Energy Economics and Policy
Prof. Shyamasree Dasgupta
Department of Humanities and Social Sciences
Indian Institute of Technology Mandi

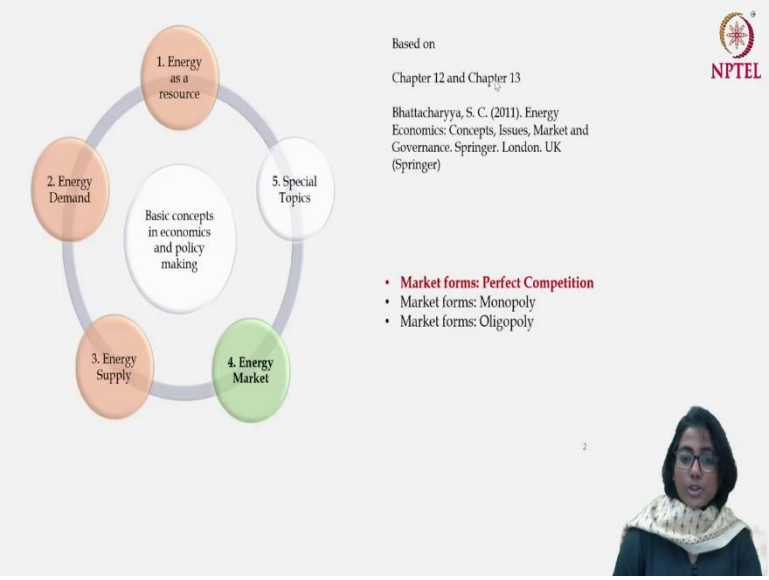
Week - 06
Energy Market
Lecture - 01
Perfect Competition as a Market Form

Welcome to the 6th week of the course Energy Economics and Policy. Since we have looked into the energy demand and energy supply separately in previous weeks, this week we will explore several market forms in order to understand what kind of market form actually suits the energy industry that is, what is the form within which the energy market operates?

Initially we will explore different theoretical forms of different types of market. This is important to understand the functioning of energy markets or any markets per say. As we have been doing it for demand as well as supply, we will also explore the theoretical and the economic foundation of different types of market and then we will try to see how the energy market actually falls in a particular category.

In the first lecture we are going to start with the form which is perfect competition. Then we will move on to monopoly and then we will also explore oligopoly and interestingly what we will see is that there is no one market form that suits the energy market as a whole. If you look at the oil market, the market dynamics that are going on are very different from what is going on for example, the natural gas market or both of them are very different from what is going on in the electricity market for example. We will try to explore as many types of market form as possible and try to fit in the energy market within that.

(Refer Slide Time: 02:04)

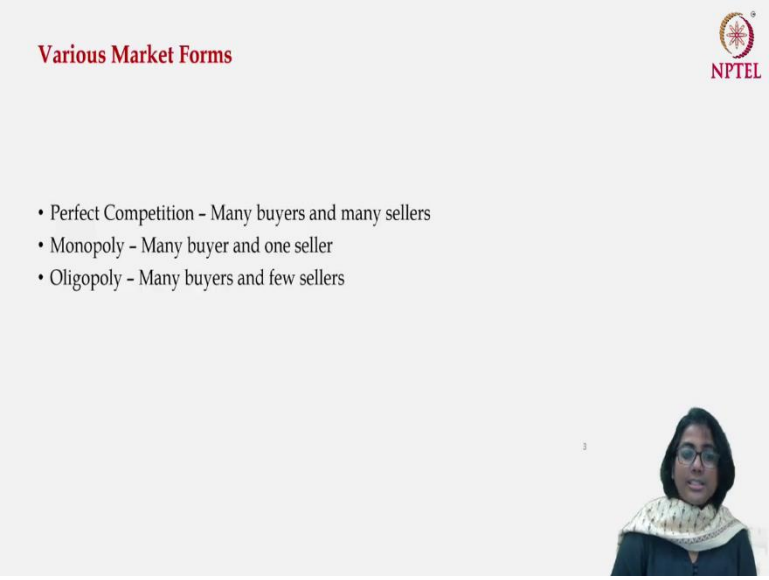


Let us just do a little bit of recapitulation, we said that we will try to cover four different aspects of energy economics as well as policy and all these aspects will actually revolve around some basic concepts in economics and policy making. So far we have covered the topic on energy as a resource, covered energy demand in week 2 and 3, in the following 2 weeks we covered energy supply and today we have moved on to the energy market.

If you want to read on this and want to have more understanding and theoretical grounding, you can always follow this book. Even for the previous chapters I have given the reference of this book by Professor Subhes Bhattacharyya, the name of the book is Energy Economics Concepts, Issues, Markets and Governance. This is a Springer publication and for the energy market you can look at chapter 12 and chapter 13.

When I say that we are going to cover market forms we are actually going to cover 3 very basic types of markets. The first one is called perfect competition, the second one is monopoly and the third one is oligopoly.

