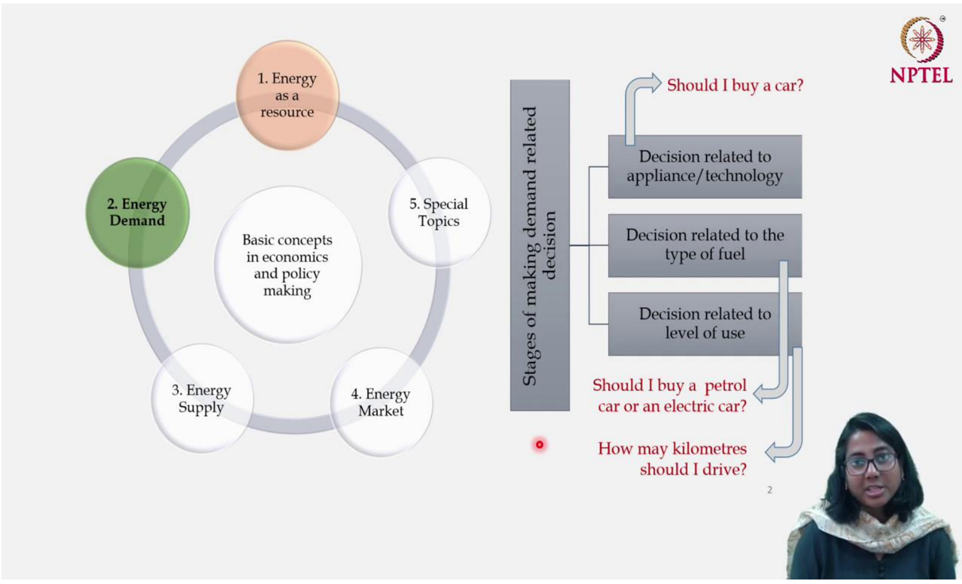
**Energy Economics and Policy**
**Prof. Shyamasree Dasgupta**
**Department of Humanities and Social Sciences**
**Indian Institute of Technology, Mandi**

**Week - 02**
**Energy Demand -Part I**
**Lecture – 01**
**Basic concepts in Economics**

Welcome everybody in the second week of the course on Energy Economics and Policy. This week and in the following week, we are going to discuss various topics that will make us understand how to measure energy demand or how to understand the nuances of energy demand.

(Refer Slide Time: 00:31)




This is the second module and as I promised we will discuss this week about energy demand. Let me begin with this understanding. Energy demand is a bit different from what you understand by the demand for food or demand for clothing or demand for any other thing. Why is it so? Because it's a little bit complex. See, if you have electricity, probably you can't use only electricity if you don't have the equipment, which can convert electricity to the energy service.

Actually, what you need is the lighting service, what you need is the space cooling service, what you need is the service for cooking. You need some equipment, which can convert the energy to some usable form. Therefore, as a consumer, your decision has different layers. What are these different layers? The first question that you have to ask yourself, what is the kind of appliance that you want to use? This is the decision related to the appliance or the technology.

The second thing is that, once you decide on the appliance or the technology, you have to think about the type of fuel that you want to consume. The third stage comes in the form: you want to take a decision related to the level of your consumption. How much energy do you want to consume? If you look at the literature, in some of the literature, they say that this comes sequentially. First, you decide about the technology, second you decide about the type of fuel, and finally, you go on and decide about the amount of energy or the level of energy that you are going to use.

But you will see that in everyday life this kind of sequence may not be followed. So, you may first decide what kind of energy you want to use and therefore, you make the choice of the equipment. This is pretty much possible. So, let me just give you an example. So, what is the decision related to the appliance or technology? This is kind of a question that you ask yourself. Should I buy a car? Should I buy a particular technology? Should I buy the equipment? This is the first question that you are asking. The moment you decide to buy a car, the next question that bugs you, what kind of car do I buy? Do I buy a car, which can be driven by petrol or by diesel or should I spend a little bit more to buy an electric vehicle?

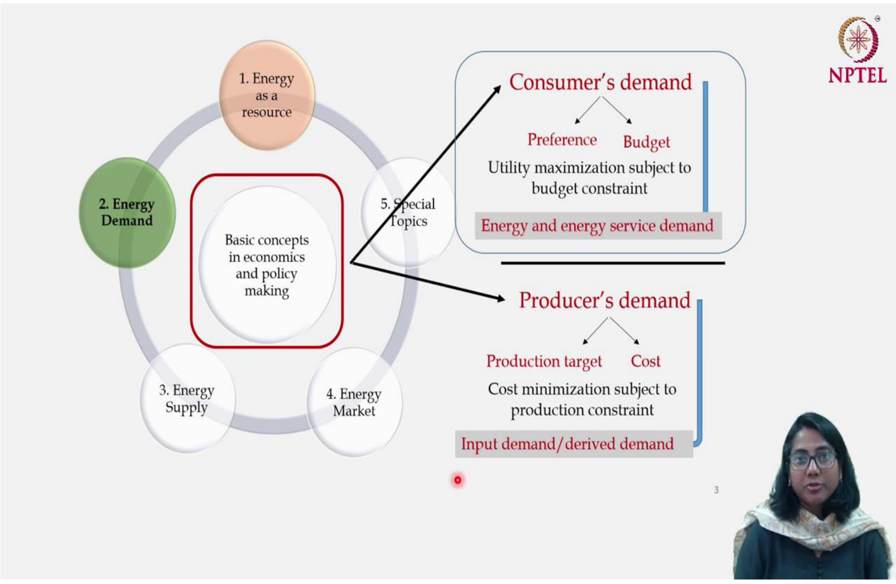
Now, why is it important to take this kind of decision? Because there are two types of costs associated with your decision. If you look at this example, you have to spend less money if you are going to buy a petrol car or a diesel car, but your running cost is going to be high. However, if you are going to buy an electricity-driven car then your initial cost is going to be high, whereas, your running cost is going to be low. And by doing this you are also deciding on the type of fuel that you want to use; whether you want to use electricity for mobility service or you want to use petrol for your mobility service.

Now once you decide on that and we assume that you have decided to buy the electric vehicle, the next question that you ask yourself: how many kilometers should I drive per day? These are all related decisions that you have to take when you are thinking about using a particular form of energy. Now, as I said that it’s not necessary that these decisions have to be taken in a sequence. It can be the other way around. For example, you already have electricity at your home, so you have already decided about the type of fuel that you are going to use. However, now you are deciding about the technology that you want to use; whether you want to use the tube light; whether you want to use the LED; whether you want to use the incandescent; it all depends on you.

You should not be highly bothered about the sequence, but there are three stages of decision that you have to make, whatever sequence it may come. This is the fundamental thing that you have to remember whenever you are thinking about energy demand. Again, to come back to the difference between energy demand and energy service demand, the amount of electricity that you need that is your energy demand but the amount of light that you need is the demand for your energy service. Lighting is not the energy but lighting is the energy service that you need.

When you are consuming energy, your energy consumption or your electricity consumption is being measured in terms of kilo Watt hour. Whereas, when you are measuring energy service that you are deriving out of electricity along with the equipment then you measure the lumen of light, i.e. the brightness of light that you are consuming. There are two aspects of energy demand; one is energy and the other is energy service.

(Refer Slide Time: 05:15)




As we have said that we need to discuss some of the basic concepts in economics and policymaking as we go on. In this lecture, we are going to devote some time to understand the economic foundation to understand the demand of both consumers as well as producers. Let us first have a look at consumers' demand. In a nutshell, if you consider yourself as a consumer:

when you decide to consume something, what are the factors that you take into account?  You go to a shop and you want to buy two different things. Now how much you buy one particular thing and how much you buy the other depends on how much you like one as compared to the other or how much do you need one as compared to the other. And the second determining factor is the money that you are carrying. There are two driving forces if you think about the consumer's demand. One is the preference pattern and the second is the budget. The interaction between these two concepts generates some kind of equilibrium for the consumer.

What does the consumer do? The consumer essentially maximizes the utility that she derives out of the consumption of different goods and services subject to a budget constraint i.e. subject to the money that you have available for spending. Once you do that, the equilibrium in the context of energy tells you what is going to be your energy demand or your energy service demand. In a nutshell, this is the framework within which we try to analyze and understand the consumers' demand for energy.

