

Lesson-19

Law of Variable Proportions

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Law of Variable Proportions is also known as the Law of Diminishing Returns. This law is a generalization which the economists make about the nature of technology which makes possible to combine the same factors of production in a number of different proportions to make the same product. The law states:

When increasing amounts of one factor of production are employed in production along with a fixed amount of some other production factor, after some point, the resulting increases in output of product become smaller and smaller. (That is, first the marginal returns to successive small increases in the variable factor of production turn down and then eventually the overall average returns per unit of the variable input start decreasing.)

Since the law assumes that the available quantity of atleast one factor of production is fixed at a given level and that technological knowledge does not change during the relevant period, the Law of Diminishing Returns normally translates into a statement about the short-run choice of production possibilities facing a firm. Since in the longer run it is virtually always possible for a firm to acquire more of the temporarily “fixed” factor-- building an additional factory building, buying additional land, installing additional machines of the same kind, installing newer and more advanced machinery and so on.

A simple example of the working of the Law of Diminishing Returns comes from gardening. A particular twenty by twenty garden plot will produce a certain number of pounds of tomatoes if the gardener just puts in the recommended number of rows and plants per row, waters them appropriately and keeps the weeds pulled. If the gardener varies this approach by adding a pound of fertilizer to the topsoil but otherwise does everything the same, he can increase the number of pounds of tomatoes the garden plot yields by quite a bit. One should notice here the amount of land which is being held fixed or constant. If he adds two pounds of fertilizer rather than just one, probably he can get still more tomatoes per season. But the increase in tomatoes harvested by going from one pound to two pounds of fertilizer is probably smaller than the increase he gets by going from zero pounds to one (diminishing marginal returns). Applying three pounds of fertilizer may still increase the harvest but by only a very little bit over the yield available by using just two pounds. Applying four pounds of fertilizer turns out to be overdoing it, i.e. the garden yields fewer tomatoes than applying only three pounds because the plants begin to suffer damage from root-burn. And five pounds of fertilizer turns out to kill nearly all the plants before they even flower.

Another similar example of diminishing returns in an industrial setting might be a widget factory that features a certain number of square feet of workspace and a certain number of machines inside it. Neither the space available nor the number of machines can be

added to without a long delay for construction or installation, but it is possible to adjust the amount of labor on short notice by working more shifts and/or taking on some extra workers per shift. Adding extra man-hours of labor will increase the number of widgets produced but only within limits. After a certain point, such things as worker fatigue, increasing difficulties in supervising the large work force, more frequent breakdowns by over-utilized machinery, or just plain inefficiency due to overcrowding of the workspace begin to take their toll. The marginal returns to each successive increment of labor input get smaller and smaller and ultimately turn negative.

The Law of Diminishing Returns is significant because it is a part of the basis for the economists' expectations that a firm's short-run marginal cost curves will slope upward as the number of units of output increases. And this, in turn, is an important part of the basis for the law of supply's prediction. According to this law, the number of units of product which a profit-maximizing firm wishes to sell increases as the price obtainable for that product increases.

Production with Two Variable Inputs-- Isoquants

The concept of marginal productivity is central to the economists' understanding of efficient allocation of resources. For an illustrative example, consider a farmer who has two fields to plant. He can grow a crop of corn on both of them but has a limited amount of labor to allocate between them. Let us say that the farmer can spend 1000 hours of labor on the two fields. If he spends one more hour of labor on the north field, that means he has one hour less to spend on the south field.

Following are the production functions for the two fields:

Labor Input and Output on Two Fields			
North Field		South Field	
labor	output	labor	output
0	0	0	0
100	9500	100	12107
200	18000	200	23429
300	25500	300	33964
400	32000	400	43714
500	37500	500	52679
600	42000	600	60857
700	45500	700	68250
800	48000	800	74858

900	49500	900	80679
1000	50000	1000	85715

Table 2.1

One can visualize the production functions for the two fields. Figure 2.1 shows the production function for the relatively fertile south field with a vertically dashed purple curve and the less fertile north field with a solid green curve. The south field can always produce more with the same amount of labor as compared to the north field.

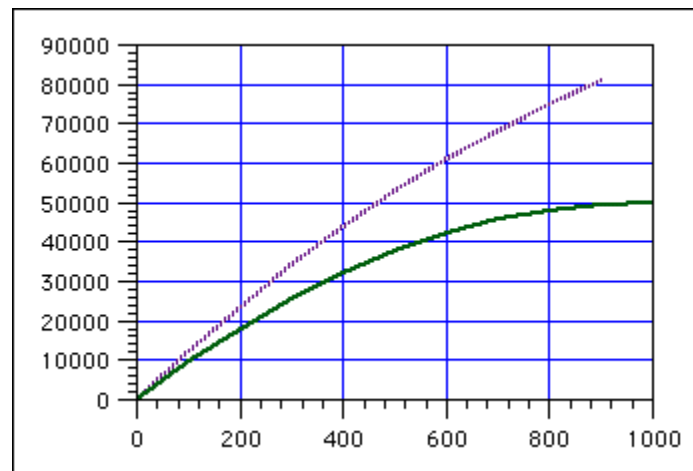


Figure 2.1 Production functions for two fields

The Problem of Allocation

The farmer's "allocation problem" is as follows:

How much labor to commit to the north field and how much to the south field?

