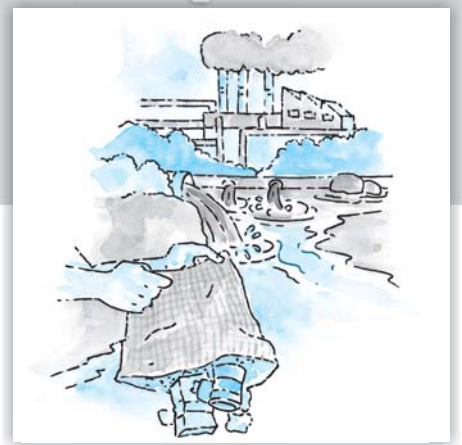
Chapter 4



The Theory of the Firm under Perfect Competition

In the previous chapter, we studied concepts related to a firm's production function and cost curves. The focus of this chapter is different. Here we ask : how does a firm decide how much to produce? Our answer to this question is by no means simple or uncontroversial. We base our answer on a *critical*, if somewhat unreasonable, assumption about firm behaviour – a firm, we maintain, is a ruthless **profit maximiser**. So, the amount that a firm produces and sells in the market is that which maximises its profit.

The structure of this chapter is as follows. We first set up and examine in detail the profit maximisation problem of a firm. This done, we derive a firm's **supply curve**. The supply curve shows the levels of output that a firm chooses to produce for different values of the market price. Finally, we study how to aggregate the supply curves of individual firms and obtain the **market supply curve**.

4.1 Perfect Competition: Defining Features

In order to analyse a firm's profit maximisation problem, we must first specify the market environment in which the firm functions. In this chapter, we study a market environment called **perfect competition**. A perfectly competitive market has two defining features

1. The market consists of buyers and sellers (that is, firms). All firms in the market produce a certain homogeneous (that is, undifferentiated) good.
2. Each buyer and seller in the market is a price-taker.

Since the first feature of a perfectly competitive market is easy to understand, we focus on the second feature. From the viewpoint of a firm, what does price-taking entail? A price-taking firm believes that should it set a price above the market price, it will be unable to sell any quantity of the good that it produces. On the other hand, should the set price be less than or equal to the market price, the firm can sell as many units of the good as it wants to sell. From the viewpoint of a buyer, what does price-taking entail? A buyer would obviously like to buy the good at the lowest possible price. However, a price-taking buyer believes that should she ask for a price below the market price, no firm

will be willing to sell to her. On the other hand, should the price asked be greater than or equal to the market price, the buyer can obtain as many units of the good as she desires to buy.

Since this chapter deals exclusively with firms, we probe no further into buyer behaviour. Instead, we identify conditions under which price-taking is a reasonable assumption for firms. Price-taking is often thought to be a reasonable assumption when the market has many firms *and* buyers have perfect information about the price prevailing in the market. Why? Let us start with a situation wherein each firm in the market charges the same (market) price and sells some amount of the good. Suppose, now, that a certain firm raises its price above the market price. Observe that since all firms produce the same good and all buyers are aware of the market price, the firm in question loses all its buyers. Furthermore, as these buyers switch their purchases to other firms, no "adjustment" problems arise; their demands are readily accommodated when there are many firms in the market. Recall, now, that an individual firm's inability to sell any amount of the good at a price exceeding the market price is precisely what the price-taking assumption stipulates.

4.2 Revenue

We have indicated that in a perfectly competitive market, a firm believes that it can sell as many units of the good as *it* wants by setting a price less than or equal to the market price. But, if this is the case, surely there is no reason to set a price lower than the market price. In other words, should the firm desire to sell some amount of the good, the price that it sets is exactly equal to the market price.

A firm earns revenue by selling the good that it produces in the market. Let the market price of a unit of the good be p. Let q be the quantity of the good produced, and therefore sold, by the firm at price p. Then, **total revenue** (TR) of the firm is defined as the market price of the good (p) multiplied by the firm's output (q). Hence,

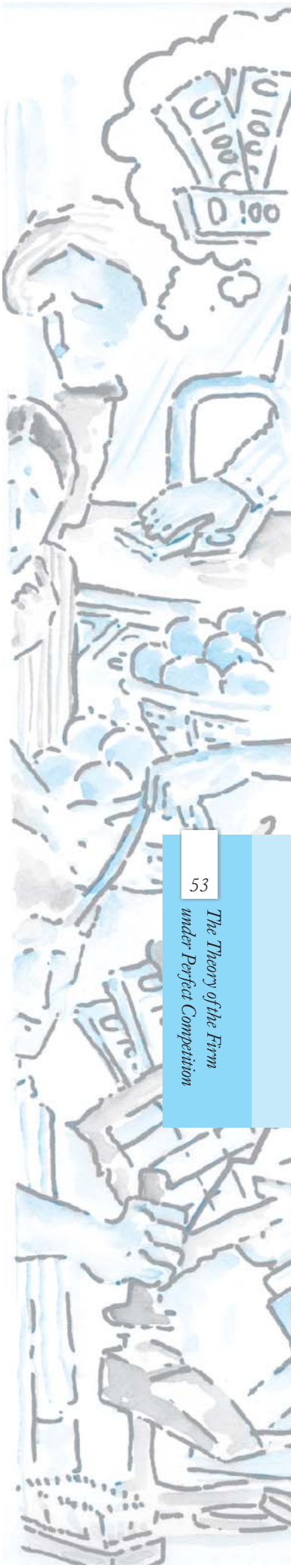
$$TR = p \quad q$$

To make matters concrete, consider the following numerical example. Let the market for candles be perfectly competitive and let the market price of a box of candles be Rs 10. For a candle manufacturer, Table 4.1 shows how total revenue is related to output. Notice that when no box is produced, TR is equal to zero; if one box of candles is produced, TR is equal to 1 Rs 10 = Rs 10; if two boxes of candles are produced, TR is equal to 2 Rs 10 = Rs 20; and so on.

With the example done, let us return to a more general setting. In a perfectly competitive market, a firm views the market price, p, as given. With the market price *fixed* at p, the **total revenue curve** of a firm shows the relationship between its total revenue (y-axis) and its output (x-axis). Figure 4.1 shows the total revenue curve of a firm. Three observations are relevant here. First, when the output is zero, the total revenue of the firm is also zero. Therefore, the TR curve passes through point O. Second, the total revenue increases as the output goes up. Moreover, the equation '$TR = p \quad q$' is that of a

Table 4.1: Total Revenue

Boxes sold	*TR (in Rs)*
0	0
1	10
2	20
3	30
4	40
5	50



straight line. This means that the TR curve is an upward rising straight line. Third, consider the slope of this straight line. When the output is one unit (horizontal distance Oq_1 in Figure 4.1), the total revenue (vertical height Aq_1 in Figure 4.1) is $p \quad 1 = p$. Therefore, the slope of the straight line is $Aq_1/Oq_1 = p$.

Now consider Figure 4.2. Here, we plot the market price (y-axis) for different values of a firm's output (x-axis). Since the market price is fixed at p, we obtain a horizontal straight line that cuts the y-axis at a height equal to p. This horizontal straight line is called the **price line**. The price line also depicts the demand curve facing a firm. Observe that Figure 4.2 shows that the market price, p, is independent of a firm's output. This means that a firm can sell as many units of the good as it wants to sell at price p.

The **average revenue** (AR) of a firm is defined as total revenue per unit of output. Recall that if a firm's output is q and the market price is p, then TR equals $p \quad q$. Hence

$$AR = \frac{TR}{q} = \frac{p \times q}{q} = p$$

In other words, for a price-taking firm, average revenue equals the market price.

