CHAPTER III

ECONOMIC PRINCIPLES OF PRODUCTION

There are physical and mathematical relationships between the levels of inputs used and output realized in a production process. Generally, a level of fixed resources, higher levels of output can only be obtained by adding more of variable resources. It is thus important to be able to identify the profitable levels of inputs to combine with a given level of fixed resources. This chapter describes the concepts necessary to identify the profitable use of variable inputs in a production process relevant both to crop and livestock enterprises.

PRODUCTION RELATIONSHIPS

In a production process, several **inputs** (factors of production) are used, which ultimately are transformed into final **output** (product) or outputs. One must choose the levels of each input, say, for instance, seed, fertilizer, feeds, concentrates, etc., that will, when transformed by the production process, produce the quantities and qualities of output(s) that best satisfy the farmer's goals.

This relationship between factors of production and output can be expressed as

$$Y = f(X_1, X_2, X_3, \ldots, X_n)$$

where Y is the output that is obtained as a result of using inputs X_1, X_2, etc. In the above equation, Y is used to denote a quantity of output, such as tons of grain, kilograms of milk or meat, dozens of eggs, while X_1 and X_2 represent units of specific inputs, such as kilograms of fertilizers or tons of green fodder.

The quantities X and Y are called **variables** because variations in one of these quantities are associated with variations in the other. The expression Y = f (X) means that Y is a function of X (that X affects Y). The production function is a mathematical statement about the relationship between X and Y once these two variables are defined.

Three basic relationships are studied in production economics, which are:

FACTOR-PRODUCT RELATIONSHIP -- output (product) is related to a single variable production input (factor) given a set of fixed inputs;

FACTOR-FACTOR RELATIONSHIP -- output (Product) is related to two or more variable production inputs (factors).

PRODUCT-PRODUCT RELATIONSHIP -- the relative quantity of two or more outputs (Products) is related to a fixed quantity of inputs (factors).

FACTOR-PRODUCT RELATIONSHIP

The production of any final product depends on the use of various inputs or factors of production. Such factors in the case of Livestock and Livestock products would be Labour, fodder, wheat straw, concentrates, buildings, medicines, machinery, management, technology, etc. Production may be affected by the use of one or all of these factors. The important aspect here is that since the production does not vary evenly in response to uniform alterations in inputs and thus, the management have to decide the quantity to be produced and the amount and type of inputs to be used in the production process. Because of these variations in production responses to uniform applications of inputs, the decision maker is supposed to know the economic principles of production.

PRODUCTION FUNCTION

The physical relationship between inputs (factors) and the output (product) is called the production function. Let us discuss a production relation where only one variable input of production combined with the fixed inputs is used to produce only one product. Suppose the output is milk. Production of milk is a function of or depends on ration intake, i.e., total digestible nutrients (TDN), while all other inputs are held constant at a fixed level. The production function would, thus, look like

2. $$Y = f(X_1|X_2, \dots, X_n),$$

where Y is the milk production per cow per lactation and X_1 represents the ration (TDN intake) per lactation per cow. Variables X_2 to X_n, which are right of the bar, are fixed inputs used to produce the milk output such as labour, medical treatment, machinery, technology and etc. Such a production relationship is known as factor-product relationship. More briefly, Equation 2 may be written as

3. $$Y=f(X_1).$$

Considering single input-output relationship, we can tabulate the levels of X_1 used and corresponding levels of Y. Columns 1 and 2 of Table 3.1 show how output varies as the variable input (Ration) changes. Column 6 tells us the additional output which results from an additional unit of ration that is called "**marginal product**".

The information presented in Table 3.1 can be summarized as a production function curve, i.e., a graphical representation. This curve describes the relationship between the input (X_1) and output (Y). Figure 3.1 is the production function that displays the information given in Table 3.1. The number of ration doses are shown on the horizontal axis and the milk output is depicted on the vertical axis.

