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CONSIDERATIONS FOR DETERMINATION OF THE OPTIMUM SIZE OF FARMS IN IRRIGATED AGRICULTURE

G. R. Soltani[1]

Invitational Paper

ABSTRACT

Major factors affecting the size of a farm and the conceptual framework for determination of its optimum are discussed. The use of a linear programming model for determination of optimum size of a farm in a developing region is described. It is indicated that management and distance from the market play an important role in determining farm size in developing regions. A procedure to study the influence of these two factors on farm size if presented.

INTRODUCTION

The purpose of thid paper is to discribe the use of budgeting and linear programming techniques in determination of the optimum size of a farm in irrigation agriculture in a developing country or region.

Optimum size is referred to as the size at which a particular farm achieves the most efficient operation. Optimizing criteion could be the minimum cost per unit of gross income. However, this criterion is not a sufficient condition for optimization. In all the practically important cases maximizing present value of net returns is a correct criterion to follow. Since this would be identical with the criterion of maximizing the rate of return on the entrepreneur's own capital.

Questions relating to the optimum size of a farm involves separate studies of the relation of size of farm to output and productivity in each location, under specific type and production situations. The results of these studies are therefore applicable to the area and types of farming for which they are conducted.

[1]Assistant Professor, Department of Agricultural Economics, College of Agriculture, Pahlavi University, Shiraz, Iran.

It is important to recognize the dynamic aspect of the optimum size of a farm. This means that the results obtained are time dated, being based on production practics and techniques employed during a specified period in time. Since quantitative combination of factors will change with changes in technology, time,price of factors, products, ect.

It should be noted that determination of the optimum size of a farm is not a simple undertaking. The method used and its results depend on the purpose of the researcher. That is, he may be interested in analysis of the size of a farm, in terms of acreage. In other words he may be interested in the number of units of land which should enter the combination of inputs in a particular area and under a specific type of farming. In some regions land may be a very critical factor in production; so it would be desirable to analyse the effects of certain limitations imposed upon land input on efficiencies of farming. Here it would be possible to assume certain relationships and specify conditions under which analysis are undertaken. Then linear programming can be applied to find out the optimum size of operation in terms of land area. That is, here the results would indicate that the optimum size lies within the specified range and it follows that this results could be generalized under such specifications.

Another question raised in the analysis of the optimum size of a farm is the assumption of diminishing returns to scale. Since diminishing returns to all factors together are not conceivable, the optimum size of a farm can not be determined unless at least one factor is fixed. Here diseconomies arising out of less than the proportionate increase in management input may be an important limiting factor. However, once we assume this fixity, then the concept of economies of scale will have a little meaning.

For the purpose of this analysis, the factors affecting the size of a farm and the general size-efficiency relationship will be discussed first. Following these discussions the theoretical framework and some of the techniques used in economies of size studies will be mentioned briefly. Finally, the procedure which can be followed in a programming approach will be outlined.

DETERMINANTS OF FARM SIZE

The following factors are likely to affect the resource combination and size of farms:

1. Risk and Uncertainty: Some authors believe that risk and uncertainty are inherent in farming and will tend to limit expansion of farms. They argue that expansion in size usually 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 farm and satisfactory incomes tend to "play it safe" to protect their current position. Some farmers may not be risk "avertors"; on the other hand, small farmers in less developed countries as a rule would try to avoid risk.

However, it is important to recognize that this factor (borrowed capital) imposes a limit in small as well as large farms. The effect of risk upon size depends upon the asset position of operators. Actually the limiting factor here is not risk, bu capital.

In agriculture on the one hand it could be argued that small farms are less money tied and hence less subject to risk. On the other hand large farms have more scope for diversification through which they can avoid risk to some extent.

The above condierations indicate that there is no simple functional relationship between the size of a farm and risk. Furthermore, this relation depends upon the type of uncertainty considered. For example, if uncertainty is brought about by weather conditions, large farms as a result of diversification will be in a more favorable position.

2. Managerial ability and distance from the market: Management has been mentioned as a limiting factor to farm enlargement. However, the precise functional relationship of management and farm size has not been estabilished by empirical studies. Cost of transportation plays an important role in limiting farm size (measured in land units). Cost of management and transportation in the farm increases progressively if farm size increases above a certain level. In some cases scarce management would tend to favor farm enlargement.

Management is one of the major limiting factors in the development of modern irrigated agriculture in developing countries. For example, of the three limiting factors in the agricultural development of Iran-foriegn exchange, capital management and skill, only the last factors may prove to be serious. Therefore, it is essential to effectively utilize the services of this resource in agriculture. The question raised here is: how large the farm size should be to achieve this objective?

3. Availability of Irrigation: It is argued that irrigation in semi-arid areas may intensify farming and reduce farm size in terms of acreage. In view of the availability of modern irrigation techniques (i.e. sprinkler irrigation) this argument is not likely to be valid.