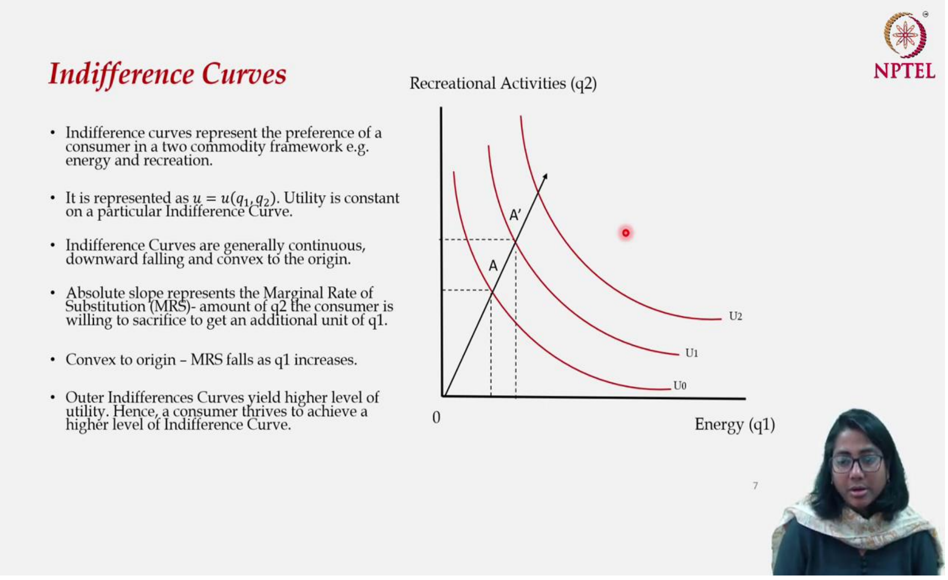
Coming to the producers' demand, the framework is pretty much the same analytically but it has a different implication. What does the producer do? The producer usually is operating within some kind of a production unit, once a production unit is already set up the capacity is decided.

Usually, the producer has a target to produce a particular amount of goods or services. The production target is sort of fixed for a particular producer. The producer will try to minimize the cost subject to a production constraint. So, I want to produce two tons of steel, which is the minimum cost that I need to incur to produce that amount of steel. When this kind of exercise is being carried out, you see what the producer is deciding what is the minimum cost so that he can meet a particular production target.

The cost is the cost of input. The input price and the quantity of input that the producer is consuming that determines the cost and that in a way also determines the amount of production that you can undertake. When we are talking about cost, this is the cost of input and there comes the role of energy because in the production process energy is used as an input. When we discuss the energy demand in the context of producer behavior we talk about the 'derived demand'. This is the input demand for energy or this is called the derived demand for energy.

In the next few slides, we are going to focus on consumers' demand and we will see how analytically we come to the equilibrium for a consumer and how does a demand curve for a consumer looks like.

(Refer Slide Time: 08:57)




We begin the discussion with the concept of the indifference curve. The indifference curve is the fundamental representation of a consumer's preferences. What is happening on an indifference curve, let us spend a little bit of time here, this is a two-commodity framework. On the x-axis we have energy, this is the amount of energy the consumer consumes or wants to consume and, on the y-axis, we have some other goods or services such as recreational activities.

For example, how many pizzas you want to eat versus how many liters of petrol you want to consume if you have a particular amount of money in your pocket. These convex downward falling curves, they represent your preference pattern. These are called indifference curves which capture the preference of a consumer in the context of energy and recreational activities here in this example. The specialty of this curve is that on this particular curve your utility is going to remain the same.

The satisfaction that you are deriving by consuming different combinations of q1 and q2 is going to be the same on this particular curve, that is the feature of this curve. Any point on U1 will yield the same level of satisfaction. Any point on U2 will also yield the same level of satisfaction. Therefore, the preference of a consumer is represented by a function U, which is a function of q1 and q2, and as we have already discussed utility is constant on a particular indifference curve.

$$U = U(q_1, q_2)$$

Let us look at different other features of the indifference curve. Indifference curves generally (mark this word, ‘generally’, as there can be exceptions but we are talking about the basic framework) are continuous, downward falling, and convex to the origin.

What does ‘downward falling’ mean? What implication does it have? It implies: suppose you are on point A on the indifference curve U0. This is yielding the level of utility or the level of satisfaction which is equivalent to U0. Now suppose, you want to increase your consumption of energy. So, you want to move rightward. The moment you increase your consumption of energy keeping your consumption of recreational activities unchanged, your total consumption goes up and the moment you increase the consumption of any one of the commodities or the services that are represented in the x or y-axis, your utility level goes up. To keep your utility level constant, what do you have to do? As you increase your consumption of energy you have to reduce the consumption of recreational activities. Therefore, if you want to be on the same level of utility as represented by A you have to move to a point, which is B, which will be situated in the southeastern part of A. Therefore, you have a downward falling indifference curve.

Similarly, you could have discussed that if you want to move from A by reducing your energy consumption, then you would have had to increase your consumption of recreational activities. On the same indifference curve since the level of utility is the same it has to be downward falling because an increase in consumption of one commodity or service has to be compensated by the decrease in the consumption of the other commodity or service. So, that is why we have the indifference curves, which are downward falling.

Coming to the next crucial observation, we have drawn the indifference curves here as convex to the origin. Again, the disclaimer is that there can be other types of indifference curves; however, this is the most general framework within which the consumer equilibrium can be discussed. What does the ‘convexity to the origin’ imply? See you have a convex curve, downward falling convex curve, where the slope is increasing as you increase the consumption of q1, or if you think about the absolute slope, the absolute slope is declining as you go on consuming more of q1.

Now, what is the meaning of the absolute slope? It has a specific meaning as we are discussing the behavior of the consumer. The absolute slope has a name: it's called the 'marginal rate of substitution (MRS)' and it tells you the amount of q2, i.e. recreational activities that you are willing to sacrifice to increase your energy consumption. As you increase your energy consumption, how much recreational activities are you willing to sacrifice? This is the marginal rate of substitution between the two commodities that are captured by the absolute slope of an indifference curve.

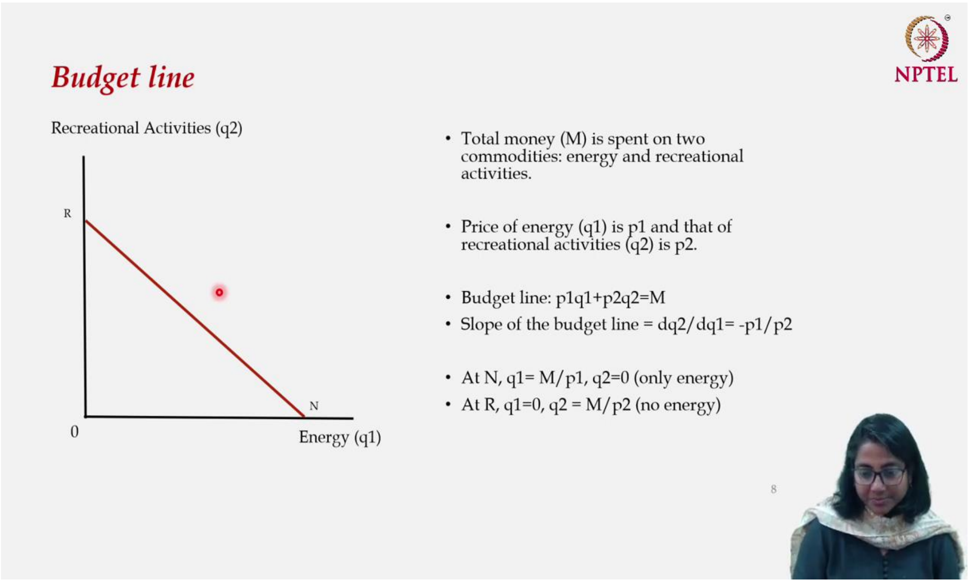
Now, when I am saying that if you increase the consumption of energy, this absolute slope is declining, what is going on in the consumer's mind? When you keep on increasing the use of energy, energy doesn't remain that useful to you. You have an abundance of energy at your disposal; however, you have a very limited amount of recreational activities. So, recreational activities become more valuable and at this point probably energy is not so valuable for you, because you already have the amount of energy that is essential for your consumption.