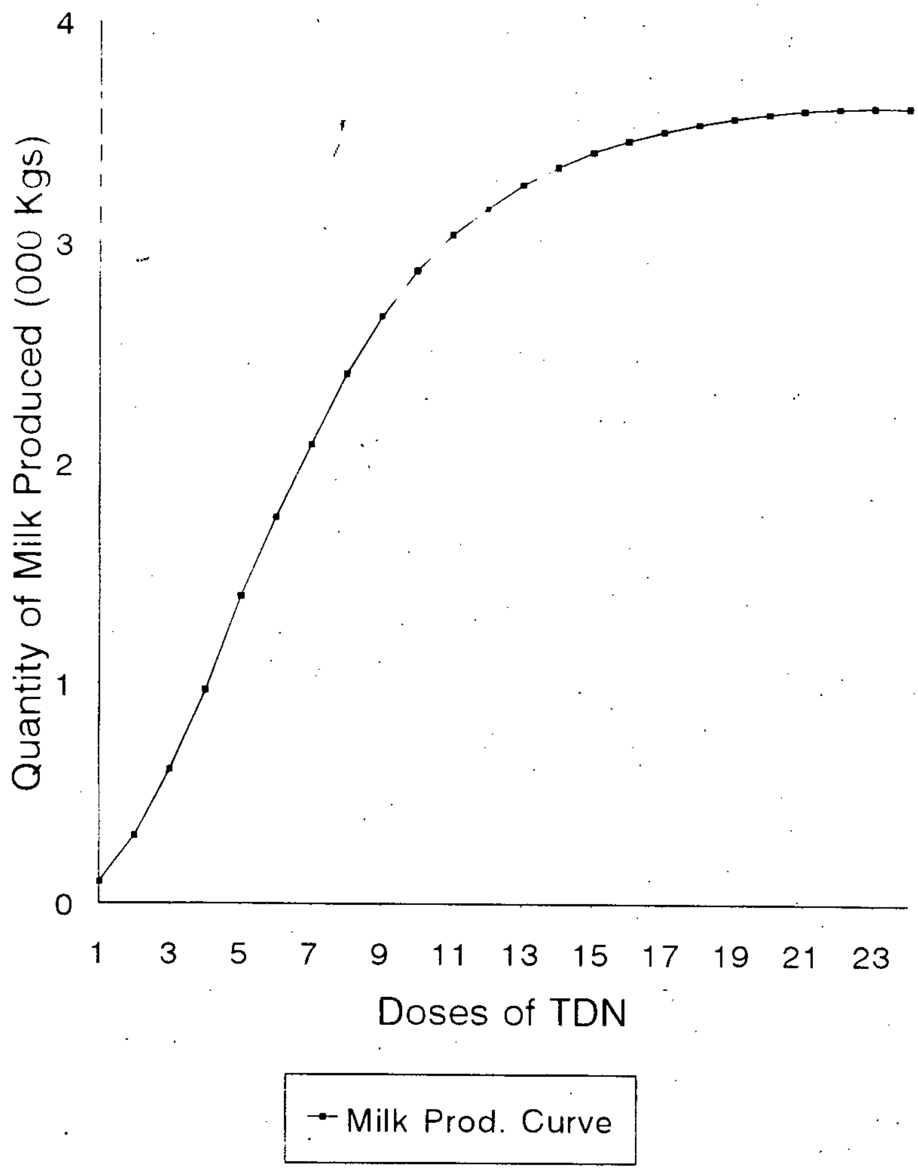
The shape of the curve in Figure 3.1 shows that the output increases at an increasing rate as the level of input increases to 5 units (1400 kgs of TDN). Between input levels 5 and 23 (4100 kgs TDN) output still increases as a result of increasing input levels, but at a decreasing rate. Further increase of input by one unit, i.e., 24th dose does not increase the total output. However, any further increase in input level, i.e., beyond 24th unit (4200 kgs of TDN) causes a fall in the level of total output (e.g., might be due to stomach upset). Consequently, the production function demonstrates diminishing returns to the variable factor. Thus, the law of diminishing returns may be stated as follows:

> "if equal increments of one factor of production to other factors of production are applied, which are kept fixed at a certain level, then the resulting additional output will decline beyond some point",
>
> or
>
> "if the quantity of any one factor of production is fixed, the application to that factor of equal successive increments of

Table 3.1: Milk Response to TDN

Doses of TDN (X)	Total Milk Per Cow (Kgs) (Y)	Change in Milk (Kgs) (Δ Y)	Average Product (Kg) (Y/X)	Marginal Product (Kgs) (Δ Y/ Δ X)
1	100	-	100	-
2	310	210	155	210
3	611	301	204	301
4	972	361	243	361
5	1399	427	280	427
6	1757	358	293	358
7	2088	331	298	331
8	2412	324	302	324
9	2673	261	297	261
10	2881	209	288	209
11	3045	163	277	163
12	3164	119	264	119
13	3271	107	252	107
14	3351	80	239	80
15	3421	70	228	70
16	3473	52	217	52
17	3515	42	207	42
18	3549	34	198	34
19	3576	27	188	27
20	3597	21	180	21
21	3614	17	172	17
22	3624	10	165	10
23	3628	4	158	4
24	3628	0	151	0

Figure 3.1: Representation of a Single Factor Production Function



the other factors will result in additional output to decline beyond some point".

This law indicates an important relationship since it is that where a farmer would like to operate rationally. For example, if the farmer is producing in the first area where the marginal product increases, then he can increase the average productivity by applying more of the input; and thus, he has a strong incentive to use more units of his input to get out of this range. Similarly, application of, for example, 24th dose does not add any thing to the total output and thus, does not make any sense to apply that dose. Moreover, application of further doses may cause the total output to decrease. So the farmer keeps himself away from that range. This implies that the most relevant part of production is that range which shows a declining marginal productivity.

If the 'law of diminishing returns' had not been operative, then it would have been possible to fulfill all the milk consumption requirements of the whole world's population from one cow by only increasing her feed intake.

Average and Marginal Products and Their Relationships

Total output curve can be drawn from different levels of the variable input and the total product as in Figure 3.1. From the total product curve, one can determine two important physical productivity relationships. These are termed as average product (AP) and marginal product (MP).

The average product or average productivity is defined as the ratio of total product to the total factor input; that is, Y/X_1, where Y is total output of milk, and X_1 is the total factor input (doses of ration). In Table 3.1, average product is given in column 4, which is obtained by dividing the total output in column 2 by the doses of input in column 1. This is represented graphically in Figure 3.2, where the input X_1 appears on the horizontal axis and the amount of average and marginal products are shown on vertical axis.