(Refer Slide Time: 03:26)



Let us start with what we understand about these three different types of market but let me just give you the disclaimer here that these are not the only 3 forms of market. There are other forms of markets as well but these are broadly used in analyzing the energy markets. The first one is perfect competition; the basic characteristic of a perfectly competitive market is that there are an infinite number of buyers as well as infinite number of sellers.

In case of monopoly the case is a little different, although you have multiple buyers there is only one seller of a particular product. You will see that both perfect competition as well as monopoly are sort of theoretical extremes, we do not really have markets of these forms existing. But when we see a market, we try to understand whether the particular form of market is actually tending towards perfect competition or is it tending towards monopoly or what are the problems of a particular market being perfectly competitive or why a particular market is monopolistic in nature or why there is oligopoly?

As I said unlike perfect competition, in monopoly there is one producer or supplier; however, you have multiple buyers in the market. So, clearly there is a lot of power that is enjoyed by the monopolist. In case of oligopoly there are many buyers however, instead of one monopolistic firm there may be 2 or 3 or may be 4 that is limited number of suppliers are present in the market. They do not enjoy the supreme power that the monopolist enjoys but of course they have some command over the market as only few of them are actually dominating the market.

(Refer Slide Time: 05:26)

Let us begin with perfect competition, we start with the features of the perfectly competitive markets. The first one that we have already discussed is that there are many buyers and sellers in a perfectly competitive market. The second one actually follows the first feature. Now you imagine a market where there are multiple buyers and multiple sellers who are buying and selling the same quality of product or the same product in the market. As a result, none of them would actually have a command over the price.

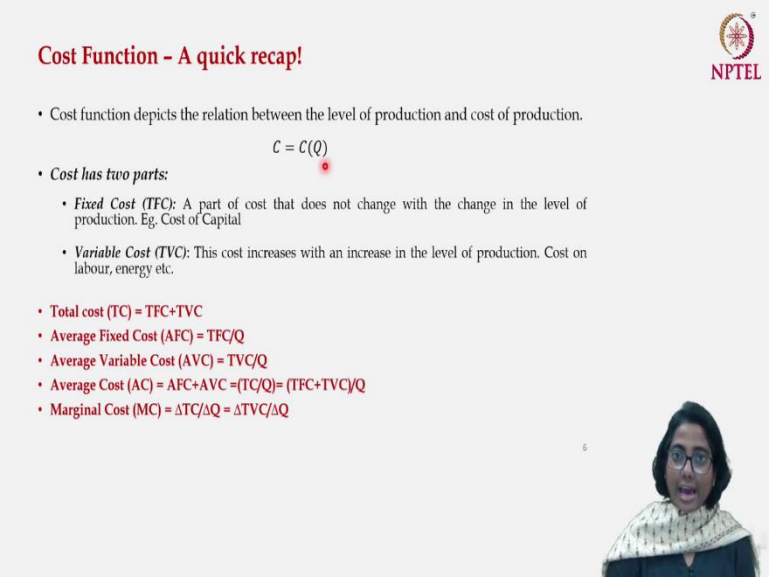
If a particular seller is motivated to charge a higher price than the rest of the sellers then the buyer actually has a number of options. At the end of the day this particular seller will lose the buyer but nothing happens to the buyer and the market equilibrium also doesn't change. Therefore, no producer will actually be encouraged to charge a price which is higher than the market price. So, we say that in a perfectly competitive market the producers or the sellers are basically the price takers. They cannot make the price; they take the market price as has been determined.

Similarly, the buyers also do not have any control over the price. They are also the price takers because if there is one particular buyer who is willing to pay less amount of money for the same product, the seller will not actually sell this product to this particular customer. This is so because there are other 'N' number of customers to whom this particular product can be sold. The price cannot be manipulated either by the seller or the buyer. Therefore, we say that both the buyer as well as the seller are the price takers in a perfectly competitive set up.

However, in order for this crucial assumption to operate the product has to be homogeneous in nature. So, everybody is selling the same quality of product, they cannot be distinguished in terms of quality. The fourth feature is that the firms can freely enter or exit the market in the long run without affecting the price. We will pay a little more attention to this in the future slides but what it essentially means is that there are so many firms in the market that if some firms leave and some firms enter the market it kind of creates an equilibrium through which the most efficient outcome can be generated.

However, it may seem a little bit vague at this point but we will look into this point in the coming slides. The fifth one which is extremely important and this says that the complete information is very important to be there in order for the perfect competitive market to exist. If there is information asymmetry, if there is lack of information with the buyer or the seller or if there is a mismatch between the information that is available with the buyer and the seller then the perfectly competitive structure actually breaks down. This is one very important and strong assumption of a perfectly competitive market structure.

(Refer Slide Time: 08:47)



Before we go into the functioning of perfectly competitive market structure, let us have a quick look at the cost functions that we had discussed in the previous weeks. We said, that the cost function is basically cost which is expressed as a function of output produced $C = C(Q)$. C is a function of output produced and we said that the cost can have two parts. There are two types of costs, the first one is called a fixed cost. The fixed cost is that component of a cost which

does not vary as we change the level of production. This is not a direct function of Q, this is a lump sum kind of cost that we have to incur in order to undertake the production. However, as we increase or reduce the level of production, cost is not going to change. For example, the cost that one has to incur in order to buy the machinery for production or to set up the boiler or the drilling machines that one needs in the oil fields are examples of fixed cost.