One "common" approach might be to abandon the infertile north field and allocate the whole 1000 hours of labor to the south field. But a little arithmetic shows that this will not work. Table 2.2 shows the correlated quantities of labor on the two fields and the total output of corn from both fields taken together.

Allocation of Labor and Total Output on Two Fields		
Labor on North Field	Labor on South Field	Total output in bushels

		of corn
0	1000	85000
100	900	89600
200	800	92400
300	700	93400
400	600	92600
500	500	90000
600	400	85600
700	300	79400
800	200	71400
900	100	61600
1000	0	50000

Table 2.2

The farmer gets his largest output by allocating most, but not all, of his labor to the south field. Because of the principle of diminishing returns, however, he should not put all his resources into the one field but divide the labor resource unevenly between the two.

But how much should go to the north plot, and how much to the south plot?

One can visualize the efficient allocation of resources as in figure 2.2. The labor used on the infertile north field is measured on the horizontal axis and the total output from both fields is shown on the vertical axis. Assume that all the labor which is not used on the North field is used on the South field. The dark green curve shows how total output changes as labor is shifted from the north field to the south field. Thus, the top of the curve is the interesting spot where one gets most of the output. In this example, that is the efficient allocation of resources between the two fields.

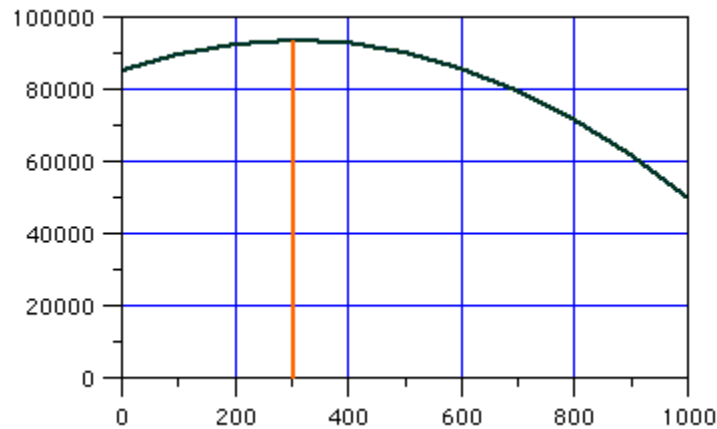


Figure 2.2 Maximum production

It is easy to say that the farmer should put some labor to work on the north field but not much feasible. The vertical orange line shows that the maximum output, i.e. the top of the dark green curve comes when about 300 labor days are allocated to the north field and the rest, 700 labor days, to the south field. And that is right.

It is easy to see where the maximum is in this simple example. But in a more realistic example, in which there could be many more than just two dimensions, it is harder to visualize. One needs a rule that can be applied in more complex, realistic examples, a rule that tells if one has or has not an efficient allocation of resources.

Here comes the economist's "marginal approach." The objective is to get to the top of the hill. One can call "the marginal approach" the "bug's-eye view." Think of yourself as a bug climbing up that production hill in the picture. How will you know when you are at the top?

Marginal Productivity and Allocation

If you were a bug, you could not see much. Perhaps you could not see to the top of the hill. But you would be able to tell if you were going up, or down, or neither. So you would just keep going as long as you were going up and stop when you were neither going up nor down. That is the way a bug gets to the top of a hill.

If you were a farmer with two fields, it is a little more complicated but the same principle would apply-- take it step by step. However, no matter how much you may be producing, ask yourself, "What would happen if I were to take one worker away from the North Field and put her to work on the South Field? How much less will the North Field produce?" The answer is the marginal productivity of labor on the North Field. "How much more will the South Field produce?" The answer is the marginal productivity of labor on the South Field. So, the move of labor from the North Field will increase production if the marginal productivity on the North Field is less than the marginal

productivity on the South Field. Like the bug, you want to keep moving in that direction as long as production keeps getting greater, i.e. as long as the marginal productivity on the North Field is less than the marginal productivity on the South Field. And you stop when further movement would not get you any higher on the hill, i.e. when the marginal productivities are equal on the two fields.

So, visualize the marginal productivities for these two fields. But this time, do it a slightly different way. Measure the labor used on the infertile north field from left to right on the horizontal axis. Then, what is left is what is available for the north field. So, measure the labor used on the south field from left to right, i.e. from 1000 hours down to zero. The marginal product on the north field is shown with the green line and the marginal product on the south field with the vertical-dashed purple line. One should always remember that the marginal productivity on the south field decreases, as the labor input on the south field gets bigger. So, the marginal productivity on that field increases, as labor used on the field gets smaller.

