CHAPTER 2

EFFICIENCY, CAPACITY, ELASTICITY, AND INTENSITY

Relationship of Land to the Firm

Much of the confusion at present existing in the use of the tools of analysis can be traced to the failure of agricultural economists to distinguish between land as a form of capital and the firm as an economic organization. Concepts which apply peculiarly to the firm have been applied to land, and economic and physical concepts have been confused. The following statements from a well-known textbook are indicative of this conceptual and terminological confusion:

"Within a given area of very similar land value, an office building, a hotel, a department store, a theatre, a filling station, and even a parking lot may exist side by side . . . The office building sells space . . . and to get the maximum of space economically a towering structure is necessary. The department store sells merchandise and space is subordinate to that function; the result is a building of moderate height. In this case the *capacity of the land* (italics mine) is much less than for the skyscraper; it is still less for the filling station and is practically non-existent for the parking lot.

"The productivity of land is two-dimensional and consists of capacity and efficiency. . . Some land can absorb only a few inputs of labor and capital but each unit returns a large output; the reverse is true for other types of land use. The skyscraper calls for high capacity and moderate efficiency, . . . whereas the filling station can operate at a low capacity but has extremely high returns for every dollar of input. . . .

"The same differences in capacity and efficiency of land may be found in agriculture."[1]

[1] Richard T. Ely and George S. Wehrwein, *Land Economics*, The Macmillan Co., New York, 1940, pp. 129 and 130.

The erroneous character of this analysis is easily laid bare. If the land is in a "given area of very similar land values" it would seem that the land is for all practical purposes identical, and any differences in the uses of different parcels are due entirely to the differences between firms and have nothing directly to do with the land as such. By a parallel reasoning process one might speak of iron, using a pound as a measuring unit, and compare a sewing machine, a farm tractor, and a cast iron roller, proceeding to the absurd conclusion that the iron in the sewing machine has a high capacity but low efficiency, in the tractor it has a lower capacity but greater efficiency, while in the roller it has almost no capacity but high efficiency. It is plainly inadmissable that the iron is not identical in all cases, and that the differences result from the combination with it of labor and other factors directed towards achieving entirely different purposes.

Furthermore, physical efficiency and economic efficiency are not rigidly related. For example, one engine might deliver more horsepower per gallon of fuel than another and therefore might be physically more efficient in turning fuel into horsepower; but if the price of the engine in question were extremely high it might be much less efficient in yielding horsepower per dollar.

Efficiency

The most useful sense of the term *efficiency* may have reference to the comparative *net returns* to the factors of production; for example, the most efficient entrepreneur tends to obtain the highest rate of profits, the most efficient land to obtain the highest rent per unit, and the most efficient labor to obtain the highest rate of wages.[2] Such differences in ability to

[2] Efficiency is a result of heterogeneïty of different units of the factor being considered; where the factor is homogeneous no difference in efficiency can occur. Moreover, physical efficiency is one thing and economic efficiency (*Footnote continued on page 22*)

earn returns are due to many factors; in the case of land they result from differences in physical productivity, location, relative scarcity, and the efficiency of any secondary production taking place in the farming system.[3] The physical efficiencies of various pieces of land can be compared only when identical physical units of input are applied to them and the same products are raised under identical managerial efficiency. Thus, differences in physical productivity may be much less important than location, management, character of product, and many other factors, singly or in combination, in determining net returns or rent. Under perfect competition the *marginal* economic efficiency of all factors of production becomes identical because the price of each factor will be such that under equilibrium conditions an added dollar of input of any one factor cannot yield more than an added dollar of input of any other factor.[4] However, a realistic analysis of land effi-

[2] (*Continued*)
another, and the independence of each concept can be well illustrated in the case of land. For example, an area of land might be homogeneous in physical productivity, but different rents and values on different parts of it tend to result from inequalities in the closeness of markets or good roads. Similarly, land in cities might contain soils varying greatly in their physical efficiency in producing corn, but they may, nevertheless, earn the same rent and have the same value for building purposes. In the first case the physical efficiency is identical but the economic efficiency differs, while in the second the economic efficiency is the same but the physical efficiency for growing corn differs.

[3] Secondary production refers to any agricultural production not directly derived from land. Primary production refers to the growing of crops. A farmer producing products from the soil for sale is engaged largely in primary production, while a farmer growing crops and feeding them to livestock is engaged in both primary and secondary production; a farmer using land as space and purchasing feed is largely engaged in secondary production. A cash grain farm represents primary production, a mixed farm producing both crops and livestock products represents a combination of both, while an intensive poultry farm where the land is largely used as exercise ground represents secondary production. This difference is also fundamental to an understanding of the relationship between intensity of land use and the intensity of agriculture.