This is a kind of one-time investment that they have to undertake whether production takes place or not or whether there is a higher quantity of production or not, this investment remains unchanged. This is called the total fixed cost. The second part is called the variable cost. Unlike fixed cost, in case of variable cost if there is no production then technically there will be no variable cost incurred. Again, take the case of the power plant, suppose you have installed the boilers however, if you want to produce electricity, we need to buy coal, that is the fuel that you need to buy is the raw material. If you have to buy coal in order to produce and have to buy more coal if you want to produce more power then the cost on coal increases with the change in the level of production of power. The cost on coal is a variable cost. So, we come across two parts of cost, one is the fixed cost and the other is the variable cost as discussed.

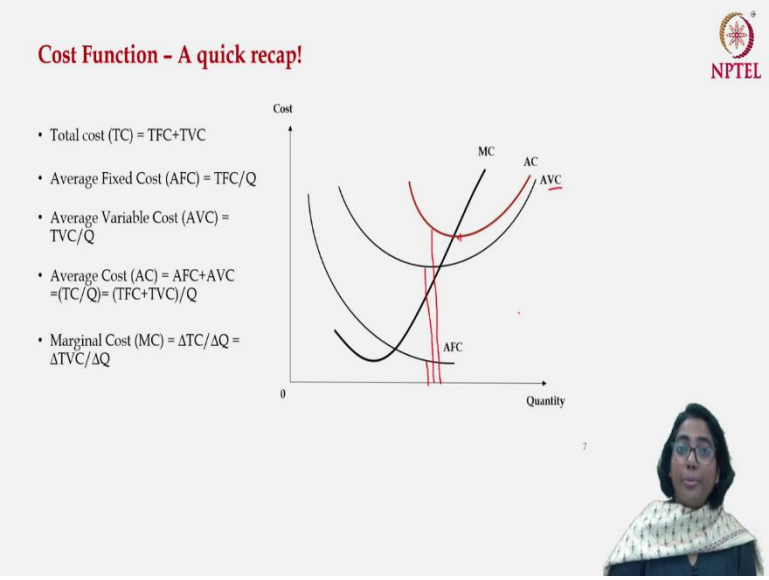
Then we talked about average fixed cost. This is the $\frac{TFC}{Q}$. Then we talked about average variable cost. This is $\frac{TVC}{Q}$. Then we have average cost, which is $AFC + AVC$ or you can also take it as $\frac{TC}{Q}$.

Finally, a very important concept in case of pricing in a market is the concept of marginal cost. Marginal cost is the incremental cost that you have to bear when you increase your output by one unit. In a discrete form we write it as $\frac{\partial TC}{\partial Q}$ or you can also write it as $\frac{dTC}{dQ}$. The change in total cost due to change in output. If there is change in the level of output this is not going to affect the total fixed cost being incurred. Marginal cost is the change in total variable cost as you change level of production.

There might be a little bit of ambiguity to understand the difference between the average cost and marginal cost. Let us consider an example of a cricket match being played and India has scored for example, 60 runs in 10 overs. The run rate is 6. This run rate is similar to the concept of average cost. Suppose in the eleventh over irrespective of the run rate being 6, India scores 10 runs. This 10 is the marginal run score by India. So, marginal is whatever is scored at the

last over, average is the average score over the entire overs that has been played. The similar concept is valid in case of the average cost and the marginal cost.

(Refer Slide Time: 13:37)



Let us have a quick look at the shape of the cost functions, we will start with the average fixed cost. If we plot the average fixed cost in the cost quantity plane what we essentially get is a rectangular hyperbola because if the average fixed cost is multiplied by quantity then we get total fixed cost which is constant. The other observation is that it's continuously declining. As we increase production, investment per unit of production or fixed cost per unit of production is falling down.

The second one is average variable cost; this is upward rising. We see that up to a point the average productivity of the variable inputs increased. As a result, average variable cost fell down but after a point the average variable cost started increasing as the average productivity of variable factor started declining.

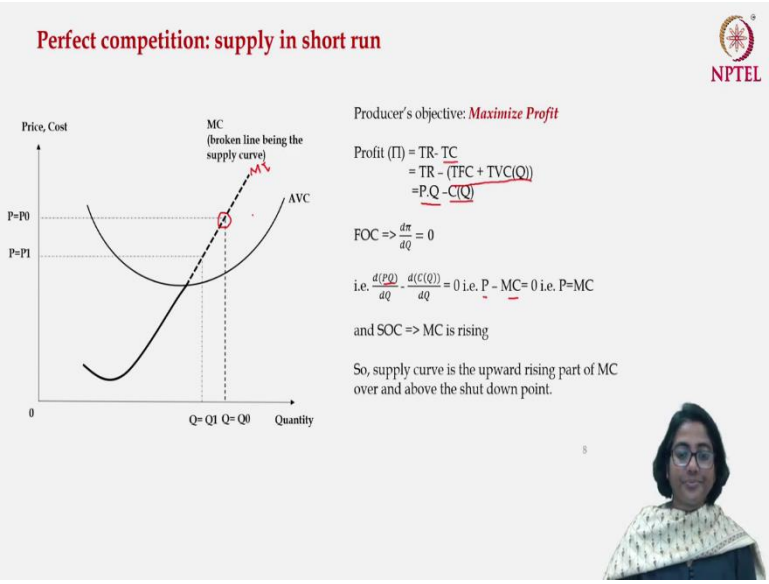
The average cost is basically a sum of $AFC + AVC$. In the diagram we are vertically adding up the distance of average fixed cost and the distance of average variable cost in order to get the distance for average cost.

