

Production and Input Choice

Prices in the market place do not depend on demand alone. They also depend on supply, or the quantities that firms offer for sale in the market. Supply decisions depend on cost. So to study how markets work we now turn to the determinants of the cost of production.

A firm's cost depends on the quantity of labor, land, and capital that it buys, and on the prices of these inputs. How much of each input should the firm buy? Firms select the amount of inputs that minimizes total costs and maximizes profit given the amount of output they produce.

First, we will study how the firm can vary the quantity of a single input. This allows us to understand how:

- (1) the quantity of inputs affects the quantity of output
- (2) the firm selects the optimal quantity of an input
- (3) these input decisions give the firm the cost information it needs to decide on output and price.

Second, we expand our analysis to allow firms to choose several inputs at once.

Production with one variable input

All businesses use more than one input, but we begin our discussion of production by focusing on the simplest case.

Consider an Arkansas chicken farmer named Florence. She owns a small poultry business. She knows that the amount of corn she feeds her chickens will have an impact on the amount of poultry meat she can produce. Of course, she could buy more land, inject the chickens with growth hormones, and hire more workers to increase her production of poultry meat. But for now, let's focus on the relationship between poultry meat and corn.

The relevant data are displayed in the following table:

Corn Input (40 lb. bags per week)	Total Physical Product (TPP) in lbs.	Marginal Physical Product (MPP) in lbs.	Average Physical Product (APP) in lbs.
0	0.0	-----	-----
1	14.0	14.0	14.0
2	36.0	22.0	18.0
3	66.0	30.0	22.0
4	100.0	34.0	25.0
5	130.0	30.0	26.0
6	156.0	26.0	26.0
7	175.0	19.0	25.0
8	184.0	9.0	23.0
9	185.4	1.4	20.6
10	180.0	-5.4	18.0
11	165.0	-15.0	15.0

12	144.0	-21.0	12.0
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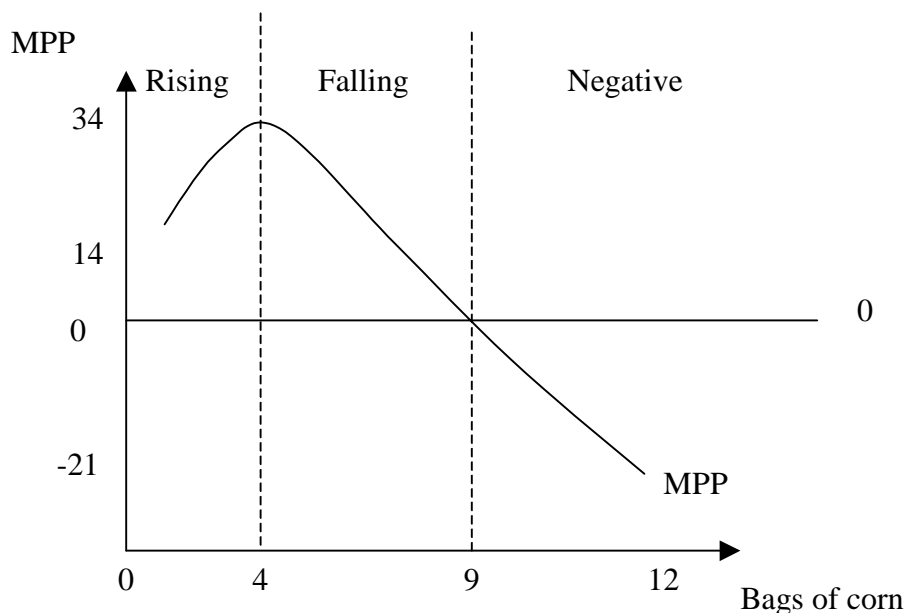
The first two columns of the table show TPP or how much chicken Flo can produce with different quantities of corn, holding all other inputs fixed. Obviously, without food there are no chickens. Each additional bag of corn yields more poultry. If 4 bags of corn are used, Flo gets 100 pounds of chicken. Except once we get past 9 bags of corn, more corn actually reduces the amount of poultry output --presumably the chickens are so overfed that they become ill.

We also consider 2 other physical product concepts --APP and MPP.

APP = TPP/(Q of the input). It measures the output per unit of input. For Flo this is the total amount of chicken divided by the number of bags of corn. For example, 4 bags of corn yield 100 pounds of chicken, so the APP is 25 pounds per bag of corn.

To decide how much to feed her flock, Flo must know how much additional output of chicken she gets from each additional bag of corn, or MPP. MPP is the additional output resulting from a 1 unit increase in the input, holding all other inputs constant. For example, if we increase our input of corn from 4 to 5 bags, the 5th bag yields an additional 30 pounds of meat.

Consider the graph of MPP:



Until input use reaches 4 bags, the MPP is increasing. Between 4 and 9 bags MPP is decreasing, and beyond 9 bags, the MPP of corn actually becomes negative. Marginal returns to an input typically rise and then fall.