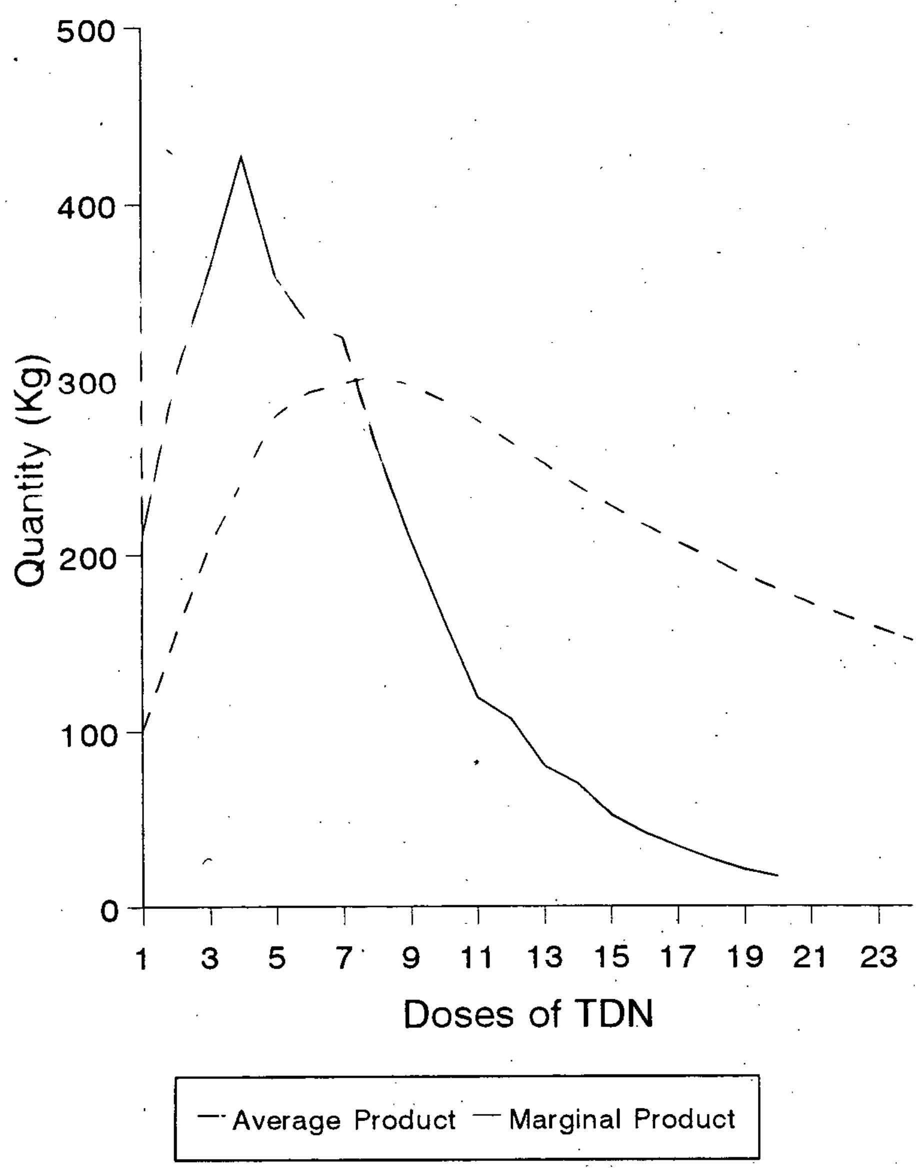
The slope of the total product curve, i.e., $\Delta Y/\Delta X_1$, indicates the marginal product and it depicts the change in output due to unit change in input. At a particular point on the total product curve, marginal product can be determined by estimating the slope of the curve at that point. A careful inspection of Table 3.1 and also Figures 3.1 and 3.2 shows that the following relationships exist between the total and marginal products:

1) when the total product is increasing, marginal product is positive;
2) when the total product is maximum, marginal product is zero;
3) when the total product is decreasing, marginal product is negative;
4) when the total product is increasing at increasing rate, the marginal product is increasing; and
5) when the total product is increasing at decreasing rate, the marginal product is decreasing but positive.

The relationships between marginal and average products are also shown in Figure 3.2 that can be delineated as:

1) when the marginal product is greater than the average product, average product is increasing;
2) when the marginal product is less than the average product, average product is decreasing; and

Figure 3.2: A Graphical Representation of MP and AP.



3) when the marginal product is equal to average product, the average product is maximum.