So, beyond this point, if you want to increase the level of energy that you are consuming, you are really not ready to sacrifice any amount of recreational activities and therefore, the marginal rate of substitution declines as you increase the consumption of any of the commodities. Here we are talking about q1 but this is true for the other commodity as well. So, that is why we have indifference curves, which are convex to the origin and as well as downward falling.

Next, we are going to discuss the location of the indifference curve and the level of utility. If you move on from U0 to U1 to U2; that is, if you move away from the origin, the indifference curve represents higher levels of utility. Why so? Again, come back to point A where you are consuming a particular amount of q1 and a particular amount of q2.

Now, we have already mentioned that if you increase the consumption of any of the two commodities, that is going to increase your utility. Consumers are never satisfied, the more the commodity or services that you consume, the more satisfied you are. If you want to move from point A along this particular ray, it shows that your consumption of both the commodities is increasing. So, from A if you move on to a point like A', there is an increase in your consumption of energy and there is an increase in your consumption of recreational activities, consumption for both commodities is increasing. Since both the commodities are increasing, then the satisfaction level i.e. utility that you are deriving at point A' is higher than the utility that you are deriving at point A. We also know that on U0 all the points represent the same level of utility. And similarly, all the points on U1 represent a similar level of utility as of A'. If we can say that the utility derived at A' is greater than the utility derived at A, then in general we can say that the utility derived at any point of U1 will be greater than the utility derived at any point on U2. And therefore, as you move out of the origin you are going from a lower indifference curve, which is giving you lower utility to a higher indifference curve and therefore, as a consumer your objective will always be to move on the outer space. That is always to move on from a lower level of utility, lower level of indifference curve to a higher level of an indifference curve. That is what you want as a consumer and that is what your optimization technique is.

(Refer Slide Time: 18:03)




Let us have a closer look at how exactly things go on. Next, we come to the budget line. So, what is the budget line? You have some amount of money, you have 100 rupees to spend and you have two things to buy one is the recreational activity that is, for example, you want to buy pizza and you want to buy some petrol. How do you decide to spend or to divide this M amount of money between these two commodities? For this, we need the information on the price of these two commodities.

We have assumed that the price of energy, that is the price of q1, is p1; and the price of recreational activities i.e. q2 is p2. Once we have this three information, then we can draw a budget line RN which looks like this. Now, what are the features of this budget line? See and this is simply a downward falling straight line in some q1-q2 plain. If that is the case, then what is the slope of this budget line? The slope of this budget line is given by $-\ {p_1}/{p_2}$. So, that is your ${dq_2}/{dq_1}$ and the equation of this budget line is given by:

$$p_1q_1 + p_2q_2 = M$$

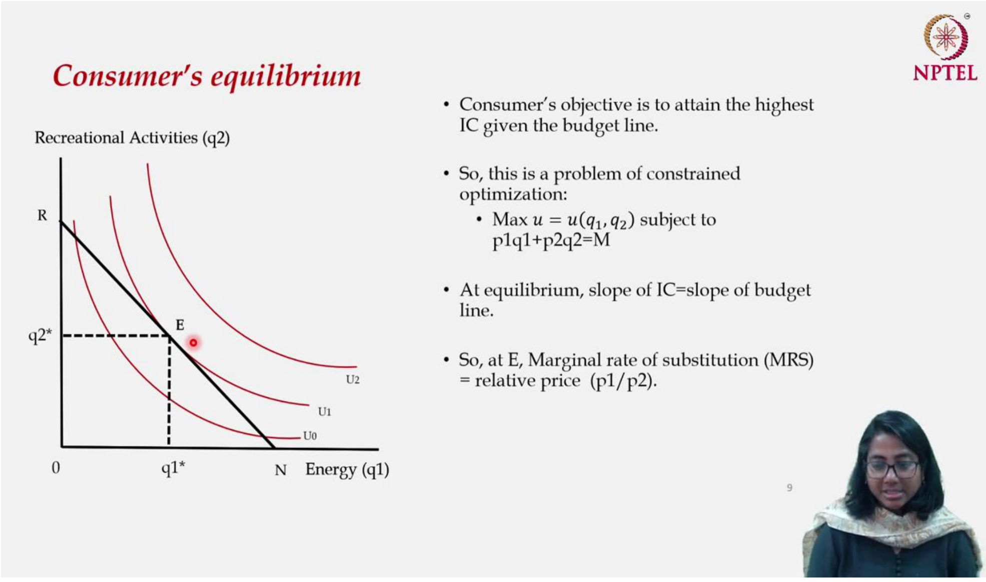
So, p1q1 is nothing, but the total expenditure on q1 and p2q2 is the total expenditure on q2.

The entire money income is being divided between the expenditure on recreational activities and expenditure on energy. There is no balance, which is left. The basic assumption is that you are spending all the money that you have. And this is the slope of this budget line. Now, let us have a quick look at what is happening on the points that we have noted as N or as R. At N, if you come to this point energy consumption is here, but what is the consumption of recreational activities that is 0.

So, at point N you are spending all your money to only buy energy and no recreational activities. At N $q_1 = {M}/{p_1}$. All your money is being spent to buy energy and $q_2 = 0$. Similarly, at point R you are not buying any energy at all. At point R you have $q_2 = 0$. The energy demand is equal to 0 or the amount of energy that you can buy is 0 or $q_2 = {M}/{p_2}$. The entire money income is being spent to purchase the second commodity, that is the recreational activity.

These are the two foundational things that are going to interact to decide the consumer's equilibrium. One is the preference, which is captured by the indifference curve, and the other is the ability to purchase, which is determined by the money income and the price, which is through the budget line. One thing to note is that the consumer always has to operate within this triangle RON, the consumer cannot go beyond this line. The consumer cannot operate somewhere here because this is beyond the consumer's budget space.

(Refer Slide Time: 21:19)




Now, let us have a quick look: what the consumer does. The objective of the consumer as we have already discussed is to achieve the highest indifference curve that can be achieved given a particular budget line. The problem of constrained optimization is given by:

$$Max\ u = \mathrm{u}(q_1, q_2)$$

$$subject\ to\ p_1q_1 + p_2q_2 = M$$

Now, if this budget line is given, then, let us superimpose the preference pattern on this and see what is going on here. If we think about U0; it is not quite rational for the consumer to choose any point on U0; although at this particular point, where the cursor is, the consumer is spending all her money, because this point is on a budget line or you can think about this point where the consumer is spending all her money. However, this is not the rationale for the consumer to stay on U0, because by spending the same amount of money the consumer can reach a higher level of utility and as we have already discussed, the target of the consumer is always to achieve the indifference curve, which is in the outer space. The consumer wants to achieve the highest indifference curve (given the budget constraint).

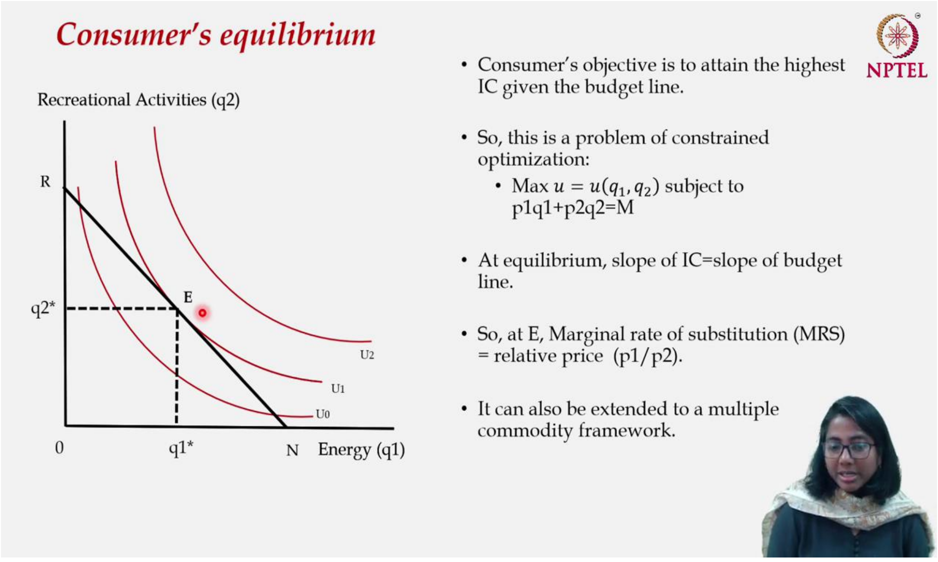
What happens in the case of U2? At U2, if this is the point of equilibrium, this is the highest level of utility that the consumer can attain given the particular amount of budget. Here she is not only spending all her money, but this is the highest attainable indifference curve because if you go beyond this, for example, the indifference curve that is captured by utility level U2, this is beyond the consumer’s reach. To reach any of the points on this utility curve, you have to spend money more than what you have. This is not within the feasible budget set of the consumer.