The area of increasing MPP indicates that each additional bag of corn adds more to TPP than the previous bag did. TPP is increasing rapidly. The area of falling MPP indicates that each additional bag of corn adds less to TPP than the previous bag did. TPP continues to rise, but at a

diminishing rate. The area of negative MPP indicates that each additional bag of corn reduces TPP by more than the previous bag did. TPP is falling.

Law of Diminishing Marginal Returns

An increase in the amount of any one input, holding the amounts of all other inputs constant, leads to lower marginal returns to the expanding input.

In this example, Flo feeds the chickens more and more, without giving them extra water, cleaning up after them more often, or buying additional chickens. They are eventually overfed and become sick.

Consider another example. To dig ditches requires at least one shovel and one worker. If another worker is hired, the first worker can take a break while the other digs. In this way, more ditches are dug. However, as more workers are hired (with 1 available shovel), the amount of digging should fall. The work area becomes crowded which disrupts the digging.

The law of diminishing marginal returns should hold for most activities. Can you think of one?

Optimal Purchase Rule for a Single Input

How does a firm decide on the quantity of an input? Suppose the corn costs \$10 per bag and that Flo can sell her chicken for \$0.75 per pound.

Consider purchasing just one bag of corn. Does this maximize profits? One bag of corn produces 14 pounds of chicken. Thus, total revenue is \$10.50 (or \$0.75*14) and total cost is \$10.00 (or \$10*1). Thus, the profit is \$0.50. We don't want to stop at one bag because two bags of corn yields total revenues of \$27.00 (or \$0.75*36) and costs \$20.00 (or \$10*2) which adds an additional \$6.50 in profit (or \$7.00-\$0.50).

There is an easier way to proceed. Until we pass 9 bags, each additional bag of corn increases the output of chicken. Thus, each bag (1-9) raises total revenue, but also costs \$10. To maximize profit, Flo should compare the revenue that each bag generates against the cost of each bag.

Marginal revenue product (MRP) = MPP x price of the output. MRP is the additional revenue generated from increasing the input by 1 unit.

MRP is shown in the table below:

Bags of Corn	TPP	MPP	TR (P*TPP)	MRP (P*MPP)	Price of a bag of corn	Profit
0	0.0	-----	\$0.00	-----	\$10.00	\$0.00
1	14.0	14.0	10.50	\$10.50	10.00	0.50
2	36.0	22.0	27.00	16.50	10.00	7.00
3	66.0	30.0	49.50	22.50	10.00	19.50

4	100.0	34.0	75.00	25.50	10.00	35.00
5	130.0	30.0	97.50	22.50	10.00	47.50
6	156.0	26.0	117.00	19.50	10.00	57.00
7	175.0	19.0	131.25	14.25	10.00	61.25
8	184.0	9.0	138.00	6.75	10.00	58.00
9	185.4	1.4	139.05	1.05	10.00	49.05
10	180.0	-5.4	135.00	-4.05	10.00	35.00
11	165.0	-15.0	123.75	-11.25	10.00	13.75
12	144.0	-21.0	108.00	-15.75	10.00	-12.00

Rule: When $MRP > \text{Price of an input}$, it pays to use more of the input.
When $MRP < \text{Price of an input}$, it pays to use less of the input.

Thus, it is optimal to purchase an input up until the point where the $MRP = \text{Price of the input}$.

For example, Flo should purchase 7 bags of corn. Can you explain why she should not buy the 8th bag of corn?

Notice that declining MPP (from bag 4 to 9) is causing MRP to decline as well. At 7 bags of corn, Flo is producing where diminishing MPP has set in. Remember that TPP is still increasing here, but at a diminishing rate. Flo should stop increasing her corn purchases when the MRP falls to the price of corn.

Multiple Input Decisions

Until this point, we have examined how production is altered by changing the use of a single input. We now consider the use of more than one input in the production process.

Firms seek the method of production that is least costly. Consider the choice between capital and labor in production. In most industrialized countries, such as the U.S., labor is relatively expensive and capital is abundant and cheap. Production that utilizes a higher ratio of capital to labor may be the least costly means of production. By contrast, lesser-developed countries like Mexico have abundant and cheap labor and scarce capital. It pays to use a higher ratio of labor to capital there.

For example, medical records are handwritten in India, but computerized in the U.S.

One input can often be substituted for another in the production process. Shoes produced in Mexico are manufactured using more labor and less capital than shoes produced in the U.S.

A firm can produce the same amount of a good with less of one input (say labor) as long as it is willing to use more of another input (like capital).

The actual combinations of inputs (such as capital and labor) depend on the relative prices of the inputs. Firms strive to produce a good using the least expensive method.