We see for the average cost curve initially it declines because both average variable cost as well as average fixed cost both are declining. Up to the minimum point of AVC the AC will decline because both the components are declining. After that, one component keeps on

declining, that is average fixed cost; however, average variable cost starts increasing. The two components are moving in two opposite directions. The question is, what happens to the average cost curve? Initially, the average cost declines as this is dominated by the decline in the average fixed cost curve. However, after a point of time the dominance goes into the part of average variable cost and you can see that after a point the average cost starts rising because the average cost is being influenced by the average variable cost. However, we actually get the U-shaped average cost curve.

The final one is the marginal cost curve. This is again U shaped, it's upward rising part actually cuts the AFC, AVC and AC from below and we also saw that it cuts the average variable cost and average cost at the minimum point of both the curves respectively. This is how the cost function looks like and this structure of the cost function actually has a lot of implication when we talk about the pricing in a market mechanism.

(Refer Slide Time: 16:55)



In case of perfect competition, we can't change the fixed input. However, in the long run we can change all the fixed inputs. The objective of the producer is to maximize profit. The profit is given by $Total\ Revenue\ -Total\ Cost$. We can break up total cost as total fixed cost and total variable cost however, that's not needed for this kind of a derivation.

We are writing $Profit = P * Q - C(Q)$. $C(Q)$ is the cost function. Instead of writing TC we are writing $C(Q)$ and TR as $P * Q$. As we write $P * Q$, we make sure that P is not a function of Q. P is a fixed number which is given from the outside. In case of perfect competition, we

started by stating that the number of buyers and the number of sellers is so big that none of them can actually influence the market price, all of them are price takers. Therefore, price is a variable which cannot be influenced or which cannot be changed even if you undertake the profit maximizing behavior. So, P is a constant which is given from the outside to a perfectly competitive market or to a producer in the perfectly competitive market. In order to maximize the profit, the first order condition is $\frac{\partial \pi}{\partial Q} = 0$. You can also write it as $\frac{d\pi}{dQ} = 0$, because there is only one variable here emphasizing on the fact that Q is the only choice variable that the producer has. Q is the only variable that the producer can choose in order to maximize the profit and not P. If I derive the first order condition, this is the first part $\frac{\partial (PQ)}{\partial Q} - \frac{\partial (C(Q))}{\partial Q} = 0$.

We are taking the derivative of PQ in terms of Q. We get $\frac{\partial Q}{\partial Q}$ which is equal to 1 minus $\frac{\partial (C(Q))}{\partial Q}$. This is the increase in cost as we increase production. This is the marginal cost of production.

The first order condition actually states that $P - MC = 0$ that is $P = MC$. In order to maximize the profit, the producer or the supplier in the perfectly competitive market has to equate the price given by the market with the marginal cost. This is the first order condition.

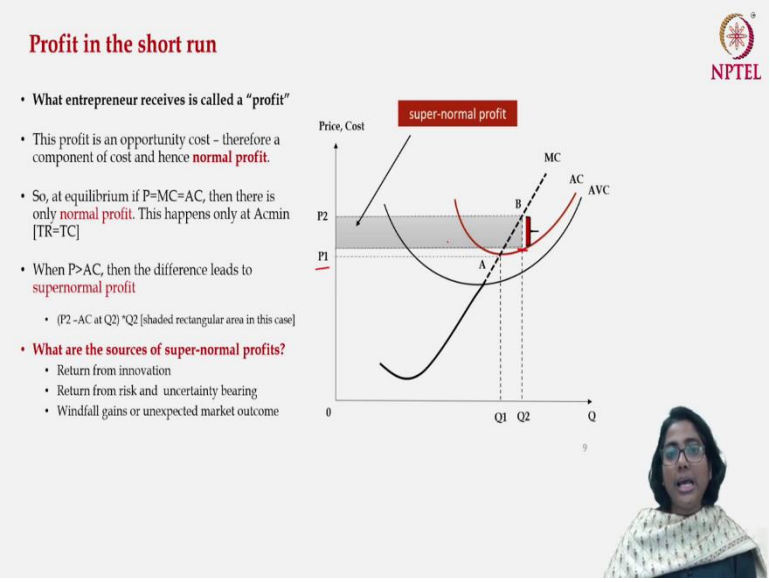
The second order condition states that $\frac{\partial^2 \pi}{\partial Q^2}$ is negative because we are maximizing. If we want to put $\frac{\partial^2 \pi}{\partial Q^2}$ equal to negative that means $\frac{\partial P}{\partial Q} = 0$ which is $0 - \frac{\partial MC}{\partial Q}$ has to be negative. Basically, $-\frac{\partial MC}{\partial Q}$ has to be negative. If we take the minus sign out this means $\frac{\partial MC}{\partial Q}$ is positive which means the slope of the marginal cost curve has to be positive that again means as you increase the quantity produced the marginal cost should be rising.