[4] This is the concept of efficiency as defined by George M. Peterson in his book *Diminishing Returns and Planned Economy*, Ronald Press, New York, 1937, p. 63. Professor Peterson discards the concept of capacity as being useless, as formulated in the past. The weakness of past definitions, however, seems to be largely overcome by the use of the concept of elasticity, which is discussed at length in later sections of this chapter. While I agree with Professor Peterson's concept of the law of diminishing returns applying to the ideal combination of
(*Footnote continued on page 23*)

ciency can hardly emphasize the highly special case of perfect competition, which obscures many of the principal conditions affecting land values and returns in the actual world.

CAPACITY

Capacity refers simply to the ability of one factor of production to absorb inputs of other factors under a given organization of the firm at the highest profit combination. As in the case of efficiency, the capacities of two pieces of land can only be compared when identical applications of variable factors (including management) are applied and the same products are raised. A statement that two pieces of land vary in capacity, while assuming at the same time that the other factors of production are organized differently, cannot be conclusive, for the difference in capacity may result from differences in the firms, while the two pieces of land may be identical. In an economic sense, therefore, capacity represents the value, at the highest profit combination, of all other factors applied in a firm (or other similar unit of economic management) to a given factor selected as a basis of measurement. Thus we might say that the capacity of farm A is $10 an acre, while for farm B it is only $7 an acre; but we cannot say categorically that the capacity of land A is greater than that of land B unless identical units of input, of output, and of management are involved. In diagrammatic presentations capacity is represented by the length of the net or gross productivity rectangle at the point of the highest profit combination.[5]

[4] (*Continued*)
flexible factors in the long run, I also feel that, because agricultural land is relatively fixed (at least in operating units over short periods), farm size is relatively inflexible and that in order to simplify the problems and deal with them more realistically, the assumption of land as a fixed factor is justified. One of the most important difficulties arises from the fact that entrepreneurial ability may also be relatively fixed, and any realistic analysis must also consider the importance of this as it affects adjustments in the combination of factors.

[5] J. D. Black and A. G. Black, *Production Organization*, Henry Holt, New York 1929, p. 155.

It is important to realize that in most of the analyses that have been made of this problem, it is usually the capacity of the firm that is represented and that land is used solely as a unit of measurement. The term is similar to the "normal" concepts of the neoclassic theoretical tradition, and theoretically the "capacity" of a firm fluctuates with every change in the relative prices of products and factors; in this sense it is a concept almost as abstract as that of the intensive and extensive margins.

Elasticity of Production

The fatal weakness in the existing body of analysis of land productivity (or returns)[6] and the problems of the intensive and extensive margins of production seems to lie in the fact that agricultural economists have not made use of concepts which dealt with the slope of the total, marginal, and average returns curves in spite of the fact that the slopes of these curves are one of the important factors affecting changes in efficiency, capacity, and margins. *Elasticity of production*, in its simplest terms, reflects the ability of the farm business or plant to maintain its average returns as more and more units of variable factors are added. In essence the concept is similar to elasticity as applied to demand and cost curves.[7] If when the units of variable input are doubled the output also doubles, the elasticity of output is said to be unity. The

[6] The terms average and marginal *returns* seem preferable to average and marginal productivity when applied to economic phenomena, as this avoids confusing economic and physical concepts. Productivity may best be used to designate physical output, and returns to mean economic output.

[7] The concept of elasticity as applied to cost and supply is not new. It has been developed by Marshall and other economists but never utilized or applied in agricultural economics. Professor R. G. D. Allen has developed the concept in his treatise, *Mathematical Analysis for Economists*, Macmillan and Co., Ltd., London, 1938, pp. 260–64. The major difference in treatment is that the marginal and average productivity curves have been used here instead of the cost curves used by the above writer. Professor Stigler has further developed a similar concept using the term "adaptability," in his article "Production and Distribution in the Short Run," *Jour. Pol. Econ.*, Vol. XLVII, No. 3, June, 1939.

elasticity may be measured by the slope of the tangent to the curve of total returns when plotted on double logarithmic paper; up to the point of diminishing average returns the value would be greater than 1, and beyond that point it would be less than 1. A simple formula for average production elasticity between two points would be

$$\frac{\text{The \% change in total returns}^{8}}{\text{The \% change in units of input}}$$