Three Stages of Production

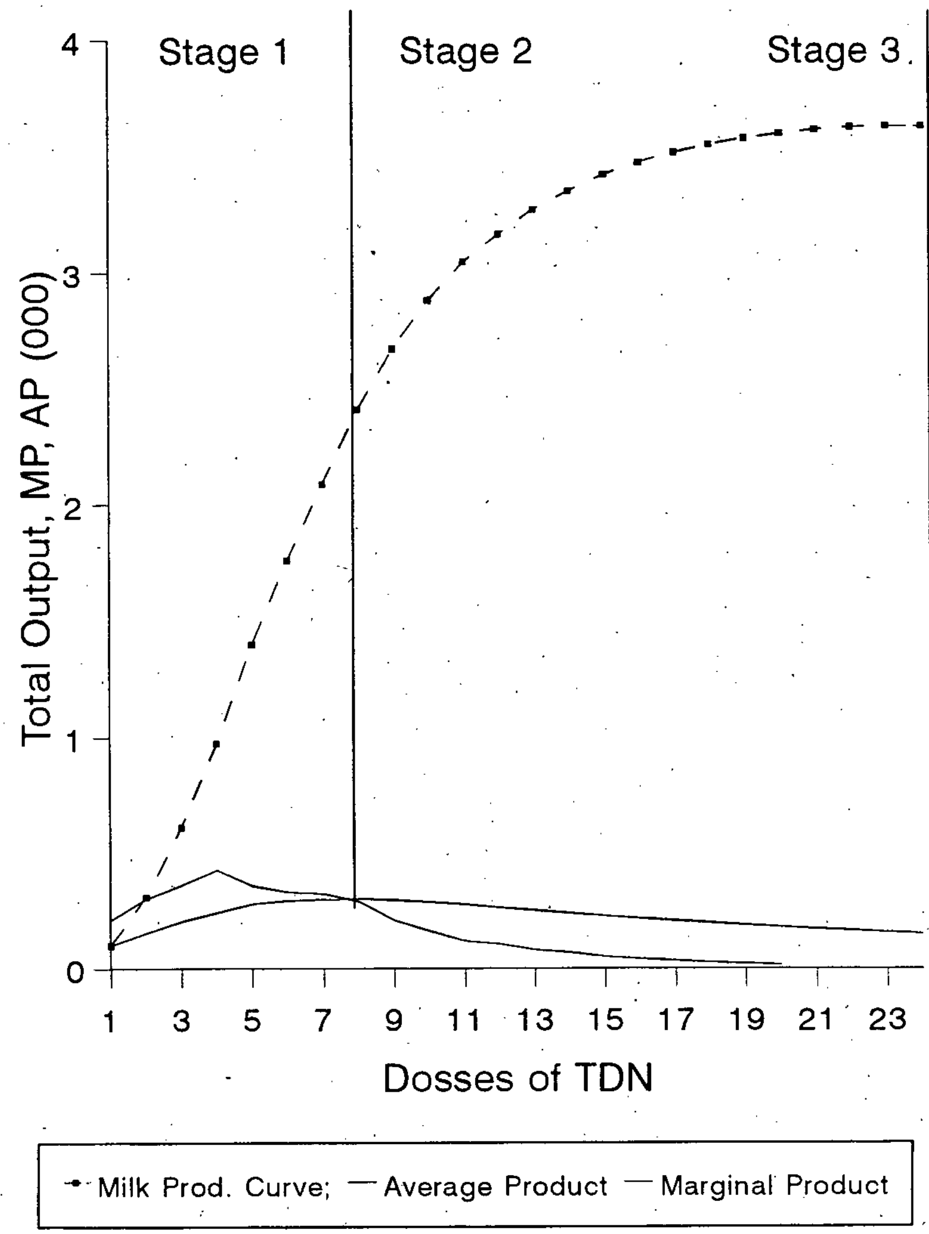
The classical production function can be divided into three segments known as stages, regions or zones. The production function is divided into these regions in order to identify a rational region where the production is most profitable (see Figure 3.3.

Region 1 of a production function goes to the level of input for which average product is maximum and that level in the present case is 8th dose of the ration. In this region average productivity of the additional units of the variable input increases progressively; marginal product in this stage of production is greater than the average product. Hence it is always profitable for the producer to continue to add inputs as long as the average productivity increases. A rational producer can always produce more product by using less of the fixed factor with the variable factors within this region. This stage is said to be irrational since greater output can be produced from the same fixed resources. Thus, in this stage the fixed factors remain underutilized.

The third region would start after the 24th dose, if used. In the third region of the production function, total product decreases. The marginal product becomes negative. In our example this stage is not shown. However, if a cow is forced to eat beyond her capacity, then she can fall sick and the total yield would decline. Thus, region III is irrational since the output can be increased by employing less of the variable factor. The fixed factors in this region are overutilized.

Region II is known as the rational region of production. In this region total product is increasing at decreasing rate; both

Figure 3.3: Three Stages of Production



marginal and average products are positive, but decreasing. Marginal product is less than the average product. The same or high level of output cannot be obtained by decreasing either the fixed or variable input. A rational producer must operate in this region in order to maximize profit. However, the most profitable level of input to use and the output to be produced in this region cannot be determined from the physical production data. It needs information about the prices of the input and the output in addition to the physical production data.

Profit Maximization With a Single Variable Input

To determine the most profitable level of a variable input, we need a) the rate of transformation of input to output, that is, production function, and b) the factor-product price ratio or choice indicator.