We can see that this point (point E) becomes the consumer’s equilibrium and if point E is the consumer’s equilibrium, this is the amount of q1 and q2 that will be consumed by this particular consumer. Now, how to solve the problem? If you are in a multi-commodity framework, this problem can be solved by the use of the Lagrange, the usual way the constrained optimization problems are solved but here because we are in a simpler framework with only two commodities, one observation can help us to solve this even more quickly.

What is the observation? See, E is the equilibrium. What is the specialty of E? At E the slope of this particular indifference curve (U1) is equal to the slope of the budget line. So, this is the peculiarity of this point E. If that is the case, we know what is the slope of the indifference curve and the budget line. The slope of an indifference curve (IC) represents the marginal rate of substitution (MRS) or the negative of the MRS because as you see if you say that the slope of IC is equal to the slope of the budget line it also says that the absolute slope of IC is equal to the absolute slope of the budget line. And the absolute slope of IC is the marginal rate of substitution and the absolute slope of the budget line is the relative price. i.e., p1/p2.

So, at equilibrium, we know that the $MRS = {p_1}/{p_2}$. If you are interested to understand the nuances and the interpretations of this, you can refer to any of the undergraduate economics textbooks, we are not going into further details about this but we will just see how the equilibrium is decided.

(Refer Slide Time: 25:07)




This is the equilibrium that is obtained by the consumer at point E and this is the most important thing to remember at this point MRS that is the marginal rate of substitution is equal to price ratio. This also gives us the solution for q1 and q2.

The problem:

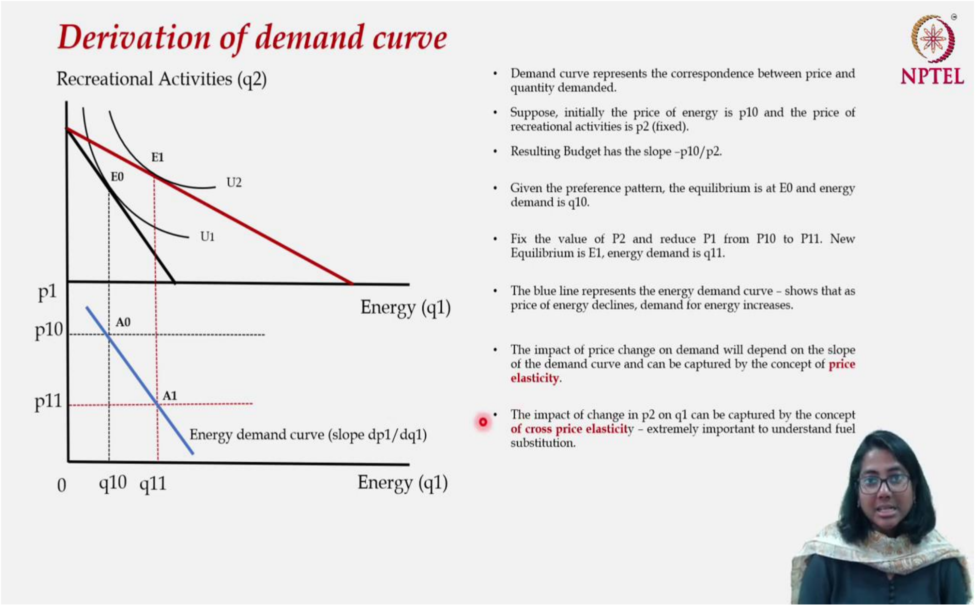
$Max\ U = U(q_1, q_2)$

$subject\ to\ p_1q_1 + p_2q_2 = M$

At equilibrium: MRS= price ratio i.e. $dq_2/dq_2 = p_1/p_2$

This gives two linear equations in terms of q1 and q2. The optimum q1 and q2 can be obtained by solving these two linear equations with two unknowns. Now, see we have determined the equilibrium for the consumer in the q1q2 plane but we haven't yet talked about that demand curve for the consumer because when we talk about the demand curve we have to talk about the correspondence between the price and the quantity.

(Refer Slide Time: 25:31)




Now from the two-commodity framework, we have to move on to the one commodity and the price of that one commodity. We have chosen energy for that. Let us pay some attention here in the construction. See this is our known panel so far. This is q1q2 right, here we are plotting q1 and q2, but below that we construct another panel, where we are keeping this q1 axis unchanged. Whatever we plot on this axis we can just take the image here; it captures the same thing: q1.

However, in the lower (bottom) panel, instead of plotting q2, here we are plotting p1. If we can derive some kind of a function on this plane i.e. the p1q1 plane that will tell us about the correspondence between the price and the quantity. Now the question is how do we derive this price-quantity correspondence based on what we have learned about the consumer's equilibrium? So, it goes on like this; See, one thing you have to notice that we are not talking about p2 here. So, we cannot consider any change in p2. So, we will keep the price of the recreational activities, that is p2, i.e. price of q2, unchanged. So, in our whole analysis now, p2 is not going to change.

What is going to change is only p1, because we are trying to understand the correspondence between p1 and q1. The first thing that we have to do we have to fix p2 and let us assume at the beginning the price of the first commodity is p10. This is the price level that we begin with. Now if you already know that the price of the first commodity is p10 and the price of the second commodity is p2, then we know that we have a budget line whose slope is – p10/p2. So, this is the budget line that we have.

Given this budget line, if I want to optimize, and if this is my preference ordering, these indifference curves capture my preference pattern, then, my equilibrium is at point E0. What is happening at E0? I am not interested in how much q2 I am consuming, but now I am only interested in how much q1 I'll consume. I am consuming q1 up to this point, which I take up to this point and I give the amount the name q10. Now see, what this point A0 is saying? the point, this point A0 is telling you, if the price of energy is p10 then you will be consuming energy whose quantity is equal to q10.

Point A0 is giving you a correspondence between the price and quantity of energy demand. A0 is going to be one point on the demand curve. This is the reference point on the demand curve. see, to get any function I need at least one more point. That is what I am trying to do now. Let us now change the price p1: from p10 to p11. Now, the price of energy falls for some reason (this may not be very logical, but for some reason, the price of energy falls).

Now, if the price of energy falls what happens? There will be a change in the slope of the budget line. So, now, the slope of the budget line becomes - p11/ p2. Now since p11 is less than p10, you can see that the absolute slope of the budget line has fallen. So, this is the new budget line that you have (red line above the old black budget line). See this point (the point where the new budget line cuts q2 axis) doesn't change. It's kind of a rotation. This point doesn't change. Why does this point not change? Because if you spend all your money only to buy recreational activities now, then the amount of recreational activities that you can purchase even with the changed price of energy is going to remain the same. So, this point is not going to change.