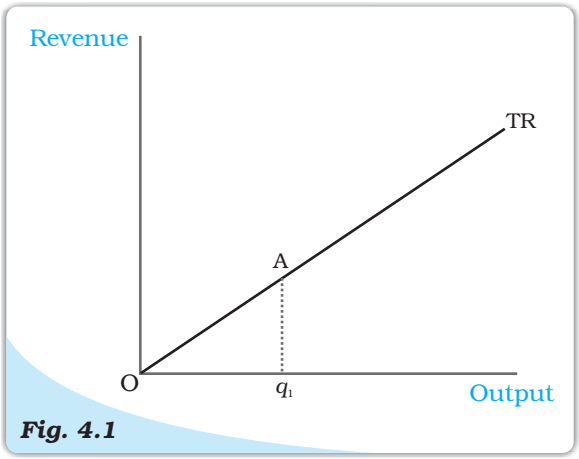


Fig. 4.1

Total Revenue curve. *The total revenue curve of a firm shows the relationship between the total revenue that the firm earns and the output level of the firm. The slope of the curve, Aq_1/Oq_1, is the market price.*

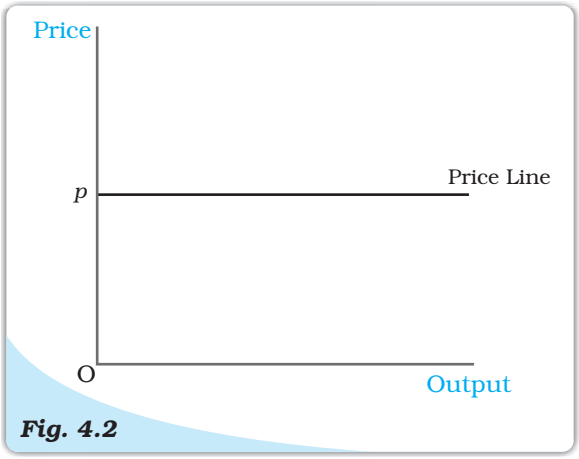


Fig. 4.2

Price Line. *The price line shows the relationship between the market price and a firm's output level. The vertical height of the price line is equal to the market price, p.*

The **marginal revenue** (MR) of a firm is defined as the increase in total revenue for a unit increase in the firm's output. Consider a situation where the firm's output is increased from q^0 to $(q^0 + 1)$. Given market price p, notice that

$$MR = (TR \text{ from output } (q^0 + 1)) - (TR \text{ from output } q^0)$$
$$= (p \quad (q^0 + 1)) - (pq^0) = p$$

In other words, for a price-taking firm, marginal revenue equals the market price.

Setting the algebra aside, the intuition for this result is quite simple. When a firm increases its output by one unit, this extra unit is sold at the market price. Hence, the firm's increase in total revenue from the one-unit output expansion – that is, MR – is precisely the market price.

4.3 Profit Maximisation

A firm produces and sells a certain amount of a good. The firm's profit, denoted by π, is defined to be the difference between its total revenue (TR) and its total cost of production (TC).[1] In other words

$$\pi = TR - TC$$

Clearly, the gap between TR and TC is the firm's earnings net of costs.

A firm wishes to maximise its profit. The critical question is: at what output level is the firm's profit maximised? Assuming that the firm's output is perfectly divisible, we now show that *if* there is a *positive* output level, q_0, at which profit is maximised, then three conditions *must* hold:

1. The market price, p, is equal to the marginal cost at q_0.
2. The marginal cost is non-decreasing at q_0.
3. In the short run, the market price, p, must be greater than or equal to the average variable cost at q_0. In the long run, the market price, p, must be greater than or equal to the average cost at q_0.

4.3.1 Condition 1

Consider condition 1. We show that condition 1 is true by arguing that a profit-maximising firm will *not* produce at an output level where market price exceeds marginal cost *or* marginal cost exceeds market price. We check both the cases.

Case 1: Price greater than MC is ruled out

Consider Figure 4.3 and note that at the output level q_2, the market price, p, exceeds the marginal cost. We claim that q_2 cannot be a profit-maximising output level. Why?

Observe that for all output levels slightly to the right of q_2, the market price continues to exceed the marginal cost. So, pick an output level q_3 slightly to the right of q_2 such that the market price exceeds the marginal cost for *all* output levels between q_2 and q_3.

Suppose, now, that the firm increases its output level from q_2 to q_3. The increase in the total revenue of the firm from this output expansion is just the market price multiplied by the change in quantity; that is, the area of the rectangle q_2q_3CB. On the other hand, the increase in total cost associated with this output expansion is just the area under the marginal cost curve between output levels q_2 and q_3; that is, the area of the region q_2q_3XW. But, a comparison of the two areas shows that the firm's profit is higher when its output level is q_3 rather than q_2. But, if this is the case, q_2 cannot be a profit-maximising output level.

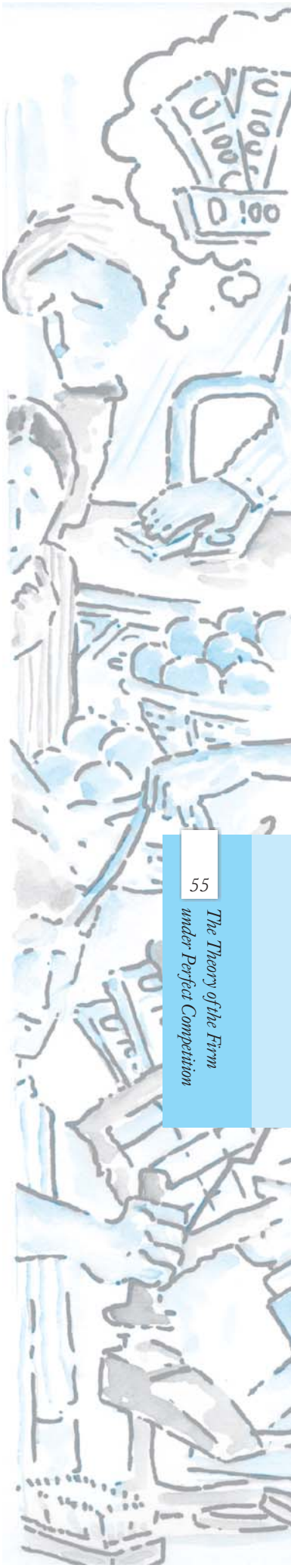
Case 2: Price less than MC is ruled out

Consider Figure 4.3 and note that at the output level q_5, the market price, p, is less than the marginal cost. We claim that q_5 cannot be a profit-maximising output level. Why?

Observe that for all output levels slightly to the left of q_5, the market price remains lower than the marginal cost. So, pick an output level q_4 slightly to the left of q_5 such that the market price is less than the marginal cost for *all* output levels between q_4 and q_5.

Suppose, now, that the firm cuts its output level from q_5 to q_4. The decrease in the total revenue of the firm from this output contraction is just the market

[1] It is a convention in economics to denote profit with the Greek letter π.



price multiplied by the change in quantity; that is, the area of the rectangle q_4q_5EF. On the other hand, the decrease in total cost brought about by this output contraction is the area under the marginal cost curve between output levels q_4 and q_5; that is, the area of the region $q_4\,q_5\,ZY$. But, a comparison of the two areas shows that the firm's profit is higher when its output level is q_4 rather than q_5. But, if this is the case, q_5 cannot be a profit-maximising output level.