4. Government Support Programs: such as stable prices and research and agricultural extension programs may encourage farm enlargement.

5. Indivisibility Introduced by substituting heavy machinery for numan labor: This pressures for larger acreage than if only human labor is used. In this case many small farms will have substantial high costs due to under-utilization of a large investment in equipment.

6. Relative Price of Labor and Capital and the effects of capital inputs on output: Changes in resource costs over time may have major effects on the sizes of farms and factor proportion. In the U.S. for example, the average size of a farm measured in land area has doubled in the last 25 years (1). A major factor in this trend has been the movement of farm people to other occupations where income earning opportunities were better than those in farming. This has resulted in decreasing costs of machinery and other capital goods relative to costs of labor. However, critical factors affecting the size of farms in the U.S. obviously differs in other developing countries. In these countries the extent of industrial development and the amount of labor which can be absorbed in the modern sector affect the farm size. For example, even a very fast rate of growth, accompanied by a rapid rise in both population and productivity, may not create sufficient jobs to absorb the surplus labor in the traditional sector (agriculture) in Iran.

7. Social or community ends with respect to the farm size: Although in this study the economic questions relating to the optimum size of farms are considered (i.e. the efficiency aspects of a farming operation). Other objectives of the society may not be in harmony with that of the economic goal. This will be discussed later.

SIZE-EFFICIENCY RELATIONSHIPS

Mechanization and the technical change in agriculture have placed new emphasis on the important economies of scale to be achieved through expanding the farm size. However, it has been argued that efficiency in farming is not necessarily obtained by farm enlargement. The basic argument is that technological changes that are economically efficient at current factor prices such as better water management, fertilizer, and improvement of plant varieties do not necessarily require the expansion of farm size. These technologies are "land saving" as opposed to mechanization which may be "labor saving". Also, the mechanization of some operations can be done through cooperative ownership or rental without changing farm size. Usually, the economics of scale do not obtain to the same extent in all farming operations; and there exists numerous possibilities of farm organization.

It should be noted, however, that questions about the appropriate sizes of farms can not be answered on a priority basis. They need to be examined in connection with economic conditions of particular countries and types of farming. While, in some types of farming such as plantation, efficiency will be attained only with size enlargement; in other farming operations efficiency could be attained by intensification of operations.

The efficiency problems relating to farm size is one of deciding in what quantities and proportions scarce resources need to be combined on farm units to achieve least-cost expansion of farm production. Differences among countries and regions in the relative supplies and costs of factors (i.e. opportunity costs of scarce resources) affect the factor proportions that are most economic, and may influence the optimum size of farms. This indicates that the size-productivity relationship will differ in different regions and countries.

Farming efficiency may be incompatible with equity if increasing returns to scale or decreasing cost economies prevail (1). While under the conditions of decreasing returns to scale, the efficiency and equity goal may be in harmony; and with constant returns these two ends are independent.

THEORETICAL BASIS

Any attempt in determining the optimum size of farms must take into account cost-size relationships. The economic theory underlying the analysis of farm size is illustrated in terms of economies of scale. Economies of size analysis is usually undertaken in terms of short-run and long-run situations. Short-run economies are stressed as resulting from fuller utilization of a fixed plant. While long-run economies are resulting from efficiencies obtained by changing plant size, involving a longer time period. For studying trends in farm size, the long-run average cost curve (planning curve) is probably most relevant. Space does not permit a detailed discussion of the theory underlying economies of scale. A thorough treatment of the subject can be found in the literature (4,7).

METHODS OF ANALYSIS

To provide insight into the question of the most efficient or optimum size of farms requires estimation of the long-run planning curves of different farms. Research approaches which may be employed are: The survivor technique, regression analysis, production function approach and programming technique. Due to the limited space, only the last approach is presented here. A detailed discussion of the use of regression analysis and the survivor technique in determining the optimum size of farms can be found elsewhere (5,6). Because of inaccuracy and insufficient data and other weaknesses these techniques are not appropriate for analysis of the farm size in developing countries.

Using a linear programm ;g technique in a synthesized operation of different farm sizes. Linear programming is an efficient tool for the analysis of cost-size relationship when there are several limiting factors (as in the case of developing countries) and a large number of enterprises or alternative techniques. This technique is particularly useful in the farming of developing regions where the needed data is usually lacking and alternative assumptions regarding technical coefficients and prices can be introduced in the analysis. In this approach, budgets are developed for hypothetical farms using the best available estimates of the technical coefficients, resource requirements and expected yields and charging market prices or opporotunity costs of all resources.