The optimum level of a variable input is where the added cost equals the added revenue. If Y stands for the physical output, X for the physical input, ΔY and ΔX_1 stand for change in Y and change in X_1, respectively. Let P_y denote the price of the product Y, P_{x1} denote the price of the input X_1. Then the equi-marginal principle states that a producer should continue to use additional units of a variable factor as long as the added revenue is greater than the added cost. The optimum level of the variable input is reached where the added revenue equals added cost. Symbolically, this principle of profit maximization can be expressed in various ways, and this phenomenon is explained below and is given in Table 3.2.

Table 3.2 **Profit Maximization in the Case of Single Input**

No. of Combination (X_1)	Milk Prod /Kgs (Y)	MP= $\frac{\Delta Y}{\Delta X_1}$	Method 1 & 2 VMP=P_X		Method 3		Method 4		Method 5		
			VMP	P_X	P_x/MP	P_Y	MP	P_x/P_y	Revenue	Cost	Profit
1	100	---	-----	800	----	10	---	80	1000	800	200
2	310	210	2100	800	3.81	10	210	80	3100	1600	1500
3	611	301	3010	800	2.66	10	301	80	6110	2400	3700
4	972	361	3610	800	2.22	10	361	80	9720	3200	6520
5	1399	427	4270	800	1.87	10	427	80	13990	4000	9990
6	1757	358	3580	800	2.23	10	358	80	17570	4800	12770
7	2088	331	3310	800	2.42	10	331	80	20880	5600	15280
8	2412	324	3240	800	2.47	10	324	80	24120	6400	17720
9	2673	261	2610	800	3.07	10	261	80	26730	7200	19530
10	2882	209	2090	800	3.83	10	209	80	28820	8000	20820
11	3045	163	1630	800	4.91	10	163	80	30450	8800	21650
12	3164	119	1190	800	6.72	10	119	80	31640	9600	22040
13	3271	107	1070	800	7.48	10	107	80	32710	10400	22310
14	3351	80	800	800	10	10	80	80	33510	11200	22310
15	3421	70	700	800	11.4	10	70	80	34210	12000	22210
16	3437	52	520	800	15.4	10	52	80	34730	12800	21930
17	3515	42	420	800	19	10	42	80	35150	13600	21550
18	3549	34	340	800	23.5	10	34	80	35490	14400	21090
19	3576	27	270	800	29.6	10	27	80	35760	15200	20560
20	3597	21	210	800	38.1	10	21	80	35970	16000	19970
21	3614	17	170	800	47.1	10	17	80	36140	16800	19340
22	3624	10	100	800	80	10	10	80	36240	17600	18640
23	3628	4	40	800	200	10	4	80	36280	18400	17880
24	3628	0	0	800	----	10	0	80	36280	19200	17080

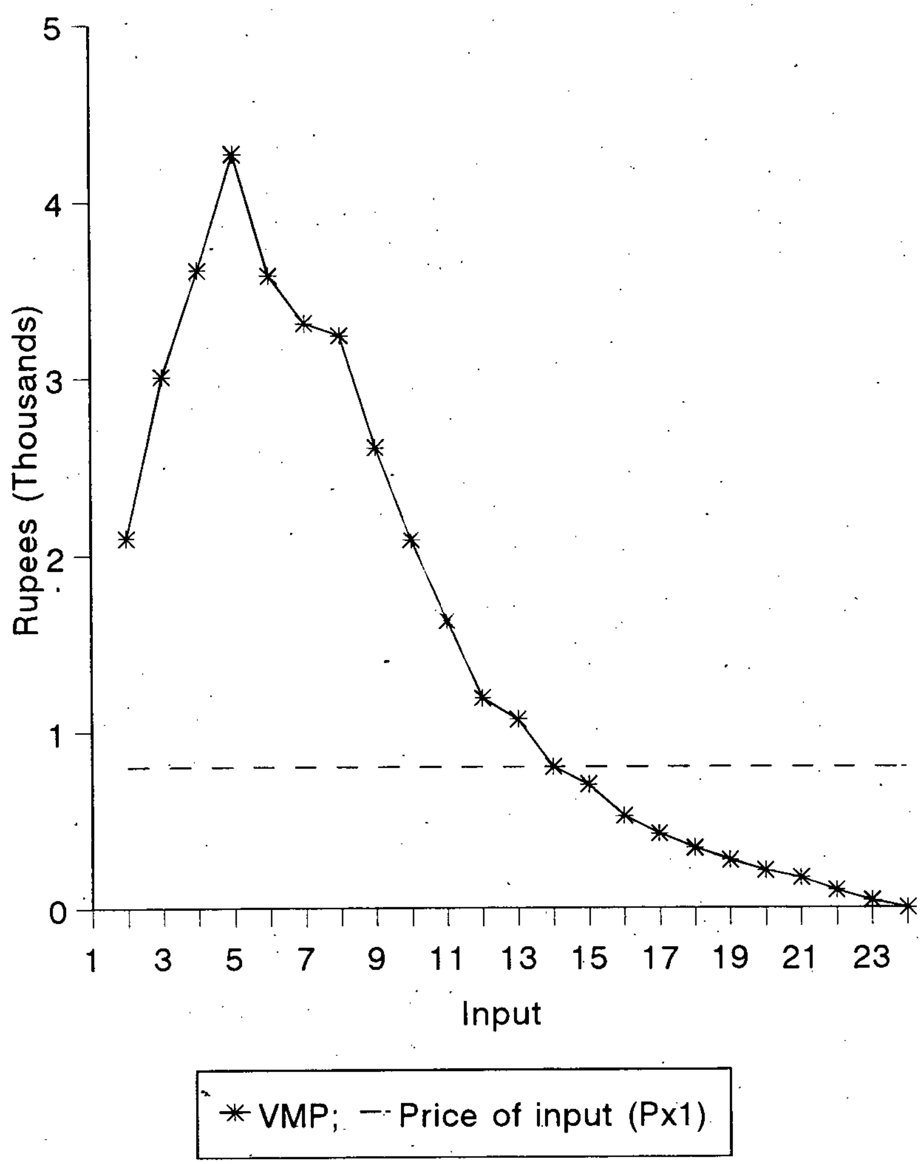
Price of X (P_x = Rs.800/unit)
Price of Y (P_y = Rs.10 /unit)