4.3.2 Condition 2

Consider the second condition that must hold when the profit-maximising output level is positive. Why is it the case that the marginal cost curve cannot slope downwards at the profit-maximising output level? To answer this question, refer once again to Figure 4.3. Note that at the output level q_1, the market price is equal to the marginal cost; however, the marginal cost curve is downward sloping. We claim that q_1 cannot be a profit-maximising output level. Why?

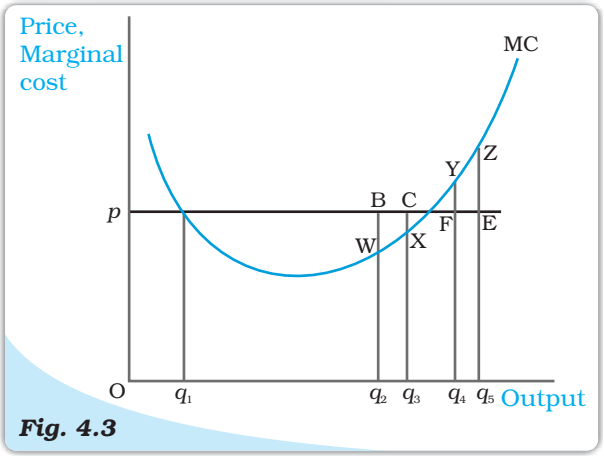


Fig. 4.3

Conditions 1 and 2 for profit maximisation. *The figure is used to demonstrate that when the market price is p, the output level of a profit-maximising firm cannot be q_1 (marginal cost curve, MC, is downward sloping), q_2 (market price exceeds marginal cost), or q_5 (marginal cost exceeds market price).*

Observe that for *all* output levels slightly to the left of q_1, the market price is lower than the marginal cost. But, the argument outlined in case 2 of section 3.1 immediately implies that the firm's profit at an output level slightly smaller than q_1 exceeds that corresponding to the output level q_1. This being the case, q_1 cannot be a profit-maximising output level.

4.3.3 Condition 3

Consider the third condition that must hold when the profit-maximising output level is positive. Notice that the third condition has two parts: one part applies in the short run while the other applies in the long run.

Case 1: Price must be greater than or equal to AVC in the short run

We will show that the statement of Case 1 (see above) is true by arguing that a profit-maximising firm, in the short run, will *not* produce at an output level wherein the market price is lower than the AVC.

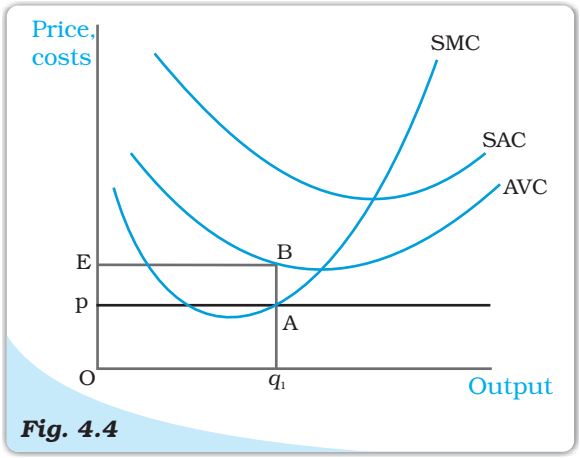


Fig. 4.4

Price-AVC Relationship with Profit Maximisation (Short Run). *The figure is used to demonstrate that a profit-maximising firm produces zero output in the short run when the market price, p, is less than the minimum of its average variable cost (AVC). If the firm's output level is q_1, the firm's total variable cost exceeds its revenue by an amount equal to the area of rectangle pEBA.*

Let us turn to Figure 4.4. Observe that at the output level q_1, the market price p is lower than the AVC. We claim that q_1 cannot be a profit-maximising output level. Why?

Notice that the firm's total revenue at q_1 is as follows

TR = Price Quantity
= Vertical height Op width Oq_1
= The area of rectangle $OpAq_1$

Similarly, the firm's total variable cost at q_1 is as follows

TVC = Average variable cost Quantity
= Vertical height OE Width Oq_1
= The area of rectangle $OEBq_1$

Now recall that the firm's profit at q_1 is TR – (TVC + TFC); that is, [the area of rectangle $OpAq_1$] – [the area of rectangle $OEBq_1$] – TFC. What happens if the firm produces zero output? Since output is zero, TR and TVC are zero as well. Hence, the firm's profit at zero output is equal to – TFC. But, the area of rectangle $OpAq_1$ is strictly less than the area of rectangle $OEBq_1$. Hence, the firm's profit at q_1 is strictly less than what it obtains by not producing at all. This means, of course, that q_1 cannot be a profit-maximising output level.

Case 2: Price must be greater than or equal to AC in the long run

We will show that the statement of Case 2 (see above) is true by arguing that a profit-maximising firm, in the long run, will *not* produce at an output level wherein the market price is lower than the AC.

Let us turn to Figure 4.5. Observe that at the output level q_1, the market price p is lower than the (long run) AC. We claim that q_1 cannot be a profit-maximising output level. Why?

Notice that the firm's total revenue, TR, at q_1 is the area of the rectangle $OpAq_1$ (the product of price and quantity) while the firm's total cost, TC , is the area of the rectangle $OEBq_1$ (the product of average cost and quantity). Since the area of rectangle $OEBq_1$ is larger than the area of rectangle $OpAq_1$, the firm incurs a loss at the output level q_1. But, in the long run set-up, a firm that shuts down production has a profit of zero. This means, of course, that q_1 is not a profit-maximising output level.

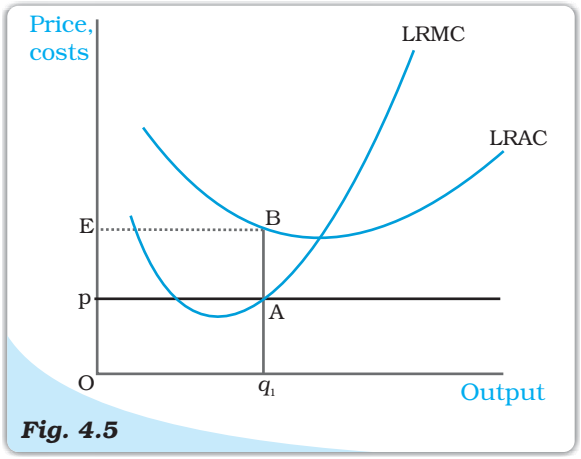


Fig. 4.5

Price-AC Relationship with Profit Maximisation (Long Run). *The figure is used to demonstrate that a profit-maximising firm produces zero output in the long run when the market price, p, is less than the minimum of its long run average cost (LRAC). If the firm's output level is q_1, the firm's total cost exceeds its revenue by an amount equal to the area of rectangle pEBA.*

4.3.4 The Profit Maximisation Problem: Graphical Representation

Using the material in sections 3.1, 3.2 and 3.3, let us graphically represent a firm's profit maximisation problem in the short run. Consider Figure 4.6. Notice

that the market price is p. Equating the market price with the (short run) marginal cost, we obtain the output level q_0. At q_0, observe that SMC slopes upwards and p exceeds AVC. Since the three conditions discussed in sections 3.1-3.3 are satisfied at q_0, we maintain that the profit-maximising output level of the firm is q_0.