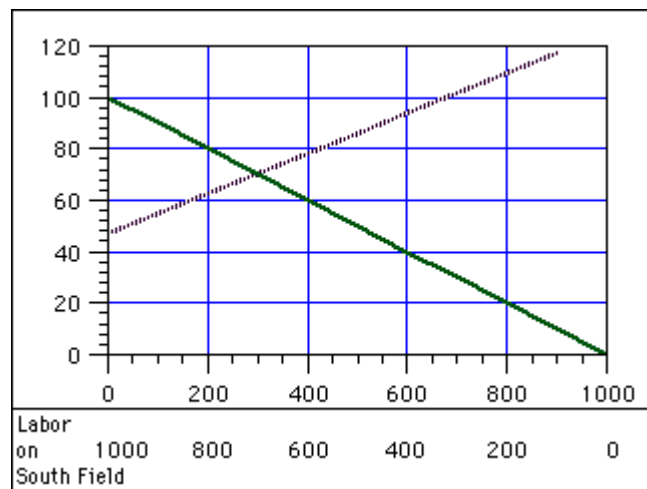


Figure 2.3 Marginal productivity and efficient allocation

Marginal Productivity

Figure 2.4 shows the most efficient allocation of resources in this case. It is to allocate 300 hours of labor to the north field and 700 hours to the south field, as shown by the vertical red-orange line. For the maximum output, labor is allocated so that the marginal productivity of labor on the north field is equal to the marginal productivity of labor on the south field.

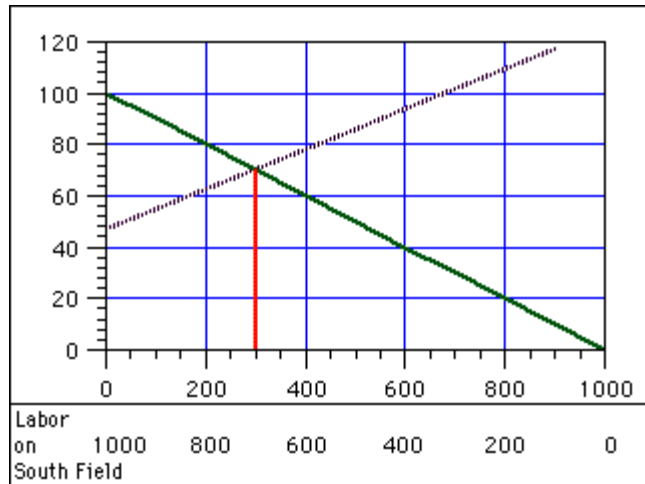


Figure 2.4 Efficient allocation

What happens if the allocation of labor is not 300 to the north field and 700 to the south field?

For example, suppose 200 hours are allocated to the south field and 800 to the north field. This puts us to the left of the orange line and we read off the diagram that the marginal productivity of labor on the north field is 80 bushels of corn while the marginal productivity on the south field is about 62. Remembering the definition of marginal productivity, that means if the farmer spends one additional hour on the north field, he will gain 80 bushels while spending one less on the south field will cost him 62 bushels, leaving a net gain of 18 bushels. What has happened is that spending 800 hours of labor on the south field has pushed the “diminishing returns” on that field so far that it is less productive at the margin than the north field and that will be true anywhere to the left of the orange line. Since, in that range, the marginal productivity on the north field is always greater than the marginal productivity on the south field.

What happens if the allocation is to the right of the most efficient one, i.e. for example, suppose the farmer were to allocate 600 hours to the north field and 400 to the south field?

Looking at the diagram, one may see that the marginal productivity on the north field is 40 while the marginal productivity on the south field is 90. Thus, moving an hour of labor from the north field to the south field will yield a gain of $90 - 40 =$ fifty bushels of corn. And the farmer will continue to gain as he moves toward the efficient allocation from the right because, in that range, the marginal product on the south field is always bigger than the marginal product on the north field.

The farmer can gain by reallocating his labor from either side toward the efficient output. Once he has 300 hours of labor on the north field and 700 on the south, the farmer cannot increase his output any further. That is why it is the “efficient” allocation of resources.

Marginal Productivity and the Equimarginal Principle

This is a quite general principle which can be stated as follows:

Rule:

When the same product or service is being produced in two or more units of production, in order to get the maximum total output, resources should be allocated among the units of production in such a way that the marginal productivity of each resource is the same in each unit of production.

This example may also be a little clearer example of what we mean by “efficient allocation of resources.” In the example, we have a tiny economy consisting of one farmer and two plots of land. When the marginal productivities on the two plots are equal, this tiny economy has an “efficient allocation of resources.” Ofcourse, real economies are more complex but the principles governing the efficient allocation of resources are the same.

This rule is called as the “Equimarginal Principle.” The idea is to make two things equal “at the margin.” In this case, one has to make the marginal productivity of labor equal to the two fields. It has many applications in economics. In more complicated cases, one will have to generalize the rule carefully. In this example, for instance, you are allocating resources between two fields that produce the same output. When the different areas of production are producing different kinds of goods and services, it will be more complicated. But a version of the Equimarginal Principle will still apply.