, Southwestern Oklahoma. Okla. Agr. Expt. Sta. Bul. B-608, May.

(125) Swanson, Earl R.
1958. Programming Optimal Farm Plans. In Farm Size and Output Research--A Study in Research Methods. South. Coop. Ser. Bul. 56, June.

(126) Thair, P. J.
1950. Risk and Uncertainty in Relation to Economic Efficiency. Univ. Chicago, Soc. Sci. Res. Council Proj. in Agr. Econ., Econ. Efficiency Ser. Paper No. 7.

(127) Thor, Eric.
1956. The Application of Economic-Engineering Research Techniques in Planning Fruit and Vegetable Packing Plants With Special Reference to Florida Citrus. Unpublished doctoral dissertation, Univ. Calif., Berkeley.

(128) U. S. Bureau of the Census.
1961. U.S. Census of Agriculture: 1959. Vol. I. U.S. Govt. Printing Off.

(129) ________
1962. U.S. Census of Agriculture: 1959. Vol. V. Special Reports Part 5, 1960 Sample Survey of Agriculture. U.S. Govt. Printing Off.

(130) ________
1962. U.S. Census of Agriculture: 1959. Vol. II, General Report of Statistics by Subjects. U.S. Govt. Printing Off.

(131) Upchurch, M. L.
1961. Implications of Economies of Scale to National Agricultural Adjustments. Jour. Farm Econ. 43(5): 1239-1249.

(132) Van Arsdall, Roy N.
1963. The Effect of Unit Size on Cattle-Feeding Profits. Paper presented at Agricultural Industries Forum, Univ. Ill., Urbana, Jan. 29, 1963. Univ. Ill. Dept. Agr. Econ.

(133) ________
1963. Guides for Use in Planning Beef Feeding Systems. Ill. Agr. Expt. Sta. Bul. AE-3971, Dec.

(134) ________
1964. Producing Beef in a 1,000-Head-Capacity System in Illinois. Paper prepared for 1964 Farmstead Mechanization Workshop, Univ. Ill. Dept. Agr. Econ.

(135) Viner, Jacob.
1931. Cost Curves and Supply Curves. From Zeitschrift fur Nationalokonomie, v. III. Reprinted in AEA Readings in Price Theory, v. VI, by Boulding, Kenneth E., and George J. Stigler, eds. Richard D. Irwin, Inc., Chicago, 1952.

(136) Walters, A. A.
1965. Production and Cost Functions: An Econometric Survey. Econometrica 31(1, 2): 1-66.

(137) White, C. Michael.
1960. Multiple Goals in the Theory of the Firm. In Boulding, Kenneth E., and W. Allen Spivey, eds., Linear Programming and the Theory of the Firm, pp. 181-201. Macmillan, New York.

(138) Whitin, T. M., and M. H. Peston.
1954. Random Variations, Risk, and Returns to Scale. Quart. Jour. Econ. 68(4): 603-612.

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