What happens at q_0? The total revenue of the firm at q_0 is the area of rectangle $OpAq_0$ (the product of price and quantity) while the total cost at q_0 is the area of rectangle $OEBq_0$ (the product of short run average cost and quantity). So, at q_0, the firm earns a profit equal to the area of the rectangle $EpAB$.

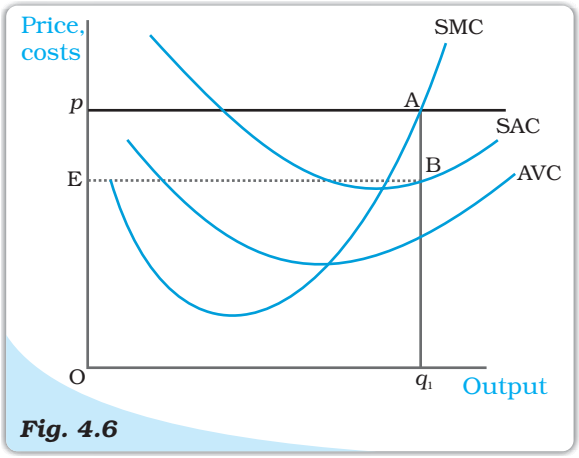


Fig. 4.6

Geometric Representation of Profit Maximisation (Short Run). *Given market price* p, *the output level of a profit-maximising firm is* q_0. *At* q_0, *the firm's profit is equal to the area of rectangle* EpAB.

4.4 Supply Curve of a Firm

The **supply curve** of a firm shows the levels of output (plotted on the x-axis) that the firm chooses to produce corresponding to different values of the market price (plotted on the y-axis). Of course, for a given market price, the output level of a profit-maximising firm will depend on whether we are considering the short run or the long run. Accordingly, we distinguish between the **short run supply curve** and the **long run supply curve**.

4.4.1 Short Run Supply Curve of a Firm

Let us turn to Figure 4.7 and derive a firm's short run supply curve. We shall split this derivation into two parts. We first determine a firm's profit-maximising output level when the market price is greater than or equal to the minimum AVC. This done, we determine the firm's profit-maximising output level when the market price is less than the minimum AVC.

Case 1: Price is greater than or equal to the minimum AVC

Suppose the market price is p_1, which exceeds the minimum AVC. We start out by equating p_1 with SMC on the rising part of the SMC curve; this leads to the output level q_1. Note also that the AVC at q_1

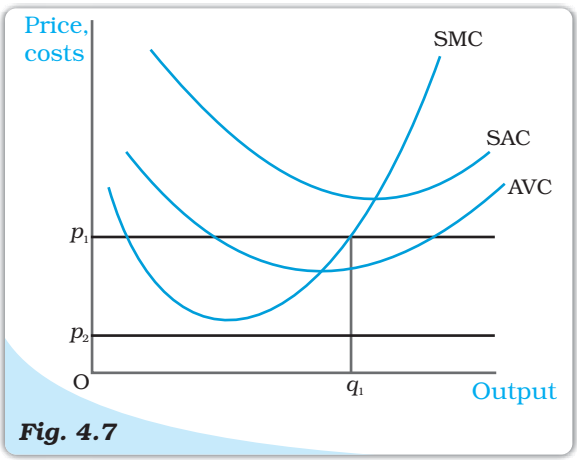


Fig. 4.7

Market Price Values. *The figure shows the output levels chosen by a profit-maximising firm in the short run for two values of the market price:* p_1 *and* p_2. *When the market price is* p_1, *the output level of the firm is* q_1; *when the market price is* p_2, *the firm produces zero output.*

does not exceed the market price, p_1. Thus, all three conditions highlighted in section 3 are satisfied at q_1. Hence, when the market price is p_1, the firm's output level in the short run is equal to q_1.

Case 2: Price is less than the minimum AVC

Suppose the market price is p_2, which is less than the minimum AVC. We have argued (see condition 3 in section 3) that if a profit-maximising firm produces a positive output in the short run, then the market price, p_2, *must* be greater than or equal to the AVC at that output level. But notice from Figure 4.7 that for *all* positive output levels, AVC strictly exceeds p_2. In other words, it cannot be the case that the firm supplies a positive output. So, if the market price is p_2, the firm produces zero output.

Combining cases 1 and 2, we reach an important conclusion. A firm's short run supply curve is the rising part of the SMC curve from and above the minimum AVC together with zero output for all prices strictly less than the minimum AVC. In figure 4.8, the bold line represents the short run supply curve of the firm.

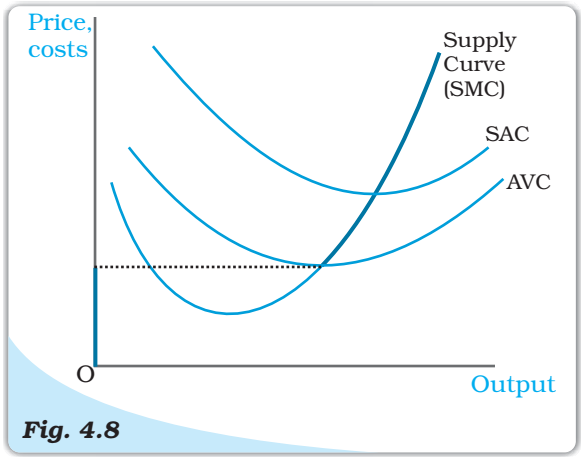


Fig. 4.8

The Short Run Supply Curve of a Firm. *The short run supply curve of a firm, which is based on its short run marginal cost curve (SMC) and average variable cost curve (AVC), is represented by the bold line.*

4.4.2 Long Run Supply Curve of a Firm

Let us turn to Figure 4.9 and derive the firm's long run supply curve. As in the short run case, we split the derivation into two parts. We first determine the firm's profit-maximising output level when the market price is greater than or equal to the minimum (long run) AC. This done, we determine the firm's profit-maximising output level when the market price is less than the minimum (long run) AC.

Case 1: Price greater than or equal to the minimum LRAC

Suppose the market price is p_1, which exceeds the minimum LRAC. Upon equating p_1 with LRMC on the rising part of the LRMC curve, we obtain output level q_1. Note also that the LRAC at q_1 does not exceed the market price, p_1. Thus, all three conditions highlighted in section 3 are satisfied at q_1.

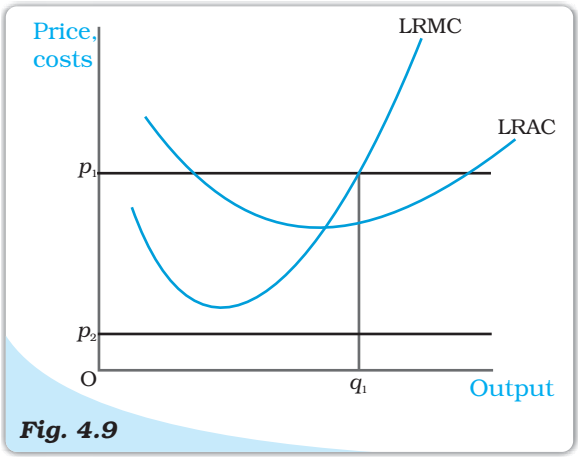
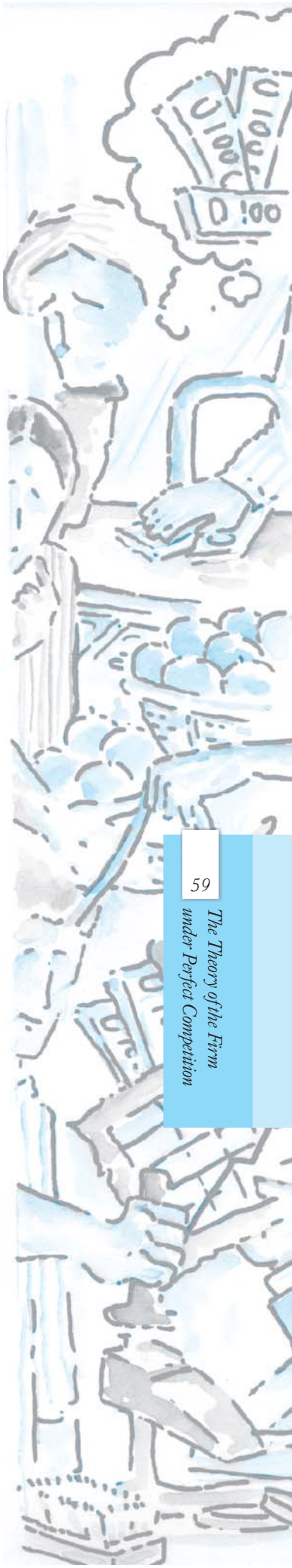