It simply means that the profit maximizing output should be on the upward rising part of the marginal cost curve. The shape of the marginal cost curve is as given in the diagram. The profit maximization of a perfectly competitive firm means if the market determined price is at $P = P_0$ then this individual supplier should supply $Q = Q_0$ because this is where we are equating $P = MC$. This is the marginal cost curve of the firm. So, equating $P = MC$ and therefore determining the quantity that needs to be produced.

Similarly, if $P = P_1$ then the producer will produce and supply $Q = Q_1$ in the market. This will go on until the shutdown point which we had discussed. This is the minimum point of the AVC where the MC cuts AVC from below. The dashed part of the marginal cost curve is the supply curve of a single producer in a perfectly competitive market. Each producer in a perfectly

competitive market will have an upward rising supply curve which is their upward rising part of the marginal cost curve over and above the shutdown point. This is the first characteristic that we have understood about the perfectly competitive market.

(Refer Slide Time: 22:53)



Let us see, what is the profit that the perfectly competitive firm will earn in the short run? We have already discussed that profit is basically $TR - TC$. $TR = P * Q$ and $TC = AC * Q$.

There is a disclaimer that I want to put forward before we enter into the discussion on profit. What the entrepreneur receives in the process of production is also often called the profit. However, this profit is actually a normal profit and is a part of the cost. When the cost of production is calculated, the payment to the entrepreneur is also calculated as a normal profit. It is not the profit that we are defining by $TR - TC$, that is the part of profit that accrues to the entrepreneur.

In this $TR - TC$, we are talking about the supernormal profit and here we are going to identify when the firm in a competitive market actually earns supernormal profit. Suppose the price is equal to P_1. $P_1$is constructed in a little clever manner such that P_1 intersects with MC at the minimum point of the average cost curve. However, if $P = P_1$then the quantity supplied will be Q_1 by this firm. The revenue earned by this firm will be OP_1AQ_1. This is the total revenue.

Interestingly, if price is equal to P_1, what is the total cost of the firm? We have said that the total cost can be conceptualized as $AC * Q$. Here the $AC = P$. Since the $AC = P$ the $TR = TC$.

The firm neither earns any supernormal profit nor is there any supernormal loss. The firm operates at normal profit and this is called a breakeven point. In this manner point A or this price P_1 is a very unique price whereby the firm breaks even where the $TR = TC$, just the desired kind of situation.

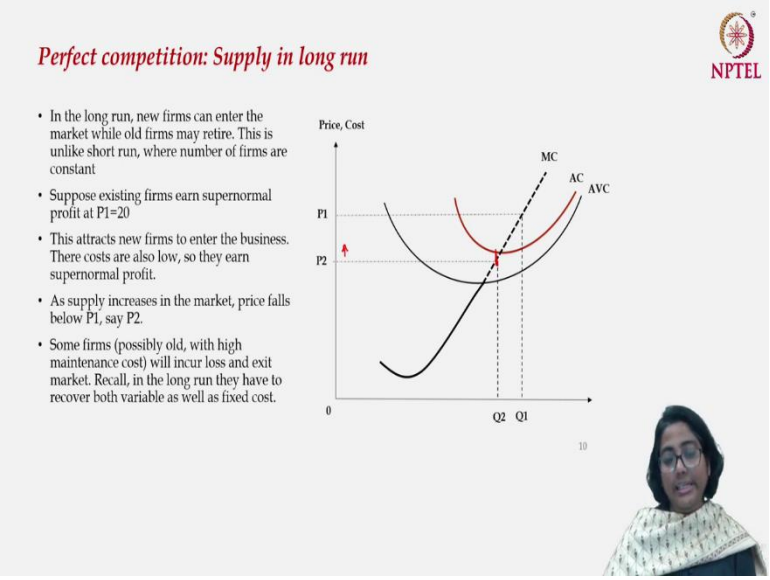
However, if the price is higher than P_1 suppose P_2, then the producer will equate $P = MC$ at point B. If that is the case then the output produced will be Q_2. If Q_2 is the amount of output produced then both total revenue as well as total cost are going to change. The total revenue will be OP_2BQ_2, the total rectangular area.

The total cost is equal to $AC * Q$. What is the average cost if we are producing Q_2 amount of output? We multiply the height with Q_2 to get the total cost and the difference between the price and average cost is actually the distance marked by red. This is the distance between the price and average cost.