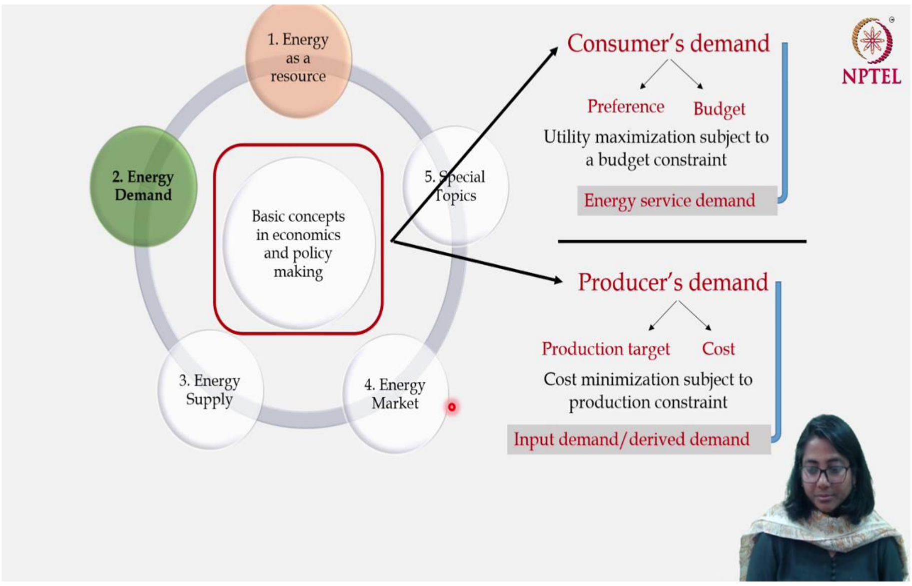
However, now if you spend all your money to buy only energy, you can buy a lot more amount of energy. So, the budget line shifts upward or you can say the budget line rotates upward. Not only that, as the price changes from p10 to p11 and the budget line shifts now you can achieve a higher indifference curve. You don't have to stick to U1, you can move up to U2 and E1 becomes your new equilibrium. So, if E1 becomes your new equilibrium then eventually the demand for energy increases. So, you see as the price of energy falls from p10 to p11, your demand for energy increases from q10 to q11 and you shift from point A0 to point A1.

Now, both these points (A1 and A2), are telling us about the correspondence between the price and the energy demand. Now if I join these two points (not ‘lines’, as mentioned in the video), what I get is the demand curve for energy which is telling me the relationship between price and quantity and what is the slope of this demand curve? The absolute slope of this demand curve, so, when I write slope it is the absolute slope of the demand curve is dp1/dq1. So, what does the slope tell us?

It tells us if there is a change in the price, what is going to be the response in terms of energy use? You can imagine a flatter demand curve here. If the demand curve is flatter, then what is the response? The response is going to be higher because the same change in price will lead to a much bigger change in your demand. If your demand curve is steeper, then you can expect limited change. So, a steeper demand curve represents less responsiveness whereas, a flatter demand curve represents more responsiveness. In the coming lectures, we are going to link this idea of responsiveness with something called the ‘elasticity of demand’.

We will discuss the price elasticity of demand where we will explore if there is a 1 percent change in price, what is the percentage change in demand? Not only can you explore the impact of change in your own price, that is, not only can you explore the impact on energy if the energy price changes, but you can also explore the effects of cross prices through cross-price elasticity. There what you do; you try to understand if there is a change in the price of q2, what is going to be the impact on q1? So, that is the cross-price elasticity, which we will be discussing in the future slides.

(Refer Slide Time: 32:21)




So, that is more or less the end of consumers' demand i.e. how the consumers' demand curve is derived and we will quickly spend some time understanding producers' demand. This is pretty much the same. If you understand the basics of the consumers' demand, you can also understand the nuances of producers' demand for inputs.

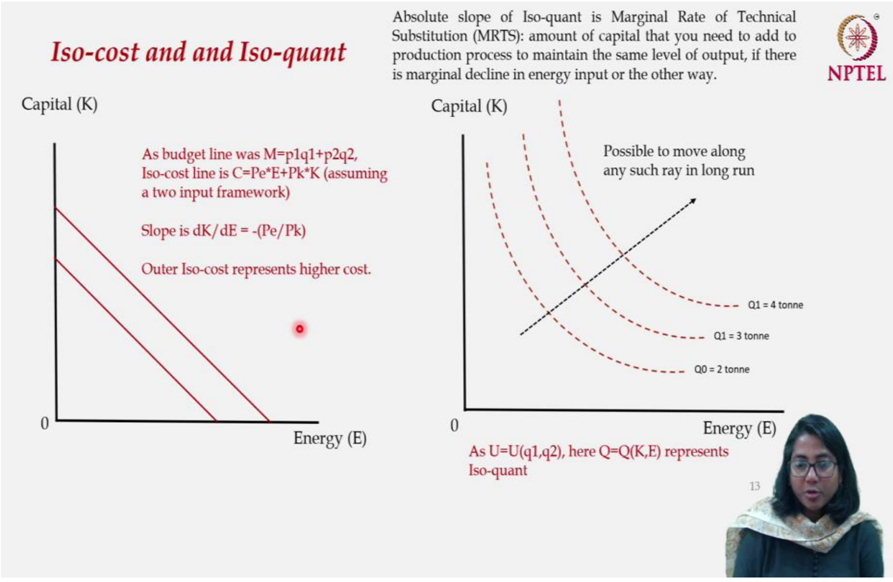
Before I go into the discussion let me just tell one thing. What are the different inputs that the producer usually requires to carry out the production? So, in the general economic literature, you will find that capital is one of the major inputs. Capital may include any kind of machinery, the building that you have, the processes that you are using and all. So, this investment goes to capital formation- this is one input.

The second input is 'labor': you need labor for the production, the third input considered is energy, the fourth input considered is 'material' and a fifth input, which is often considered is the 'service'. So, these are the major four-five inputs that have been usually considered when we analyze the producers' demand and each of the inputs may have its own demand curve because the way we have the consumers go to a product market the firms have to buy these inputs from the input market.

There are input prices as well: The price of labor is the 'wage', the price of capital is rent and is usually considered to be the same as the 'rate of interest'. So, there are several prices for several inputs. Similarly, if you think about energy input, energy also needs to be bought from a particular market and that commands a particular price. So, the behavior of the producer i.e.

how much energy the producer wants to buy will depend on how much the producer wants to produce and what is the cost of energy in the market. So, if you keep this thing in mind it's pretty much the same as the framework that we have used for consumer demand.

(Refer Slide Time: 34:25)




So, here we come across two concepts, one is called an 'isocost line' and the other is called an 'isoquant line'. So, we start with the isocost line and you may recall what was the objective of the producer? The objective of the producer is to minimize the cost subject to a production constant. So, coming back to the isocost line, what is the isocost line? See, I have chosen two inputs here, because if you are doing a two-dimensional diagram then you can't go beyond two inputs, but this can be readily extended to any multiple numbers of inputs, that is possible. Only the diagram becomes a bit clumsy. So, that is why we restrict ourselves to a two-commodity framework or two-input framework.

So, what is happening here is the space for the producer. So, the producer has to buy some capital and some energy with the money that it has. Not exactly with the money that it has, but it has to decide how much capital and how much energy it has to buy and so, what is going to be the cost. Now, what is this line? This is an isocost line. What is happening on this isocost line? This is the analogy of the budget line.

So, here the equation of the isocost line is given as:

$$P_e * E + P_k * K = C$$

Pe is the energy price, Pk is the price of capital, which is often referred to as a ‘rent’. $P_e * E$ is the expenditure on energy and $P_k * K$ is the expenditure on capital. If you add them up in this two-input framework this is the total cost (C) that the producer has to incur. Now if you increase the quantity of energy and capital purchased then the cost that you incur is also going to increase.

So, as you move outward, basically you are moving from a low isocost line to a high isocost line. And similar to what the consumer was trying to do, here the producer will try to choose an isocost line, which is closer to the origin. So, it tries to minimize the cost of production. And also similar to the budget line, on any point on this particular isocost line, the cost that is incurred is the same. So, what is happening if you move from a point here to a point here is that you are increasing your energy purchase and you are reducing the purchase of capital. So, that sort of adjusts your cost so that you can stay on the same line. This is the concept of isocost and the slope of the isocost line is given by $-{P_e}/{P_k}$ and the absolute slope is again the relative price which is ${P_e}/{P_k}$.

The next concept that we are going to discuss is the isoquant lines. So, ‘isoquant’ means ‘equal quantity’, the equal quantity being produced. So, if you think of a line like this, I have written q0 equal to 2 tonnes. This particular curve represents the production of 2 tonnes of steel for example. And this particular producer has to produce 2 tonnes of steel given the capacity that it has. So, the target is set at 2 tonnes of steel. This is called the isoquant line.