i) Added revenue equals added cost, $\Delta Y\ P_Y = \Delta X_1\ P_{X_1}$. If $\Delta Y\ P_Y > \Delta X_1\ P_{X_1}$ use more of X to maximize profit, and use less of X when $\Delta Y\ P_Y < \Delta X_1\ P_{X_1}$.

ii) Given $\Delta Y\ P_Y = \Delta X_1\ P_{X_1}$ and dividing ΔX_1 on both sides, we get $\frac{\Delta Y}{\Delta X_1} P_Y = P_{X_1}$ or $MP_{X_1} = P_{X_1}/P_y$ or $MP_{X_1}\ P_Y = P_{X_1}$ or $VMP_{X_1} = P_{X_1}$. This condition states that profit of the producer is maximum where the value of marginal product is equal to the price of the input, where the value of marginal product may be defined as the addition made to total revenue with the application of an additional unit of the variable input. If $VMP_{X_1} > P_{X_1}$ then use more of X,and if $VMP_{X_1} < P_{X_1}$ then use less of X to maximize profit (see Figure 3.4).

iii) Given $\Delta Y\ P_Y = \Delta X_1\ P_{X_1}$ and dividing ΔY on both sides, we get $P_Y = \frac{\Delta X_1\ P_{X_1}}{\Delta Y}$ or $P_Y = \frac{P_{X_1}}{MP_{X_1}}$ (marginal revenue = marginal cost). This states that price of output equals the cost of additional output using an additional unit of input. This situation expresses that profit is maximum where the marginal revenue or price of output is equal to the marginal cost. This implies that if $P_Y > \frac{P_{X_1}}{MP_{X_1}}$ use more of

Figure 3.4: A Graphical Representation of Method 2 of Profit Maximization.



X_1 and if $P_Y < \frac{P_{X_1}}{MP_{X_1}}$ use less of X_1 to maximize profit (see Figure 3.5).

iv) Given $\Delta Y \; P_Y = \Delta X_1 \; P_{X_1}$ and by rearranging it we get $\frac{\Delta Y}{\Delta X_1} = \frac{P_{X_1}}{P_Y}$ (marginal product = inverse price ratio). This states that profit of the producer is maximum where the marginal product is equal to the price ratio. Here the principle for profit maximization is; if $\frac{\Delta Y}{\Delta X_1} > \frac{P_{X_1}}{P_Y}$ then use more of X_1; and if $\frac{\Delta Y}{\Delta X_1} < \frac{P_{X_1}}{P_Y}$, then use less of X_1 to maximize profit (see Figure 3.6).

v) Another way of stating the principle is that add input until the difference between the total revenue ($Y \; P_y$) and the total cost ($X_1 \; P_{X1}$) is maximum (see Figure 3.7).

Application of the above methods to the data presented in Table 3.2 shows that the producer is maximizing his profit with 14 units of ration input. With the use of method (v), Figure 3.7 and also Table 3.2 show that the producer could earn Rs. 22310.33 with either 13th or 14th unit of input. It may be pointed out that we are using the average marginal product concept in output calculations. If the use of input units in fractions were possible, it could then be shown that the profit maximizing level of input would lie between 13 and 14 units of the input.

Figure 3.5: A Graphical Representation of Method 3 of Profit Maximization.