In comparing two farm enterprises we might find that in case A the total product for one unit of input is \$10 and for two units of input it is \$15; the elasticity of production at this point would then be $\frac{50\%}{100\%}$ or 0.5. In case B, if one unit produced \$20 and two units of input produced \$35 then the elasticity would be $\frac{75\%}{100\%}$ or 0.75. When we compared farms A and B at 2 units of input, we would find the returns of A relative to B equal to $\frac{15}{35}$ or 3 to 7, whereas for one unit of

[8] Only as the limit of this ratio is reached do we obtain the measure of elasticity of a given point on the curve of total production. If Y = the total product and X = the units of input, the formula becomes the proportional increase in Y divided by the proportional increase in X or

$$\frac{\frac{\Delta Y}{Y}}{\frac{\Delta X}{X}}\text{; multiplying numerator by denominator,}$$

we get $\frac{\Delta Y}{\Delta X} \cdot \frac{X}{Y}$ and elasticity = limit of $\frac{\Delta Y}{\Delta X} \cdot \frac{X}{Y}$ as ΔX approaches

zero, or elasticity $= \frac{XdY}{YdX}$

input it has been $\frac{10}{20}$ or 1 to 2; the cause of this change in the relationship between the returns of A and B is the fact that the elasticities were different.[9]

These elementary relationships are stated here in order that the limitations of the use of the terms may be clearly seen. The relative returns of two firms vary at different inputs if their elasticities vary; the elasticities of output of two farm enterprises can be compared when the average and marginal returns at the same units of input are known. Relative returns are represented by the ratio of the ordinates of the average return curves for two farms at the same scale of input; the relative returns of the same farm at differing levels of input would be the ratio of the ordinates of the average returns curves at these points. Elasticity is related to the slope of both the marginal and average return curves. The exact relationship is that elasticity equals marginal returns divided by the average returns.[10]

As in the case of efficiency and capacity the elasticity of production can be applied in a physical sense to the productivity of land, and land having a high elasticity of output

[9] The fact that the figures 0.5 and 0.75 represent only average (or arc) elasticity between the units 1 and 2 must be kept in mind. Actually the elasticity would usually vary at every point on the curve. It can be the same for all inputs only when its function plotted on a logarithmic graph is a straight line, which is an impossibility if the principle of diminishing returns is applicable.

[10] Elasticity $= \frac{dY}{dX} \cdot \frac{X}{Y}$ or $\frac{dY}{dX} \div \frac{Y}{X}$, therefore, since marginal returns =

the limit of $\frac{Y_2 - Y_1}{X_2 - X_1}$ or $\frac{\Delta Y}{\Delta X}$ which becomes $\frac{dY}{dX}$ as ΔX approaches O,

and since average returns $= \frac{Y}{X}$, then elasticity $= \frac{\text{marginal returns}}{\text{average returns}}$

and all values up to the point of diminishing average returns will be above 1 and below it will be less than 1, while at the point of intersection of the marginal and average return curves the value will be 1.

would, over the range of high elasticity, be able to absorb many units of fertilizer or labor with comparatively little change in average productivity. Land with low elasticity would be subject to rapidly diminishing average productivity which would decline rapidly as additional units of input were added. In this case the elasticity of production of two pieces of land can be compared only when the same crop is grown and identical physical inputs and management are applied. In the economic sense elasticity of production refers to the dollar output of the total farm organization in relationship to any combination of variable factors with a constant fixed factor (or fixed set of factors) measured in terms of dollars.

Elasticity of Production and Fixed and Variable Factors

The basic factor affecting the elasticity of production for any given farm is the flexibility of the ratio of fixed to variable costs. In general an inflexible and high ratio of fixed to variable costs means low elasticity of production and vice versa. In the case of a cash grain farm where there is almost no processing of the produce of the land through feeding to livestock or other means (i.e., very little secondary production), almost all the factors of production may be fixed. Climate, the size of the farm, taxes, and family labor are relatively rigid, and the only significant variables are the quality and quantity of seed, of fertilizer, hired labor, and machinery. Assuming output to be at the highest profit combination, when an increase in price occurs further applications of the variable factors may be made; but the extra output for each additional input will decline rapidly, so that there is very little flexibility of the ratio of fixed to variable costs. In the case of a specialized dairy farm, where the land is largely in permanent pasture and concentrate feeds are purchased, the variable factors are much more numerous. Higher producing cows may be purchased, larger and better rations of concentrates may be fed, more roughage in the form of hay may be purchased, the size of the milking herd might be increased, and the ratio of variable to fixed costs is thereby increased. Thus, in response to a rise in price a large increase in milk production might take place with only a small increase in unit costs, and the return curves of the dairy farm would be much more elastic than those of the cash grain farm. A fruit ranch would generally have a highly inelastic production curve while an Iowa beef-feeding farm would have a highly elastic curve.