Fig. 4.9

Profit maximisation in the Long Run for Different Market Price Values. *The figure shows the output levels chosen by a profit-maximising firm in the long run for two values of the market price: p_1 and p_2. When the market price is p_1, the output level of the firm is q_1; when the market price is p_2, the firm produces zero output.*



Hence, when the market price is p_1, the firm's supplies in the long run become an output equal to q_1.

Case 2: Price less than the minimum LRAC

Suppose the market price is p_2, which is less than the minimum LRAC. We have argued (see condition 3 in section 3) that if a profit-maximising firm produces a positive output in the long run, the market price, p_2, *must* be greater than or equal to the LRAC at that output level. But notice from Figure 4.9 that for *all* positive output levels, LRAC strictly exceeds p_2. In other words, it cannot be the case that the firm supplies a positive output. So, when the market price is p_2, the firm produces zero output.

Combining cases 1 and 2, we reach an important conclusion. A firm's long run supply curve is the rising part of the LRMC curve from and above the minimum LRAC together with zero output for all prices less than the minimum LRAC. In Figure 4.10, the bold line represents the long run supply curve of the firm.

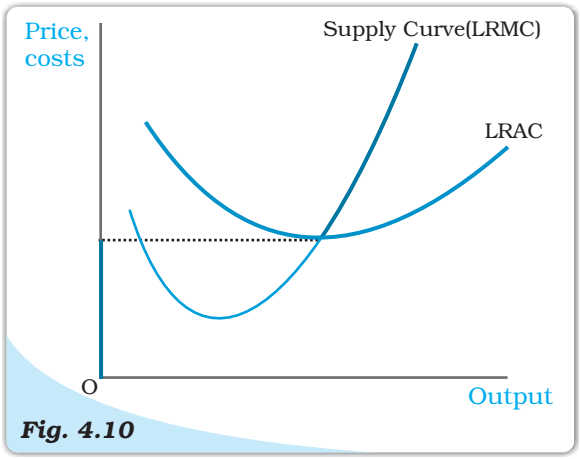


Fig. 4.10

The Long Run Supply Curve of a Firm*. The long run supply curve of a firm, which is based on its long run marginal cost curve (LRMC) and long run average cost curve (LRAC), is represented by the bold line.*

4.4.3 The Shut Down Point

Previously, while deriving the supply curve, we have discussed that in the short run the firm continues to produce as long as the price remains greater than or equal to the minimum of AVC. Therefore, along the supply curve as we move down, the last price-output combination at which the firm produces positive output is the point of minimum AVC where the SMC curve cuts the AVC curve. Below this, there will be no production. This point is called the short run **shut down point** of the firm. In the long run, however, the shut down point is the minimum of LRAC curve.

4.4.4 The Normal Profit and Break-even Point

A firm uses different kinds of inputs in the production process. To acquire some of them, the firm has to pay directly. For example, if a firm employs labour it has to pay wages to them; if it uses some raw materials, it has to buy them. There may be some other kinds of inputs which the firm owns, and therefore, does not need to pay to anybody for them. These inputs though do not involve any explicit cost, they involve some opportunity cost to the firm. The firm instead of using these inputs in the current production process could have used them for some other purpose and get some return. This forgone return is the opportunity cost to the firm. The firm normally expects to earn a profit that along with the explicit costs can also cover the opportunity costs. The profit level that is just enough to cover the explicit costs and opportunity costs of the firm is called the **normal profit**. If a firm includes both its explicit costs and opportunity costs in the calculation of total cost, the normal profit becomes that level of profit when total

revenue equals total cost, i.e., the zero level of profit. Profit that a firm earns over and above the normal profit is called the **super-normal profit**. In the long run, a firm does not produce if it earns anything less than the normal profit. In the short run, however, it may produce even if the profit is less than this level. The point on the supply curve at which a firm earns normal profit is called the **break-even point** of the firm. The point of minimum average cost at which the supply curve cuts the LRAC curve (in short run, SAC curve) is therefore the break-even point of a firm.

Opportunity cost

In economics, one often encounters the concept of opportunity cost. Opportunity cost of some activity is the gain foregone from the second best activity. Suppose you have Rs 1,000 which you decide to invest in your family business. What is the opportunity cost of your action? If you do not invest this money, you can either keep it in the house-safe which will give you zero return or you can deposit it in either bank-1 or bank-2 in which case you get an interest at the rate of 10 per cent or 5 per cent respectively. So the maximum benefit that you may get from other alternative activities is the interest from the bank-1. But this opportunity will no longer be there once you invest the money in your family business. The opportunity cost of investing the money in your family business is therefore the amount of forgone interest from the bank-1.

4.5 Determinants of a Firm's Supply Curve

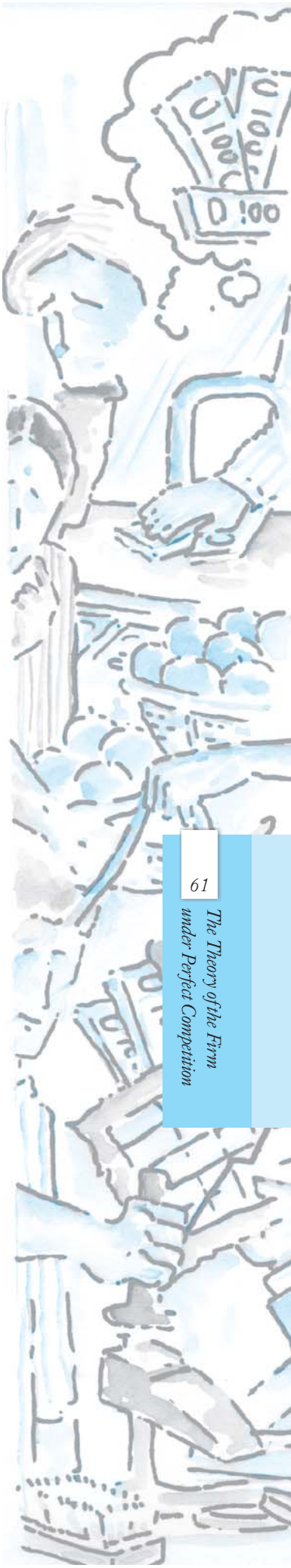
In the previous section, we have seen that a firm's supply curve is a part of its marginal cost curve. Thus, *any* factor that affects a firm's marginal cost curve is of course a **determinant of its supply curve**. In this section, we discuss three such factors.