Why is it an isoquant? On any point on the particular curve, the quantity of output produced is going to stay at 2 tonnes. It’s not going to change at all. Why is it happening? It’s similar to what was happening in the case of the consumer. The consumer was reducing the consumption of one commodity and increasing the consumption of the other commodity to stay on the same indifference curve.

Here what the producer is doing, the producer is using more of one commodity, one input, and reducing the use of the other input to produce the same. Now, what exactly is the shape of this isoquant line that depends on the technology that you have in place, that, that you need to take care of the technological specification. But usually, this is downward falling and convex to the origin, for the same reasons that we have discussed in the case of the consumers.

So, this is the equation for the isoquant line that is given, this is q that is the quantity of output that is being produced with two inputs capital and energy. So, as your input goes up, as you increase K and E of course, your q is going to go up. So, these are positive so, q is a positive function of K and E. Now if you move beyond the origin, if you go from q0 to q1 it's quite evident that you are using more of inputs, more of both the inputs, or at least more of one input and therefore, your output is increasing. (***There is a mistake here (Video: 39:38 min); this should be q2, which is equal to 4 tonnes and not q1.)***

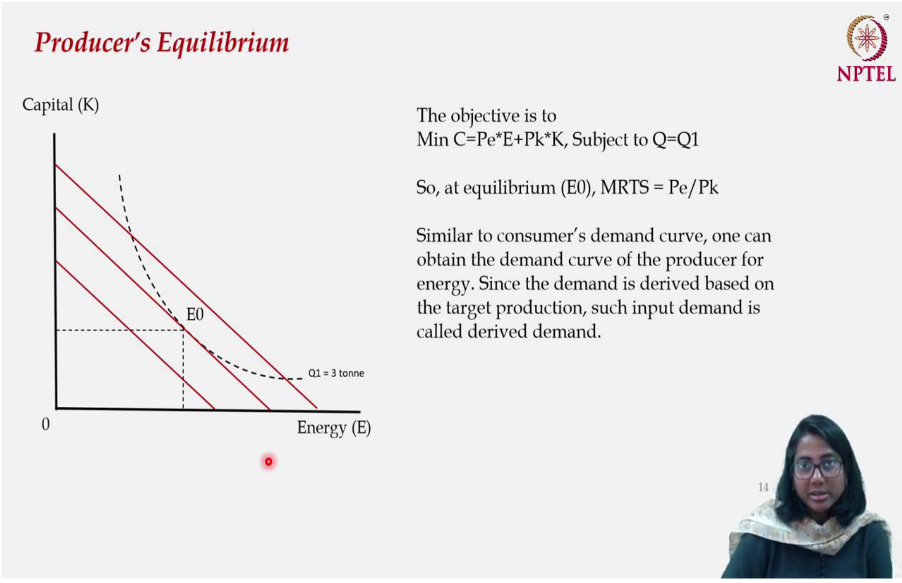
As you are moving from q0 to q1 to q2, your production gradually increases. So, now let us have a quick look at what the slope of an isoquant tells you. So, again you can recall what was the concept of MRS, the marginal rate of substitution. Here, in the context of the producer behavior, this is called the marginal rate of technical substitution (MRTS) and this refers to for this particular diagram, the amount of capital that is the amount of one input that you need to add in the production process to maintain the same level of output if you reduce the energy demand. So, what is the rate at which capital can be substituted by energy or the rate at which energy can be substituted by capital? Now it may seem a little bit abstract, but the relationship between capital and energy is very important because you think about a situation where there is a lot of discussion about energy efficiency in the industrial sector.

Now if you want to install energy-efficient technology, that is going to increase your capital cost. So, your capital is going to go up; however, once you install capital-intensive technologies you can expect that your energy consumption is going to go down. So, you are staying on the same isoquant and you are gradually moving to this direction (higher capital and lower energy) if you are replacing your less energy-efficient technology with more energy-efficient technology.

Now, how much capital do you need there to substitute some part of the energy that again depends on technology, whether it gives you any kind of saving or not and hence boils down to an economic decision. So, this is the interpretation of the slope of the isoquant curves and as I have said if you move along this line you are using both the inputs at a greater quantity, and therefore, you are producing more output.

Now one point of caution that you have to understand when we are talking about the movement along this line we are saying that both capital and energy can be varied. Now, this happens only in the longer-term. In the short run, we assume that capital is fixed. So, in the short run, the movements are usually along the horizontal lines, but here in our discussion, we will consider the long-run movements where we assume that both capital and energy can be changed. So, this is the basic framework for the producer. What did the producer want to do now? For the producers, some amount of production is fixed, and the producer is trying to choose the minimum isocost line based on which it can go on for that production.

(Refer Slide Time: 42:31)




So, the objective is to minimize the cost (C: the expenditure on energy plus the expenditure on capital) subject to a level of production. Suppose, q1 is some predefined quantity, for example, = 3 tonnes. So, this particular firm has to produce 3 tonnes of steel. Now, these are the different isocost lines that are available to the firm. Which is the lowest isocost line that the firm can choose? This is this line because the same amount of production can be made at this point. So, if the production takes place at this point also 3 tonnes of steel are being produced, but the cost is much higher.

So, what shall the producer do? The producer will come back to a point E0, which is the equilibrium and at equilibrium, you will see this is the amount of capital and energy that are being consumed by the producer to produce 3-tonne of steel. So, at equilibrium, as we had seen in the case of the consumer, here you see that the slope of the isoquant is equal to the slope of the isocost line or you can say that the marginal rate of technical substitution is equal to the relative price of the inputs.

The problem of the producer is given by:

$$Min\ C = P_e * E + P_k * K$$

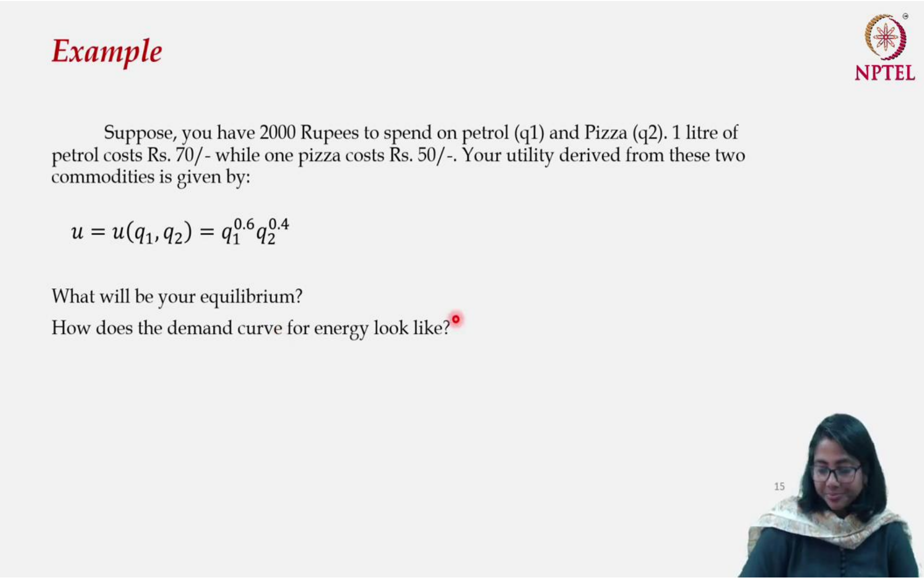
$$Subject\ to\ Q = Q_1$$

$$At\ equilibrium: MRTS = {dK}/{dE} = {P_e}/{P_k}$$

This condition and the equation of the isocost line gives two linear equations with two unknowns K and E that can be solved to obtain the solution for E and K.

Here is the producer's equilibrium and for the production, this is the energy input demand for the producer. This is how the energy demand, this is the energy demand for the producer and if you add one more panel here the way we did it for the consumers, you can vary the price of the energy and you can get the energy demand curve for the producer in a similar manner. In a nutshell, this is the framework within which the producers demand energy, and consumers demand energy is discussed in economics and we will just explore one example to understand how the problems are solved so that it becomes clearer to you.