In considering the inflexibility of certain factors the question of short- and long-run periods must be considered. In agriculture we find that many factors such as population density and farm size are relatively fixed over long periods, and concepts which theoretically apply only to short-run phenomena may apply over fairly long periods of time. These fixed factors, however, usually affect primary production much more than secondary production, and high elasticity of total production may be associated with an inelastic primary production when there is much greater elasticity of secondary production.

Intensity

The concept of intensity can have many different meanings when applied to agriculture, and in many cases these differences have not been clearly distinguished by those using this term. Most of the obscurity and misunderstanding in past treatments seem to result from a failure to observe clear-cut definitions of intensity and efficiency and a failure to distinguish clearly between the physical and economic meanings.

Just as we have distinguished between primary and secondary production so may a distinction be drawn between primary intensity and secondary intensity.

1. *Primary intensity* (or intensity of primary production) refers to the direct application of labor and capital to the land in the production and harvesting of plant material. Intertilled crops represent a high degree of primary intensity, while permanent pasture represents a low degree of such intensity. An increase in grass crops represents a move towards conservation while an increase in primary intensity by the use of more intertilled crops may mean an increase in exploitation.

2. *Secondary intensity* (or intensity of secondary production) refers to the application of labor and capital to all processing of agricultural raw materials undertaken on the farm land. Livestock enterprises and all other agricultural production where the inputs are not directly applied to the land determine the level of secondary intensity. Dairying, beef-feeding, and poultry farms represent intensive secondary production.

3. *Intensity* without any prefix refers to the sum of primary and secondary intensity; that is, the total amounts of labor and capital per acre applied in the farm business. This is in harmony with the generally accepted use of the term and tells us nothing about the intensity of primary production or the land use pattern.

Physical and Economic Meanings of Intensity and Elasticity of Production

In its economic meaning intensity must always refer to the value of inputs, not to physical inputs. Physical intensity can only be measured, for comparative purposes, when identical physical units of input are used. It may well be questioned whether the economic meaning of primary intensity is of great value in the discussion of physical land use problems because inputs of dollars may represent entirely different things. A similar problem exists when dollars are replaced by physical units—labor hours or machine hours—and we are left with only broad measures of land use, in terms of rotations and crops grown, as a realistic approach to the meaning of the intensity of "land use" or cultivation.[11]

The general statement that an increase in "intensity" leads to conservation has often been made. Whether this is true or not depends upon whether the increase in intensity was primary or secondary. Even if we assume an increase in primary intensity, it does not necessarily mean a movement towards conservation because this will depend upon the type of changes in land use introduced by the increase in intensity. If, for example, pasture land is plowed up for grain crops we have an increase in primary intensity and very probably increased exploitation of the soil. On the other hand, the building of terraces, contour farming, and increased applications of manure also represent an increase in primary intensity, and these would be associated with conservation.

Similarly, for elasticity, the same distinctions may be made. Primary elasticity of production, in a physical sense, is a measure of the ability of the land to absorb additional units of fertilizer, labor, etc., and produce proportionate increases in yields. Secondary elasticity in this physical sense indicates the ability of secondary production to absorb more physical units and result in proportionate increases in physical output. In all cases the economic concept of elasticity refers to the ability of the enterprise to absorb additional inputs of dollars and produce additional money returns.

In the case of capacity the physical meaning refers to the

[11] The *land use capability classes* developed by the Soil Conservation Service are said to reveal the upper limits of the intensity of land use. For example, E. A. Norton states "classes of land according to use capability indicate the maximum intensity of agricultural use that can be practiced safely." This is a misuse of the term intensity and, as previously pointed out, "actually, land use capability classes establish land use and practice patterns or limits of tillage operations but do not represent levels of intensity." *See* E. A. Norton, "Land Classification as an Aid in Soil Conservation Operations," and the "Discussions" by G. A. Pond and by A. C. Bunce in *The Classification of Land*, Bul. 421, Mo. Agr. Exp. Sta., Dec., 1940, pp. 293–304, 305–8, and 309–13.

quantity of physical units of labor and capital goods applied to a unit of land at the highest profit combination for a given firm, while the economic meaning refers to the total value of all inputs at this point.

In the case of agriculture the use of these terms in a physical sense is extremely limited because of the lack of homogeneity in both the factors applied and the goods produced. The economic applications are developed in the next chapter.