4.5.1 Technological Progress

Suppose a firm uses two factors of production – say, capital and labour – to produce a certain good. Subsequent to an organisational innovation by the firm, the same levels of capital and labour now produce more units of output. Put diferently, to produce a given level of output, the organisational innovation allows the firm to use fewer units of inputs. It is expected that this will lower the firm's marginal cost at any level of output; that is, there is a rightward (or downward) shift of the MC curve. As the firm's supply curve is essentially a segment of the MC curve, technological progress shifts the supply curve of the firm to the right. At any given market price, the firm now supplies more units of output.

4.5.2 Input Prices

A change in input prices also affects a firm's supply curve. If the price of an input (say, the wage rate of labour) increases, the cost of production rises. The consequent increase in the firm's average cost at any level of output is usually accompanied by an increase in the firm's marginal cost at any level of output; that is, there is a leftward (or upward) shift of the MC curve. This means that the firm's supply curve shifts to the left: at any given market price, the firm now supplies fewer units of output.



4.5.3 Unit Tax

A unit tax is a tax that the government imposes per unit sale of output. For example, suppose that the unit tax imposed by the government is Rs 2. Then, if the firm produces and sells 10 units of the good, the total tax that the firm must pay to the government is 10 Rs 2 = Rs 20.

How does the long run supply curve of a firm change when a unit tax is imposed? Let us turn to figure 4.11. Before the unit tax is imposed, $LRMC^0$ and $LRAC^0$ are, respectively, the long run marginal cost curve and the long run average cost curve of the firm. Now, suppose the government puts in place a unit tax of Rs t. Since the firm must pay an extra Rs t for each unit of the good produced, the firm's long run average cost and long run marginal cost at any level of output increases by Rs t. In Figure 4.11, $LRMC^1$ and $LRAC^1$ are, respectively, the long run marginal cost curve and the long run average cost curve of the firm upon imposition of the unit tax.

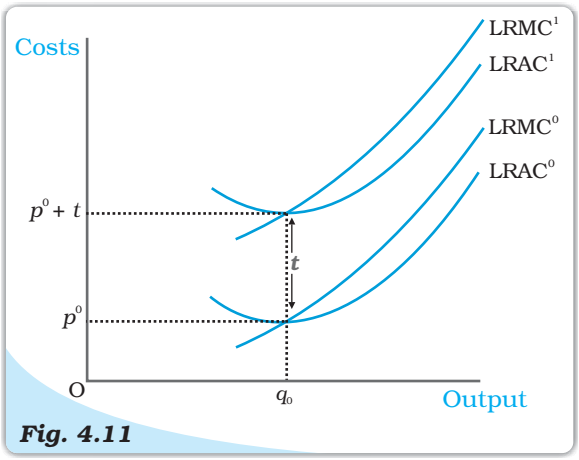


Fig. 4.11

Cost Curves and the Unit Tax. *$LRAC^0$ and $LRMC^0$ are, respectively, the long run average cost curve and the long run marginal cost curve of a firm before a unit tax is imposed. $LRAC^1$ and $LRMC^1$ are, respectively, the long run average cost curve and the long run marginal cost curve of a firm after a unit tax of Rs t is imposed.*

Recall that the long run supply curve of a firm is the rising part of the LRMC curve from and above the minimum LRAC together with zero output for all prices less than the minimum LRAC. Using this observation in Figure 4.12, it is immediate that S^0 and S^1 are, respectively, the long run supply curve of the firm before and after the imposition of the unit tax. Notice that the unit tax shifts the firm's long run supply curve to the left: at any given market price, the firm now supplies fewer units of output.

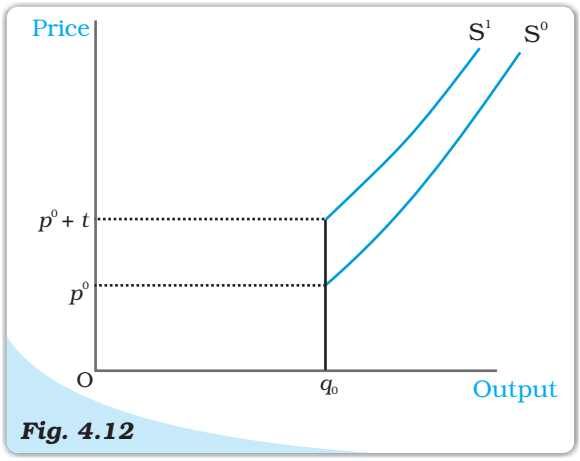


Fig. 4.12

Supply Curves and Unit Tax. *S^0 is the supply curve of a firm before a unit tax is imposed. After a unit tax of Rs t is imposed, S^1 represents the supply curve of the firm.*

4.6 Market Supply Curve

The market supply curve shows the output levels (plotted on the x-axis) that firms in the market produce in aggregate corresponding to different values of the market price (plotted on the y-axis).

How is the market supply curve derived? Consider a market with n firms: firm 1, firm 2, firm 3, and so on. Suppose the market price is fixed at p. Then,

the output produced by the n firms in aggregate is [supply of firm 1 at price p] + [supply of firm 2 at price p] + ... + [supply of firm n at price p]. In other words, the market supply at price p is the summation of the supplies of individual firms at that price.

Let us now construct the market supply curve geometrically with just two firms in the market: firm 1 and firm 2. The two firms have different cost structures. Firm 1 will not produce anything if the market price is less than $\bar{p}_1$ while firm 2 will not produce anything if the market price is less than $\bar{p}_2$. Assume also that $\bar{p}_2$ is greater than $\bar{p}_1$.

In panel (a) of Figure 4.13 we have the supply curve of firm 1, denoted by S_1; in panel (b), we have the supply curve of firm 2, denoted by S_2. Panel (c) of Figure 4.13 shows the market supply curve, denoted by S*m*. When the market price is strictly below $\bar{p}_1$, both firms choose not to produce any amount of the good; hence, market supply will also be zero for all such prices. For a market price greater than or equal to $\bar{p}_1$ but strictly less than $\bar{p}_2$, only firm 1 will produce a positive amount of the good. Therefore, in this range, the market supply curve coincides with the supply curve of firm 1. For a market price greater than or equal to $\bar{p}_2$, both firms will have positive output levels. For example, consider a situation wherein the market price assumes the value p_3 (observe that p_3 exceeds $\bar{p}_2$). Given p_3, firm 1 supplies q_3 units of output while firm 2 supplies q_4 units of output. So, the market supply at price p_3 is q_5, where $q_5 = q_3 + q_4$. Notice how the market supply curve, S_m, in panel (c) is being constructed: we obtain S_m by taking a horizontal summation of the supply curves of the two firms in the market, S_1 and S_2.

It should be noted that the market supply curve has been derived for a fixed number of firms in the market. As the number of firms changes, the market supply curve shifts as well. Specifically, if the number of firms in the market increases (decreases), the market supply curve shifts to the right (left).