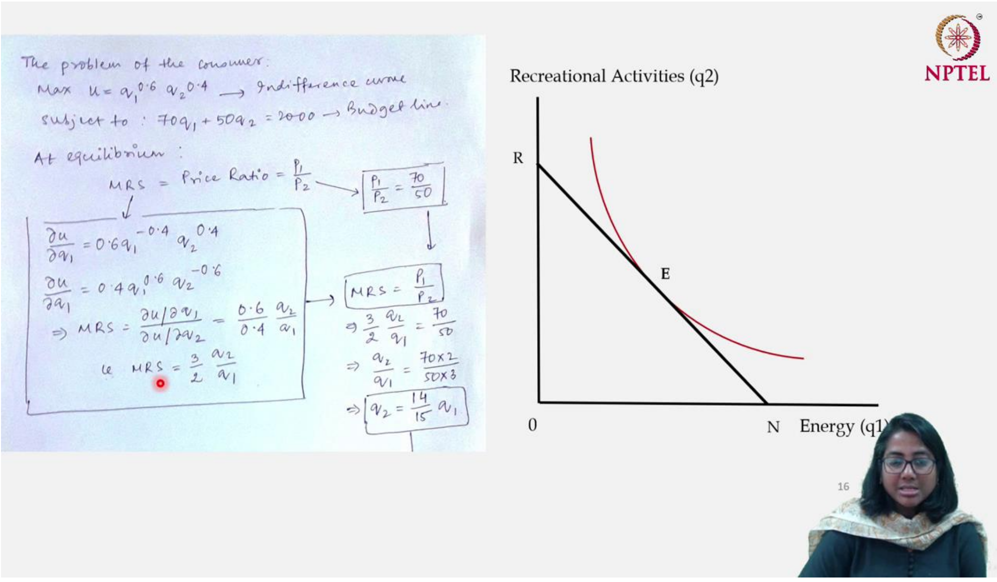
(Refer Slide Time: 44:35)




We start with this example; suppose you have 2000 rupees as a consumer and you want to spend the money on petrol and pizza. You have to divide the 2000 rupees that you have between the purchase of petrol and pizza. Now 1 liter of petrol costs 70 rupees while 1 pizza (you can think of a small pizza) that costs you 50 rupees.

Now the question is how you are going to divide this money between pizza and petrol. Now suppose, your utility function this one, that captures your preference pattern is given by q1 to the power 0.6 and q2 to the power 0.4. So, remember q1 is petrol and q2 is pizza. The question is where will be your equilibrium and how does the demand curve for petrol look like?

(Refer Slide Time: 45:31)




So, let us have a look, how we are going to solve this problem. So, the objective that we have is to

$$Maximize\ U = U(q_1^{0.6} q_2^{0.4})$$

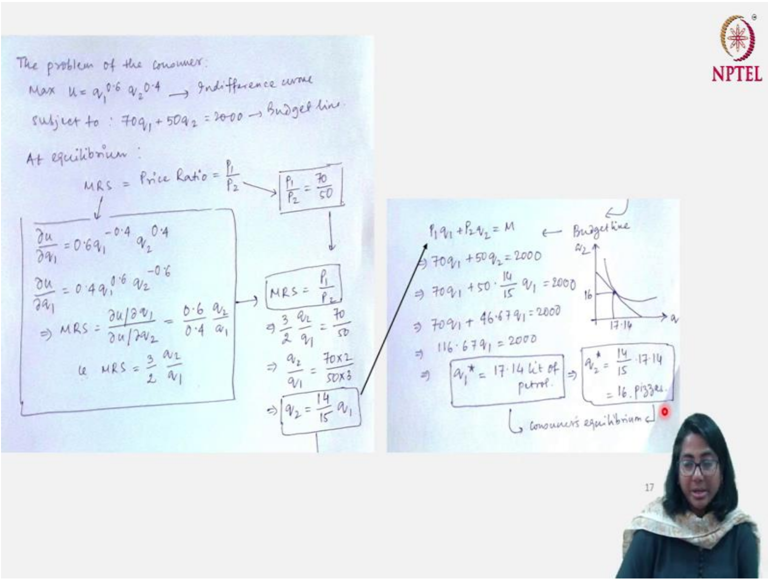
$$subject\ to\ 70\ q_1 + 50\ q_2$$

Now, why $70\ q_1$ and $50\ q_2$, because here you see we have said the price of petrol is 70 rupees and the price of pizza is 50 rupees. So, $70\ q_1 + 50\ q_2$ should add up to 2000. So, this is your budget line i.e. the constraint that you have.

As I have said, you can always formulate a Lagrange and solve the problem of constrained optimization, but you have some liberty in case of a two-commodity framework. As you can see here that the slope of the indifference curve is equal to the slope of the budget line,

we have, absolute slope of the indifference curve = the absolute slope of budget line i.e. MRS = price ratio, i.e. $3q_2/_{2q_1} = {}^{70}/_{50} = {}^{7}/_{5}$ (70 is the price of the first commodity, 50 is the price of the second commodity). So, at equilibrium that is at point E what do you have? You have $MRS = {p_1}/{p_2}$ and that gives you a solution $q_2 = {14}/{15\ q1}$.

(Refer Slide Time: 47:07)



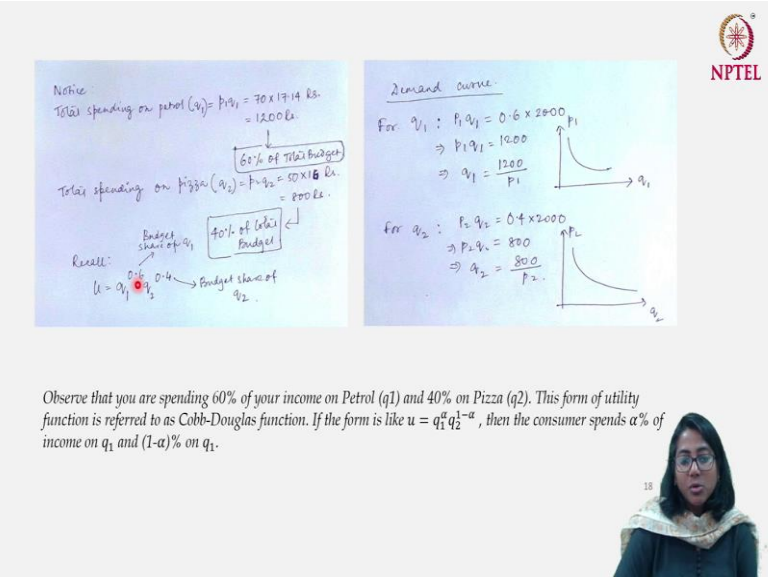

Now, what do you have? You have two equations, two linear equations in q1 and q2.

$q_2 = {14}/{15\ q1}$

$70q_1 + 50q_2 = 2000$

So, from these two equations, easily you can solve the values for q1 and q2 and what you see the optimum amount of q1 that you are going to buy at point E is 17.1 liter of petrol and what you are going to and here if you plug this value 17.14 here you get the optimum amount of q2 which is 16. So, finally, given your preference pattern and given the money income that you have, you are going to buy 17.14 liter of petrol- this is your demand for energy and 16 pizzas. So, this is how your equilibrium looks like.

(Refer Slide Time: 47:59)




Now, coming to spending; there are some other corollaries which are very important and interesting. What is the total spending on pizza and what is this total spending on petrol? See your total spending is $p_1 * q_1$ . So, for petrol, your spending will be $70 * 17.4 = 1200$. Now if you observed in aggregate you had 2000 rupees, out of that 1200 is being spent on petrol. So, this is 60% of your budget; so, 1200 out of 2000 that is 60% of your budget.

On the other hand, if you see how much you are spending on pizza, this is 800= 50x16. So, 40% of your budget is going to pizza whereas, 60% of your budget is going to petrol. So, from this pattern what you can see, your expenditure share towards energy is higher than your expenditure share on the recreational activities here. The other important thing to observe is the shape of the demand curve. See we said that the correspondence between p and q gives you the demand curve. So, what is the demand curve for petrol? It's represented by $p_1 q_1 = 1200$.

$p_1 q_1 = 1200$ means if you draw this on p1q1 space, this is going to give you the shape of a rectangular hyperbola. So, this is not a straight line this is a downward falling rectangular hyperbola that is presenting your energy demand. Similarly, if you look at this $p_2 q_2 = 800$ this gives you the demand curve for pizza, and for the similar logic in the p2q2 space this again is your demand curve which has the shape of our rectangular hyperbola.