The price is higher than average cost by this amount per unit. If that is the case, then what is the total supernormal profit being earned? The shaded area is actually $TR = TC$. This area captures $P_2 - AC * Q_2$. This is the supernormal profit.

The question arises, in a competitive market structure how can a firm have supernormal profit because it is not a price maker. However, there can be multiple sources of supernormal profit. First, some firms may be more innovative in nature, they may invest more in innovation and the innovation may pay some return. Similarly, return can be from risk and uncertainty bearing. You take some risk and you gain some return or there can be some windfall gains, there can be some unexpected market situation and so on. So, these are the things that can lead to a supernormal profit in case of perfectly competitive market structure. One more thing that happens is once the existing firms in the competitive market actually start earning the supernormal profit, the other firms get attracted and they want to enter the market.

(Refer Slide Time: 28:50)



As we move on to the discussion on the long run supply curve of the firm, we will see that the existence of supernormal profit encourages more firms to enter the market. Suppose at $P_1 = 20$ the existing firms are earning a supernormal profit. It is called supernormal profit because the average cost is actually lower than the price. As this firm is earning supernormal profit other firms are interested in this market and they start entering into the market. As more firms enter into the market the supply increases while the demand remains unchanged, this situation leads to a decline in price. This is a very common phenomena, whenever there is over supply of something in the market with demand remaining unchanged, the price falls.

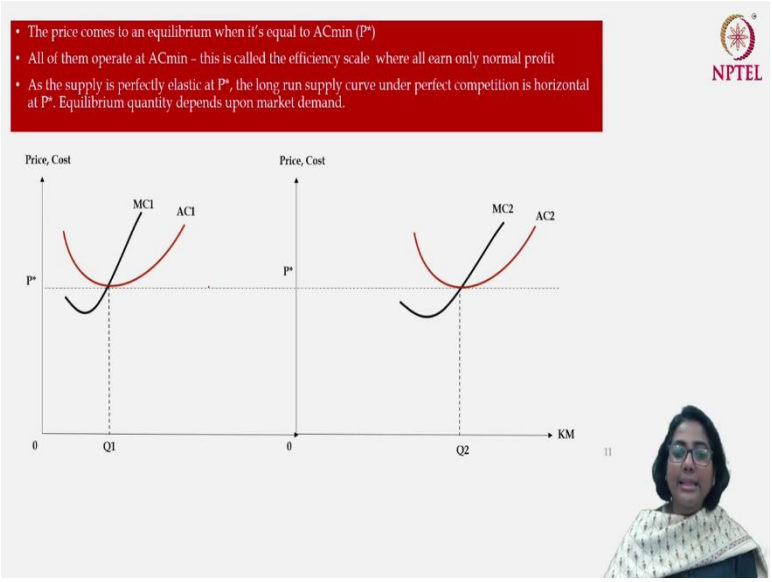
Suppose the price falls and we know that these firms are price takers as they have to take the price that is determined in the market depending on the interaction of aggregate demand and supply. Suppose the price declines and reaches P_2. Once the price reaches at P_2 the same firm will reduce the production and the production will come down to Q_2.

When the production comes down to Q_2 the firm will start experiencing supernormal loss. The loss is because of the fact that average cost is higher than the price that is being charged in the market. Therefore, the total revenue is falling short of total cost. As a result, we are unable to recover the total cost that is being incurred in order to produce Q_2.

This will drive some of the inefficient firms out of the market. Once the inefficient firms leave the market, the supply will reduce and the price will again slowly see some kind of an upward trend. This dynamic goes on in a perfectly competitive market in the long run and finally, the

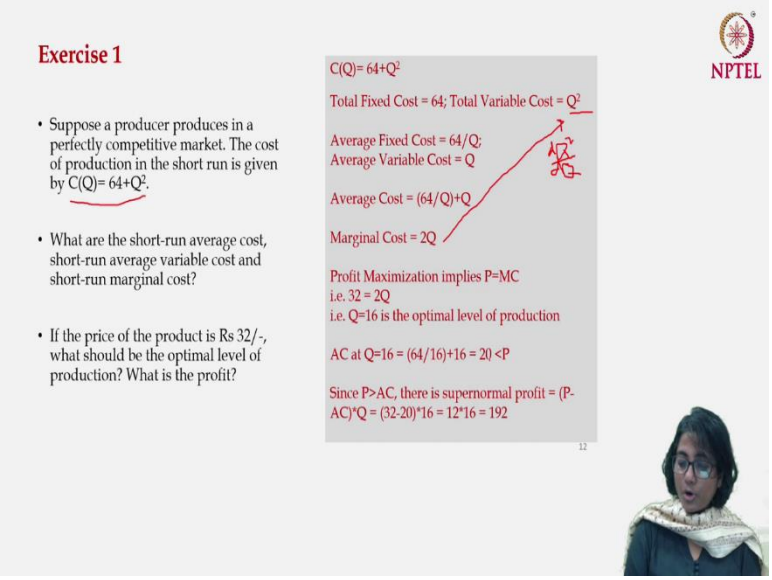
perfectly competitive market settles down at a price where those firms will exist who will operate at the minimum point of their average cost curve.