We now supplement the graphical analysis given above with a related numerical example. Consider a market with two firms: firm 1 and firm 2. Let the supply curve of firm 1 be as follows

$$S_1(p) = \begin{cases} 0 & : p < 10 \\ p - 10 & : p \geq 10 \end{cases}$$

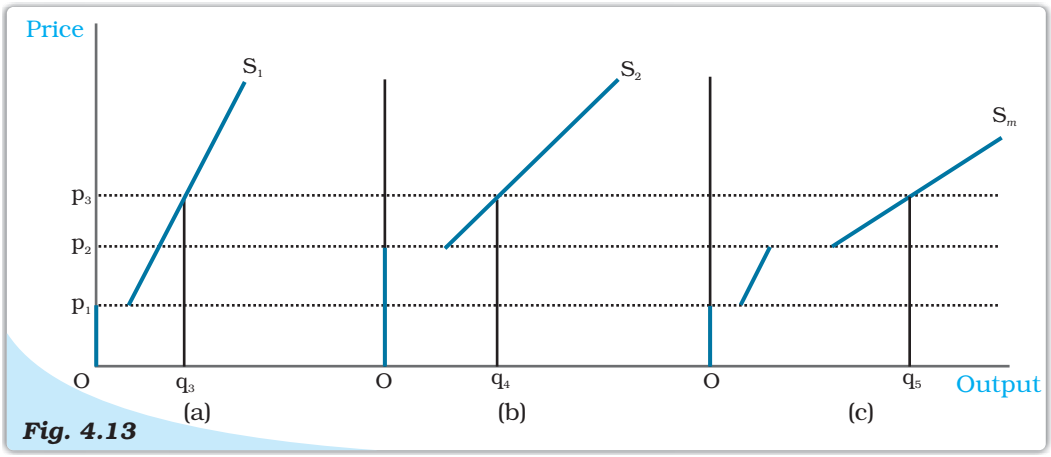


Fig. 4.13

The Market Supply Curve Panel. *(a) shows the supply curve of firm 1. Panel (b) shows the supply curve of firm 2. Panel (c) shows the market supply curve, which is obtained by taking a horizontal summation of the supply curves of the two firms.*

Notice that $S_1(p)$ indicates that (1) firm 1 produces an output of 0 if the market price, p, is strictly less than 10, and (2) firm 1 produces an output of $(p - 10)$ if the market price, p, is greater than or equal to 10. Let the supply curve of firm 2 be as follows

$$S_2(p) = \begin{cases} 0 & : p < 15 \\ p - 15 & : p \geq 15 \end{cases}$$

The interpretation of $S_2(p)$ is identical to that of $S_1(p)$, and is, hence, omitted. Now, the market supply curve, $S_m(p)$, simply sums up the supply curves of the two firms; in other words

$$S_m(p) = S_1(p) + S_2(p)$$

But, this means that $S_m(p)$ is as follows

$$S_m(p) = \begin{cases} 0 & : p < 10 \\ p - 10 & : p \geq 10 \text{ and } p < 15 \\ (p - 10) + (p - 15) = 2p - 25 & : p \geq 15 \end{cases}$$

4.7 Price Elasticity of Supply

The price elasticity of supply of a good measures the responsiveness of quantity supplied to changes in the price of the good. More specifically, the price elasticity of supply, denoted by e_S, is defined as follows

$$\text{Price elasticity of supply } (e_S) = \frac{\text{Percentage change in quantity supplied}}{\text{Percentage change in price}}$$

Given the market supply curve of a good (that is, $S_m(p)$), let q^0 be the quantity of the good supplied to the market when its market price is p^0. For some reason, the market price of the good changes from p^0 to p^1. Let q^1 be the quantity of the good supplied to the market when the market price is p^1. Notice that when the market price moves from p^0 to p^1, the percentage change in price is $100 \quad \frac{(p^1 - p^0)}{p^0}$; similarly, when the quantity supplied moves from q^0 to q^1, the percentage change in quantity supplied is $100 \quad \frac{(q^1 - q^0)}{q^0}$. So

$$e_S = \frac{100 \times (q^1 - q^0)/q^0}{100 \times (p^1 - p^0)/p^0} = \frac{q^1/q^0 - 1}{p^1/p^0 - 1}$$

To make matters concrete, consider the following numerical example. Suppose the market for cricket balls is perfectly competitive. When the price of a cricket ball is Rs 10, let us assume that 200 cricket balls are produced in aggregate by the firms in the market. When the price of a cricket ball rises to Rs 30, let us assume that 1,000 cricket balls are produced in aggregate by the firms in the market. Then

1. $\left(\frac{q^1}{q^0 - 1}\right) = (1{,}000/200 - 1) = 4,$
2. $\left(\frac{p^1}{p^0 - 1}\right) = (30/10 - 1) = 2,$
3. $e_S = \frac{4}{2} = 2.$

When the supply curve is vertical, supply is completely insensitive to price and the elasticity of supply is zero. In other cases, when supply curve is positively sloped, with a rise in price, supply rises and hence, the elasticity of supply is positive. Like the price elasticity of demand, the price elasticity of supply is also independent of units.

4.7.1 The Geometric Method

Consider the Figure 4.11. Panel (a) shows a straight line supply curve. *S* is a point on the supply curve. It cuts the price-axis at its positive range and as we extend the straight line, it cuts the quantity-axis at *M* which is at its negative range. The price elasticity of this supply curve at the point *S* is given by the ratio, Mq_0/Oq_0. For any point *S* on such a supply curve, we see that $Mq_0 > Oq_0$. The elasticity at any point on such a supply curve, therefore, will be greater than 1.

In panel (c) we consider a straight line supply curve and *S* is a point on it. It cuts the quantity-axis at *M* which is at its positive range. Again the price elasticity of this supply curve at the point *S* is given by the ratio, Mq_0/Oq_0. Now, $Mq_0 < Oq_0$ and hence, $e_S < 1$. *S* can be any point on the supply curve, and therefore at all points on such a supply curve $e_S < 1$.

Now we come to panel (b). Here the supply curve goes through the origin. One can imagine that the point *M* has coincided with the origin here, i.e., Mq_0 has become equal to Oq_0. The price elasticity of this supply curve at the point *S* is given by the ratio, Oq_0/Oq_0 which is equal to 1. At any point on a straight line, supply curve going through the origin price elasticity will be one.

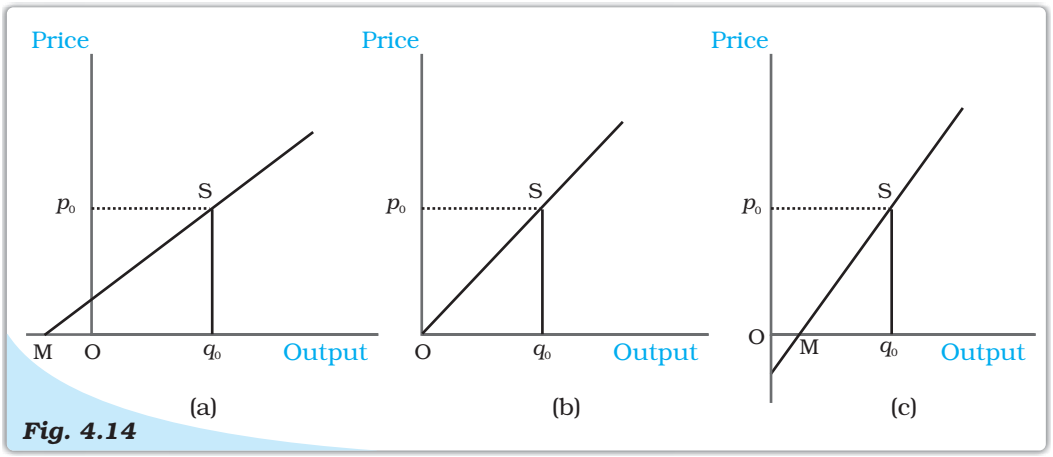


Fig. 4.14

Price Elasticity Associated with Straight Line Supply Curves. *In panel (a), price elasticity (e_S) at S is greater than 1. In panel (b), price elasticity (e_S) at S is equal to 1. In panel (c), price elasticity (e_S) at S is less than 1.*

Summary

- In a perfectly competitive market, firms are price-takers.
- The total revenue of a firm is the market price of the good multiplied by the firm's output of the good.
- For a price-taking firm, average revenue is equal to market price.
- For a price-taking firm, marginal revenue is equal to market price.
- The demand curve that a firm faces in a perfectly competitive market is perfectly elastic; it is a horizontal straight line at the market price.
- The profit of a firm is the difference between total revenue earned and total cost incurred.