The problem of the consumer:

Max $u = q_1^{0.6} q_2^{0.4}$ → Indifference curve

subject to : $70q_1 + 50q_2 = 2000$ → Budget line.

At equilibrium :

MRS = Price Ratio = $\frac{P_1}{P_2}$ → $\frac{P_1}{P_2} = \frac{70}{50}$

$$\frac{\partial u}{\partial q_1} = 0.6 q_1^{-0.4} q_2^{0.4}$$

$$\frac{\partial u}{\partial q_1} = 0.4 q_1^{0.6} q_2^{-0.6}$$

$$\Rightarrow MRS = \frac{\partial u/\partial q_1}{\partial u/\partial q_2} = \frac{0.6}{0.4}\frac{q_2}{q_1}$$

ie $MRS = \frac{3}{2}\frac{q_2}{q_1}$

$$MRS = \frac{P_1}{P_2}$$

$$\Rightarrow \frac{3}{2}\frac{q_2}{q_1} = \frac{70}{50}$$

$$\Rightarrow \frac{q_2}{q_1} = \frac{70\times 2}{50\times 3}$$

$$\Rightarrow q_2 = \frac{14}{15} q_1$$

$P_1 q_1 + P_2 q_2 = M$ ← Budget line

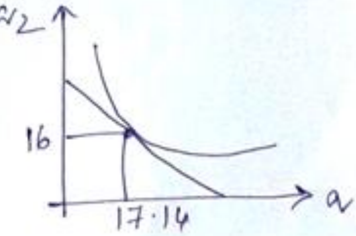
$$\Rightarrow 70q_1 + 50q_2 = 2000$$

$$\Rightarrow 70q_1 + 50 \cdot \frac{14}{15} q_1 = 2000$$

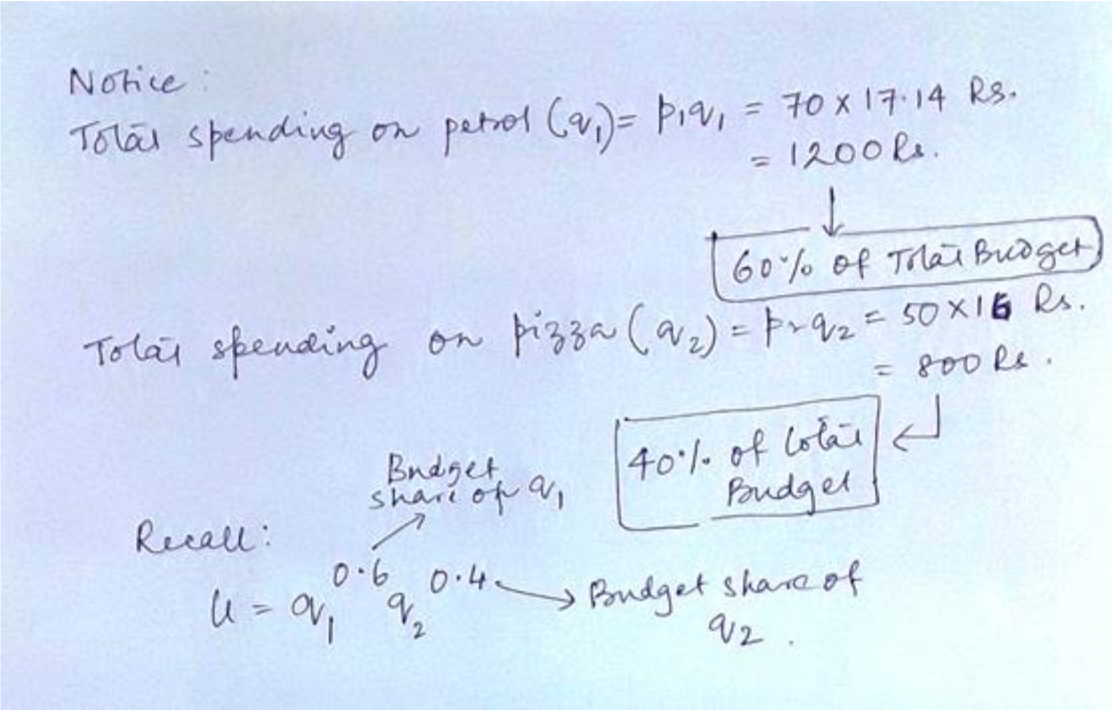
$$\Rightarrow 70q_1 + 46.67q_1 = 2000$$

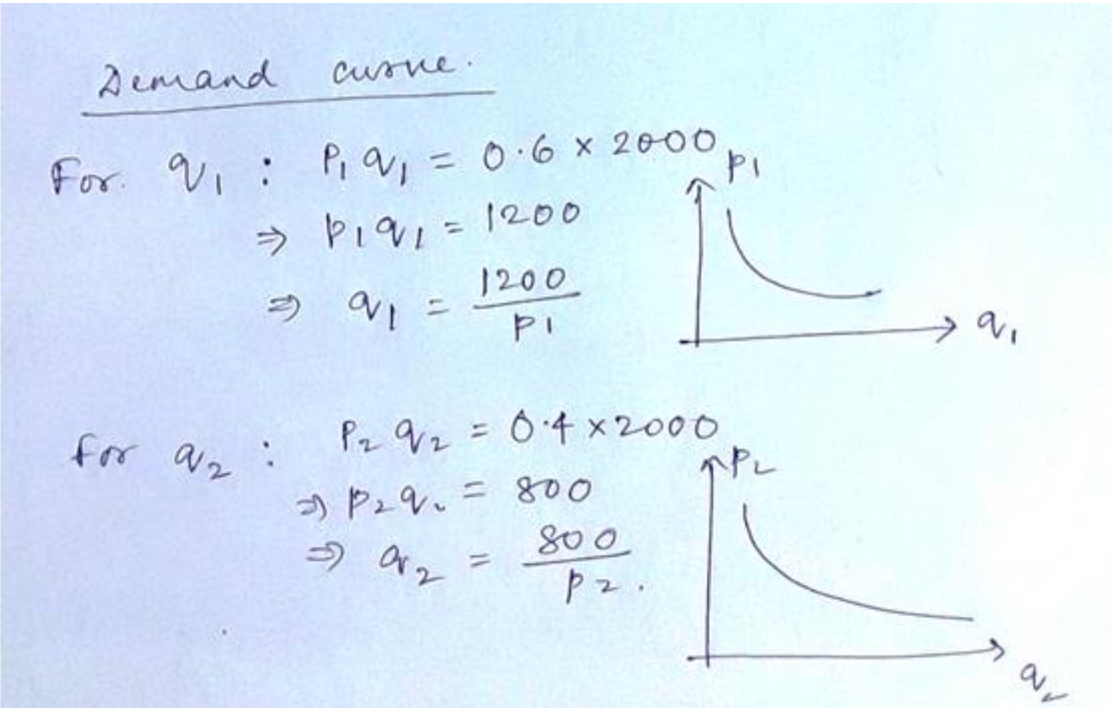
$$\Rightarrow 116.67 q_1 = 2000$$

$$\Rightarrow q_1^* = 17.14 \text{ lit of petrol.} \Rightarrow q_2^* = \frac{14}{15} \cdot 17.14 = 16 \text{ pizzas.}$$




↳ consumer's equilibrium




The final thing that is most important to observe, this particular form of utility function, this is called the Cobb Douglas function. This is used for the utility function; this is also used to represent the production function. So, this Cobb Douglas utility function is very interesting because if you simply by looking at it if you look at it you see its q1 to the power 0.6 and what was your spending on petrol that was 60 percent. So, the power of q1 actually tells you, what is the proportion of expenditure being consumed on q1. The power of q2 tells you what is the proportion of your total expenditure that is going to q2. So, 60 percent money you are spending on q1 and 40 percent money you are spending on q2.

So, you know, once you keep on doing this kind of an exercise, just by looking at the utility function and the total amount of money that you have you should be able to infer what is the demand for q1 and what is the demand for q2 even without solving the whole problem. So, this is the broader economic framework within which the consumers demand and producer demand for input that is energy input is discussed. So, we are going to stop here in this lecture. In the next session we are going to come with some of the analytical framework that you use in order to understand or in order to measure the demand for energy.

Thank you.