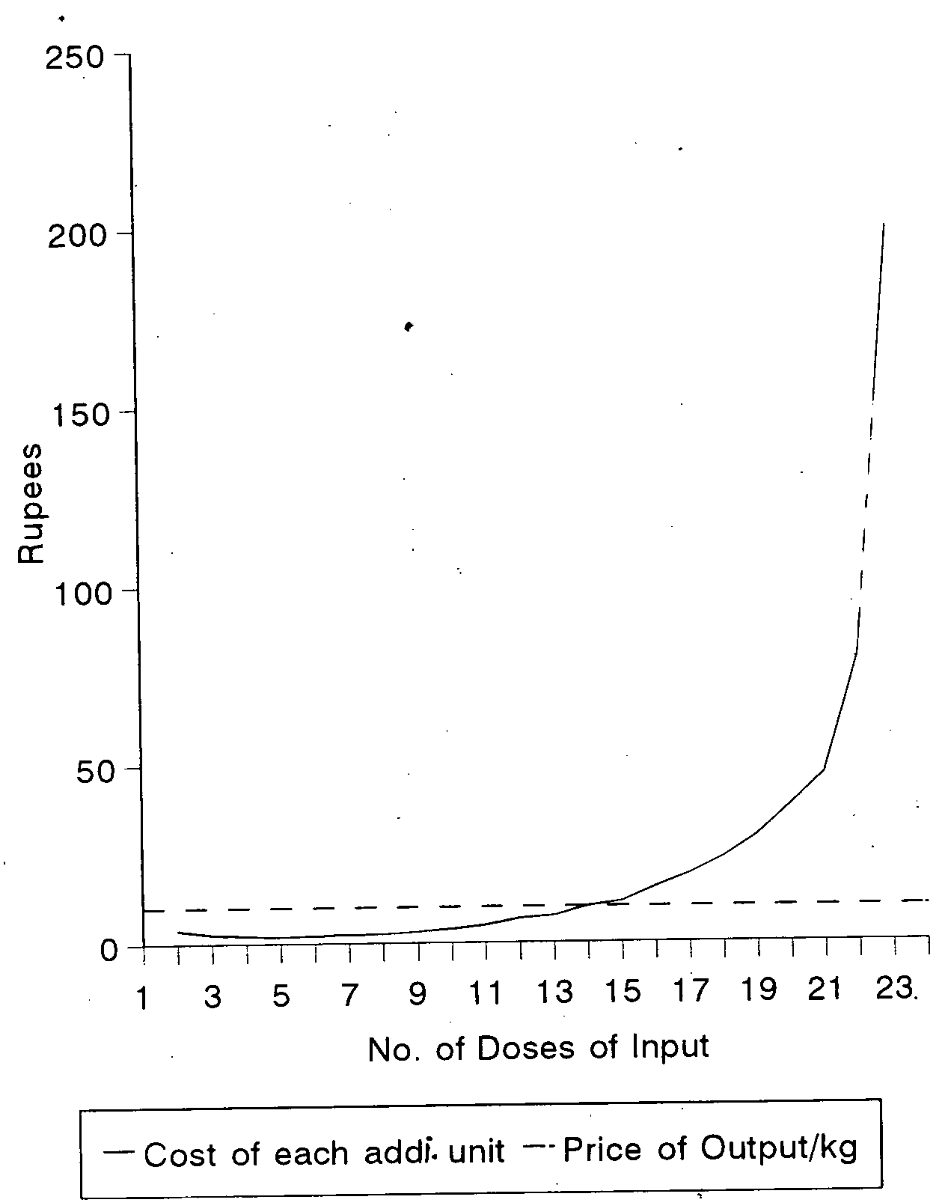


Figure 3.6: A Graphical Representation of Method 4 of Profit Maximization.