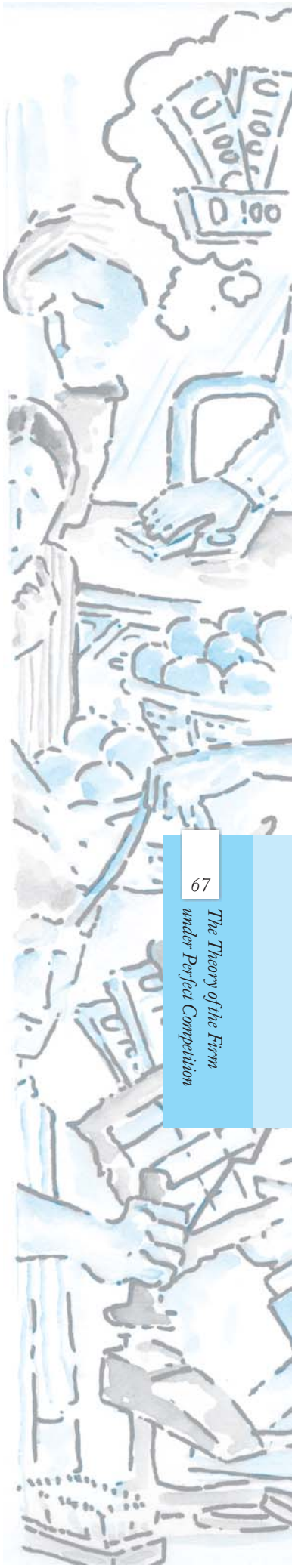
- If there is a positive level of output at which a firm's profit is maximised in the short run, three conditions must hold at that output level
  (i) $p = SMC$
  (ii) SMC is non-decreasing
  (iii) $p \geq AV\,C$.
- If there is a positive level of output at which a firm's profit is maximised in the long run, three conditions must hold at that output level
  (i) $p = LRMC$
  (ii) $LRMC$ is non-decreasing
  (iii) $p \geq LRAC$.
- The short run supply curve of a firm is the rising part of the *SMC* curve from and above minimum *AVC* together with 0 output for all prices less than the minimum *AVC*.
- The long run supply curve of a firm is the rising part of the *LRMC* curve from and above minimum *LRAC* together with 0 output for all prices less than the minimum *LRAC*.
- Technological progress is expected to shift the supply curve of a firm to the right.
- An increase (decrease) in input prices is expected to shift the supply curve of a firm to the left (right).
- The imposition of a unit tax shifts the supply curve of a firm to the left.
- The market supply curve is obtained by the horizontal summation of the supply curves of individual firms.
- The price elasticity of supply of a good is the percentage change in quantity supplied due to one per cent change in the market price of the good.

Key Concepts

Perfect competition
Profit maximisation
Market supply curve
Revenue, Profit
Firms supply curve
Price elasticity of supply

Exercises

1. What are the characteristics of a perfectly competitive market?
2. How are the total revenue of a firm, market price, and the quantity sold by the firm related to each other?
3. What is the 'price line'?
4. Why is the total revenue curve of a price-taking firm an upward-sloping straight line? Why does the curve pass through the origin?
5. What is the relation between market price and average revenue of a price-taking firm?
6. What is the relation between market price and marginal revenue of a price-taking firm?
7. What conditions must hold if a profit-maximising firm produces positive output in a competitive market?
8. Can there be a positive level of output that a profit-maximising firm produces in a competitive market at which market price is not equal to marginal cost? Give an explanation.



9. Will a profit-maximising firm in a competitive market ever produce a positive level of output in the range where the marginal cost is falling? Give an explanation.
10. Will a profit-maximising firm in a competitive market produce a positive level of output in the short run if the market price is less than the minimum of *AVC*? Give an explanation.
11. Will a profit-maximising firm in a competitive market produce a positive level of output in the long run if the market price is less than the minimum of *AC*? Give an explanation.
12. What is the supply curve of a firm in the short run?
13. What is the supply curve of a firm in the long run?
14. How does technological progress affect the supply curve of a firm?
15. How does the imposition of a unit tax affect the supply curve of a firm?
16. How does an increase in the price of an input affect the supply curve of a firm?
17. How does an increase in the number of firms in a market affect the market supply curve?
18. What does the price elasticity of supply mean? How do we measure it?
19. Compute the total revenue, marginal revenue and average revenue schedules in the following table. Market price of each unit of the good is Rs 10.

Quantity Sold	*TR*	*MR*	*AR*
0			
1			
2			
3			
4			
5			
6			

20. The following table shows the total revenue and total cost schedules of a competitive firm. Calculate the profit at each output level. Determine also the market price of the good.

Quantity Sold	*TR (Rs)*	*TC (Rs)*	*Profit*
0	0	5	
1	5	7	
2	10	10	
3	15	12	
4	20	15	
5	25	23	
6	30	33	
7	35	40	

21. The following table shows the total cost schedule of a competitive firm. It is given that the price of the good is Rs 10. Calculate the profit at each output level. Find the profit maximising level of output.

Price (Rs)	*TC (Rs)*
0	5
1	15
2	22
3	27
4	31
5	38
6	49
7	63
8	81
9	101
10	123

22. Consider a market with two firms. The following table shows the supply schedules of the two firms: the SS_1 column gives the supply schedule of firm 1 and the SS_2 column gives the supply schedule of firm 2. Compute the market supply schedule.

Price (Rs)	SS_1 *(units)*	SS_2 *(units)*
0	0	0
1	0	0
2	0	0
3	1	1
4	2	2
5	3	3
6	4	4

23. Consider a market with two firms. In the following table, columns labelled as SS_1 and SS_2 give the supply schedules of firm 1 and firm 2 respectively. Compute the market supply schedule.

Price (Rs)	SS_1 *(kg)*	SS_2 *(kg)*
0	0	0
1	0	0
2	0	0
3	1	0
4	2	0.5
5	3	1
6	4	1.5
7	5	2
8	6	2.5

24. There are three identical firms in a market. The following table shows the supply schedule of firm 1. Compute the market supply schedule.

Price (Rs)	SS_1 *(units)*
0	0
1	0
2	2
3	4
4	6
5	8
6	10
7	12
8	14

25. A firm earns a revenue of Rs 50 when the market price of a good is Rs 10. The market price increases to Rs 15 and the firm now earns a revenue of Rs 150. What is the price elasticity of the firm's supply curve?

26. The market price of a good changes from Rs 5 to Rs 20. As a result, the quantity supplied by a firm increases by 15 units. The price elasticity of the firm's supply curve is 0.5. Find the initial and final output levels of the firm.

27. At the market price of Rs 10, a firm supplies 4 units of output. The market price increases to Rs 30. The price elasticity of the firm's supply is 1.25. What quantity will the firm supply at the new price?