Marginal Rule for Optimal Input Proportions

Farmer Flo can feed her chickens soymeal or cornmeal because they are substitutes in the poultry production process. But they aren't perfect substitutes because soymeal has more protein but fewer carbohydrates than corn. So its best if the chickens are fed some combination of the 2 meals. The output of poultry meat would fall if Flo relies too much on one input. There are diminishing returns to substitution among the inputs.

Assume:

Price corn = \$10 per 40 lb. bag	MPP bag corn = 30 lbs. meat
Price soy = \$20 per 40 lb. bag	MPP bag soy = 50 lbs. meat

What should Flo do? How much of each input should she purchase?

She should feed them more corn and less soy. The soy costs twice as much as corn, yet it contributes only 67% more meat.

If Flo decreases her purchases of soy by one bag she saves \$20.00, but the output falls by 50 pounds of meat. If she can buy $(50/30)$ 1.67 bags of corn to make up for the reduction in output, the cost is \$16.70. So she saves \$3.30 while continuing to produce the same amount of output.

In this example:

$$\frac{\text{MPP}_{\text{soy}}}{P_{\text{soy}}} < \frac{\text{MPP}_{\text{corn}}}{P_{\text{corn}}}$$

i.e., $\frac{50}{\$20} < \frac{30}{\$10}$

Soy yields 2.5 pounds of chicken per dollar spent while corn yields 3 pounds of chicken per dollar spent. Thus, Flo gets more output for her money by purchasing corn rather than soy at the margin.

$\frac{\text{MPP of an input}}{P \text{ of an input}}$ is the additional output from spending \$1 on the input.

By switching away from the input with lower output per \$1 spent and into the input with higher output per \$1 spent; the firm can reduce its costs while holding the level of output fixed.

Rule for producing output cheaply:

$$\text{If } \frac{\text{MPP}_b}{P_b} > \frac{\text{MPP}_a}{P_a} \text{ then spend less on input a and more on input b.}$$

$$\text{Optimally } \frac{\text{MPP}_a}{P_a} = \frac{\text{MPP}_b}{P_b}.$$

$$\text{In our example: } \frac{\text{MPP}_{\text{corn}}}{P_{\text{corn}}} > \frac{\text{MPP}_{\text{soy}}}{P_{\text{soy}}}.$$

These ratios will equalize at an optimum because of diminishing MPP. As Flo uses more corn and less soy, the MPP of corn is falling and the MPP of soy is rising, until the two ratios are equalized.

Changes in Input Prices and Input Proportions

$$\text{Optimally } \frac{\text{MPP}_{\text{corn}}}{P_{\text{corn}}} = \frac{\text{MPP}_{\text{soy}}}{P_{\text{soy}}}.$$

What if the price of corn rises? Then the MPP of corn must rise to match the higher price of corn. How is this achieved? Flo will use less corn and more soy until the ratios are equalized.

As the price of an input rises, firms switch to cheaper inputs.

The Production Function and Total Costs

The production function indicates the amount of a good that any collection of inputs is capable of producing.

For example, the production function shows how much chicken Flo can produce with different amounts of land, labor, corn, soy, etc.

Suppose Flo only needs 2 inputs --corn and soy. The following table represents the production function for the combinations of corn and soy capable of yielding 80 or 120 pounds of chicken.

Ways to produce 80 lbs. of chicken			Ways to produce 120 pounds of chicken			
Corn (bags)	Soy (bags)	Total Cost		Corn (bags)	Soy (bags)	Total Cost
5.0	0	\$50		7.0	0.0	\$70
3.5	0.5	45		4.5	0.7	59
2.0	1.0	40		2.9	1.4	57
1.5	2.1	57		2.0	2.8	76
0.0	4.0	80		0.0	5.5	110

Question: How was total cost calculated? Which input combinations will Flo choose to produce 80 pounds? to produce 120 pounds?

Economies of Scale

Returns to scale describes the physical relationship between inputs and outputs. It indicates how the level of output changes when *all* of the firm's inputs are doubled. Returns to scale are calculated by looking at the production function. There are 3 possibilities:

Increasing returns to scale (IRTS): When all of the firm's inputs are doubled, the quantity of output more than doubles.

IRTS gives an advantage to large firms over smaller firms. IRTS are found in many industries --including telecommunications, electricity, automobiles, and aircraft.

Constant returns to scale (CRTS): When all of the firm's inputs are doubled, the quantity of the output doubles.

Decreasing returns to scale (DRTS): When all of the firm's inputs are doubled, the quantity of the output less than doubles.

Most U.S. industries have DRTS.

The law of diminishing marginal returns and IRTS may seem contradictory, but they are not. Diminishing marginal returns refers to a *single* input. One input is increased while holding all of the other inputs fixed. In contrast, returns to scale refers to a doubling of *all* inputs. The two concepts are unrelated. A firm that is experiencing diminishing returns to a single input could have IRTS, CRTS, or DRTS.