POSSIBLE STEPS TO FOLLOW

1. Specific plant sizes, representing different levels of fixed resources are recognized (e.g. machine power units, managerial and skilled man power, etc.)
2. For each level plant size and output (gross income) it is possible to compute the least-cost combination of product and variable resources for that specific plant and level of gross income, using a cost-minimizing linear programming model. The cost function obtained in this fashion, under existing efficient technology for each crop, and within specified resources, rotation and institutional restrictions represents the "optimum" or minimum-cost product mixes (cropping systems) for attaining each level of output.
3. Several points on the short-run cost curve are determined by setting the level of gross income at various levels (representing different degrees of plant utilization) and computing linear programming solutions. A short-run average cost curve is plotted for a specific plant size in this way. Then the envelope curve is plotted as the tangency of the short-run cost curves by freehand, or by estimating a regression curve for the quantities representing the points. Therefore the programming technique determines the least-cost method of producing specified levels of gross income with certain size determining fixed resources.

The appropriate levels of gross income for a given plant size may be determined by trial and error. Other points needed to specify cost curve are obtained by the basic cost-minimization model.

The accuracy of this method depends on: (1). The prices which are used and (2). The input-output ratios estimated before. In developing regions it is important that solutions be obtained for a range of input-output and price estimates (by parametic programming). This is due to the inaccuracy of most data and uncertainty inherent in farming (yield and price uncertainty).

The model described above could be shown symbolically as follows:

$$\text{Minimize} \quad \sum_{j=1}^{n} bjyj$$

Subject to:

1. $\sum_{j=1}^{n} aijyj \leqslant mi$

2. $\sum_{j=1}^{n} rjyj = M$ a specified level of gross income

3. $yj \geqslant 0$ for all j

4. and several other institutional or economic constrainsts imposed upon the farming operation.

Where: aij = technical input-output coefficients, bj(variable costs); rj(average gross revenue for real activities), and mi(resource constaint levels) are predetermined data. The problem would be to determine the activity levels yj such that the above constraints hold.

The major task in the programming approach would be to improve the basic data required, and set up the problem. Improvement of basic data involves selecting repressentative cost and price coefficients, collecting and interpreting field observations, making full use of experimental results from physical production research, and fully utilizing the synthetic techniques that combine into a process the field observations and experimental results by experienced judgment.

The synthetic approach might well show the efficiency achievable for different farm sizes under the ideal conditions assumed, but it would be difficult to use this method in estimating the economies achievable by any group of farmers, taking into account their individual abilities, uncertainties, and adjustment opportunities.

Numerous programming techniques have been used in the economies of size studies in the highly sophisticated irrigation agriculture of California and other regions of the U.S. For example, Carter and Dean (3) used variable capital programming and calculated the maximum gross income per dollar of capital for various levels of investments.

In another study (2) they analysed the economies of size for cash crop farms in Yolo County, California near Woodland. The main crops grown in the study area were: sugar beets, tomatoes, milo barley, alfalfa and safflower. Their model selected the optimum (least-cost per dollar of gross income) combination of enterprise levels for each level of output.

APPLICATION TO A DEVELOPING REGION

Although management and transportation costs play an important role in determining farm size, the examination of the relation between farm size and these factors has been ignored in the studies mentioned above. As indicated earlier skilled managers and agricultural personnel are among the major limiting factors in the development of modern irrigated agriculture in the developing regions. It is therefore important to effectively use the services of skilled people.

In order to study the influence of management on farm size one possible approach may be to assume different input-output coefficients in the programming model reflecting different levels of management and to recognize skilled man power along other factors as limiting resources.

To examine the relationship between farm size (measured in land units) and distance from the market requires the intorduction of transportation cost on the farm level. For example, it would be possible to formulate an activity of transporting proudcs to the market in the programing model. Here the activity level would be charged with the actual cost of transportation in the region (depending on the transport rates and distance from the market).

SUMMARY

Many factors affect the appropriate size of farms in irrigated agriculture, among which the decline in the costs of capital relative to that of labor and technological improvements in agriculture appear to favor farm enlargement. Also the shortage of skilled labor and management is likely to favor farm size expansion in a developing country.

To determine the optimum size of farms the conditions and relationships under which farming operations are undertaken should be specified. Since the most efficient size of a farm will differ in different locations and under different types of farming and production situations, the optimum size of farms can be determined by specifying certain relationships and conditions. The results obtained under such specifications can therefore be generalized.

Several research methods have been traditionally employed in economies of size analysis. It appears that where the number of alternative choices are few the synthetic firm can be constructed and budgeting techniques employed. Where a large number of enterprises, or alternative techniques or levels of resources are considered, programming would be a more useful tool. This technique is particularly useful for the analysis of farm size in a developing region where the basic data is usually lacking and a number of limiting resources are present. This approach involves specification of different sizes

of farms and output levels and using a cost-minimizing programming model. Hence, the resultant size obtained here would be a size with minimum cost for producing a unit output.

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