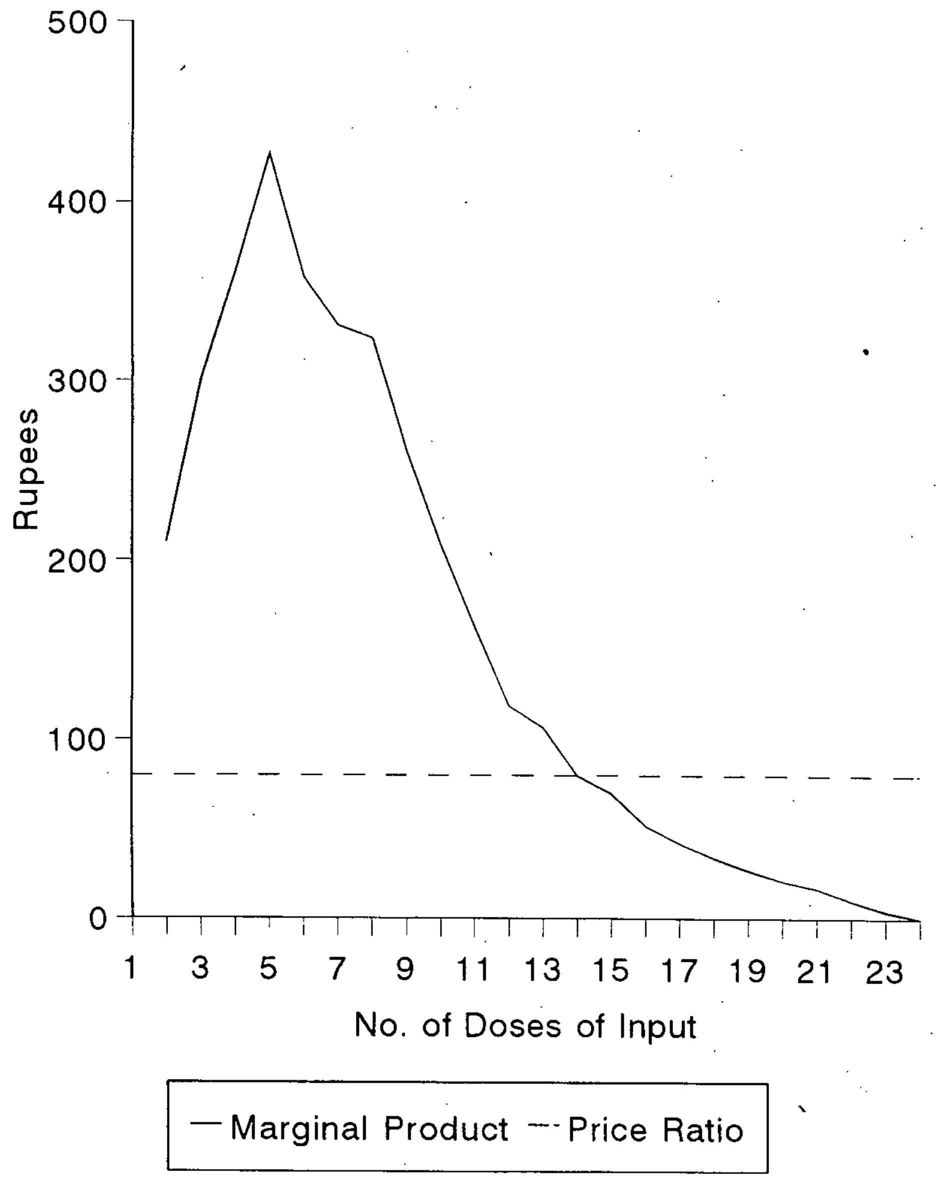
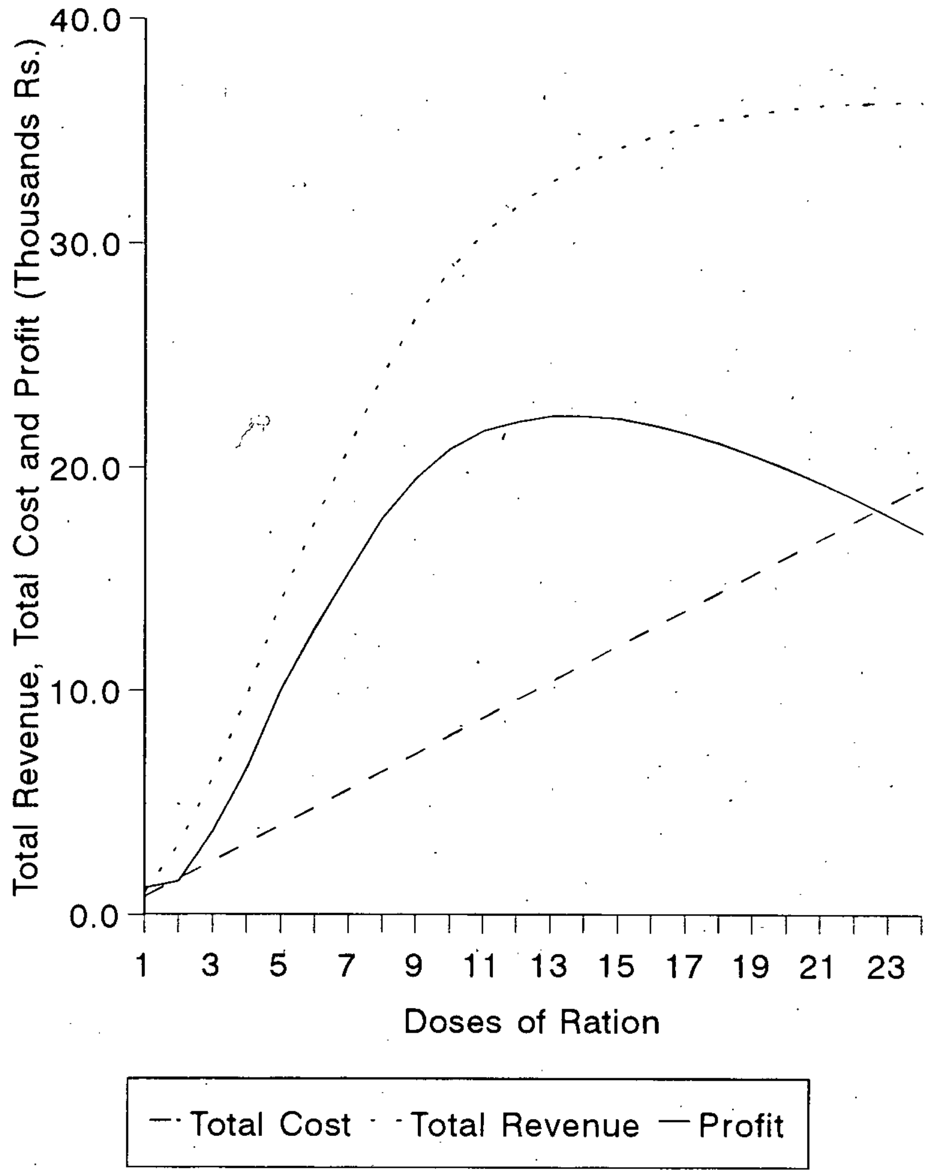


Fig.3.7: A Graphical Representation of Profit Maximization Using Method 5.



Of the various methods discussed above, the marginal value product concept is of particular importance to the economists because in case where there is a single variable factor then the marginal value product of the factor is also the demand curve for the factor.