(Refer Slide Time: 31:30)



In the long run we see that P* is the long run perfectly competitive price where all the existing firms are actually operating at the minimum point of average cost curve. All the firms are operating at the minimum point of average cost curve, none of them is earning a supernormal profit and none of them are incurring any kind of loss. It is a no profit no loss kind of a situation under which the long run perfectly competitive market equilibrium operates and this is the most efficient outcome.

(Refer Slide Time: 32:20)



Now we are going to discuss the working of the perfectly competitive market through an example. Suppose for a producer in the perfectly competitive market the cost function in the short run is given as $C(Q) = 64 + Q_2$. If you look at the cost function one thing is clearly evident that 64 is irrespective of the quantity. So, this is the fixed cost. However, Q_2 part keeps on changing as you keep on changing the production. As such this is the variable cost component. The questions that arise are what are the short run average cost, short run average variable cost and short run marginal cost. The other question that follows is if the price of the product is rupees 32, that is the price given from the outside and the supplier has no control over the price, what could be the optimum level of production? What is the profit of this particular firm?

Let us have a quick look at the mathematics of the problem. The cost function is given s $C(Q) = 64 + Q_2$. The total fixed cost is 64 and total variable cost is Q_2. This 64 is actually scaled down in some particular measure, it doesn't mean that it's 64 rupees. What is AFC? $AFC = \frac{TFC}{Q}$, that is $\frac{64}{Q}$. $AVC = \frac{Q^2}{Q} = Q$. So, we get Q here.

The average cost is the $(AFC + AVC)$ which is $\frac{64}{Q} + Q$ and the marginal cost is given by $2Q$ that we get by taking the derivative of TVC in terms of Q. We get the marginal cost by taking derivative that is by taking $\frac{\partial Q^2}{\partial Q}$. We are getting the marginal cost as $2Q$.

The first order condition of profit maximization is $P = MC$ because the price is given to the producer as 32. All the producer has to do is to equate 32 with the marginal cost that it has and here if it equates the marginal cost with 32 it should produce $Q = 16$ which gives the optimum level of output because 32 should be equated with $2Q$. So, 16 is the optimum level of production.

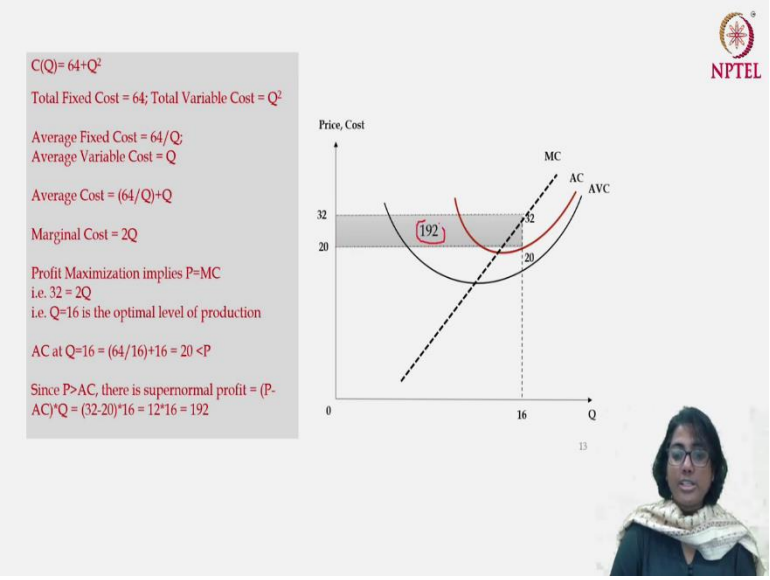
What is the price and quantity solution for this particular producer in the market? The price is 32 given by the market and the quantity produced is 16. This is the market share or is the share that this particular firm is producing and supplying in the market. This is not the market outcome. In the market there are multiple producers like this firm and they are supplying their own product as well. This 16 actually stands for the output produced by one particular firm**.**

The next question is, what is the profit? In order to calculate the profit, we need the total revenue as well as total cost. The supernormal profit is $(P - AC) * Q$ that is giving total revenue minus total cost in a sense.

Here also we are going to do it in the same way. The average cost at $Q = 16$ is actually $\frac{64}{16} + 16$. $\frac{64}{16}$ is the average fixed cost and 16 is the average variable cost. The average cost at $Q = 16$ is 20. This is less than the price that is being charged in the market. To produce one unit of output this firm has to bear the cost of 20 rupees for example and is selling the same product at 32 rupees. So, per unit there is a super normal profit of 12 rupees and this firm is earning12 rupees of supernormal profit for 16 units.

The total profit that this firm is getting is $12 * 16 = 192$. In this scenario we can say that the firm is actually earning a supernormal profit in the short run which in the long run is going to attract more firms to enter the market and therefore, the price is going to reduce. This is what we can conclude from here and this is how the equilibrium in the perfectly competitive market looks like.

(Refer Slide Time: 37:50)



If we juxtapose the same numbers on the diagram that we are familiar with we can see the prices at 32 and at 20 and the difference between 32 and 20 that is 12 multiplied by 16 we get a supernormal of 192. This is how it looks like in the diagram.

(Refer Slide Time: 38:14)

So far, we have discussed the supply curve of the firm but the question is what happens to the supply curve of the market itself? What happens to the supply curve of industry, how does it look like for a perfectly competitive market because that is again going to have big implications

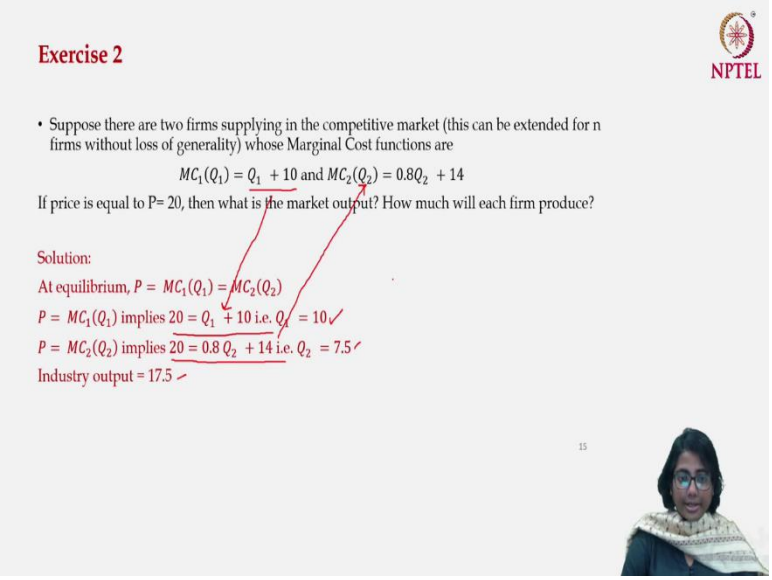
in terms of price mechanism. Suppose given is the supply curve of the first firm and the supply curve of the second firm. What happens if both the firms are supplying in the market?

We know that the firms are price taker and suppose the price is somehow set at rupees 32 per unit of the product. How much will be the aggregate supply in the market? The first firm is supplying Q_1 amount of output and at optimum the first firm will supply Q_1 amount of output if the price is equal to 32. The second firm will supply Q_2 amount of output if the price is 32. In the market the industry comprises of these two firms only, they are going to supply $Q_1 + Q_2$ amount of output. This is going to be the industry supply curve. Now, what is important to observe is that the industry supply curve is flatter than the individual firm's supply curve because we are adding individual firm supply curves horizontally in order to get the market supply curve in the perfectly competitive market.

In this way if you keep on adding more firms one after the other the aggregate supply curve will become flatter and flatter. If there are very large number of firms, the aggregate supply curve becomes flatter and flatter, it will become even more flatter and after a point of time we see a horizontal line at $P = 32$ becomes the flattest possible option for the aggregate supply curve and so this becomes the market supply curve of this particular product.

Therefore, the market supply curve of a particular product in the perfectly competitive market is basically a horizontal line at a particular price. So, whatever will be demanded will finally be supplied but the market has the capability to produce any amount of output at a particular price because there are n number of producers in the market.

(Refer Slide Time: 40:46)



This is the dynamics of the perfectly competitive market. We will take up one more example and then we move on to see what happens in the energy market. Are the features of the energy market suitable for being perfectly competitive or not? In this example we are saying that there are two firms which are producing and supplying in the market. The marginal cost curves of these firms are given by $\frac{MC_1}{Q_1}$ and $\frac{MC_2}{Q_2}$.

AS we already know that the marginal cost curves are also the supply curve of the firms. The supply curve of the first firm is given by $P = MC$. The supply curve of the first firm will be $P = Q_1 + 10$ and the marginal cost and the supply curve of the second firm is going to be $P = MC$ of the second firm which is equal to $0.8\,Q_2 + 14$.

If the $P = 20$, what is the market output? Nobody is asking what is the price outcome because that is already given. The question is what is going to be the market output and how much each firm is going to produce? This is very easy to solve if you remember this diagram, each firm is actually equating the market price with their marginal cost, whatever they are producing individually that is being added up and supplied in the market at the same price.

We will address the problem in a similar manner. If at equilibrium we equate $P = MC_1 = 20$ which is equal to $Q_1 + 10$. So, $Q_1 + 10$ is being plugged here and from here you can quickly solve it that your Q_1 is equal to 10. So, the first firm will be producing 10 units of output. For

the second firm we are equating 20 with $0.8\ Q_2 + 14$. Solving for Q_2 we get $Q_2 = 20 - 14/0.8$ which is equal to 7.5.

The industry output is $10 + 7.5$. So, the industry output is 17.5 and the market price remains 20. This is how the market share of each of the firms can be determined in a perfectly competitive market. We are really not going to use this particular kind of exercise in the energy market but this is just for the sake of completeness to understand what is the mechanism of a perfectly competitive market.

So, we are going to stop here. In the next lecture we will take up the case of the energy market and see whether that will suit the perfectly competitive market structure or not.