Petroleum Economics and Management
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Module -10
Theories of Price Formation of Petroleum
Lecture - 46
Intertemporal Allocation and Utility

Hi everyone, I am Dr. Anwesha Aditya, your instructor for the NPTEL course Petroleum Economics and Management. So, welcome to our course where we are going to discuss the Theories of Price Formation of Petroleum. So, this is our lecture number 46 in the course and 1st lecture in module 10, where we are going to discuss Intertemporal Allocation and some overview of the concept of Utility.

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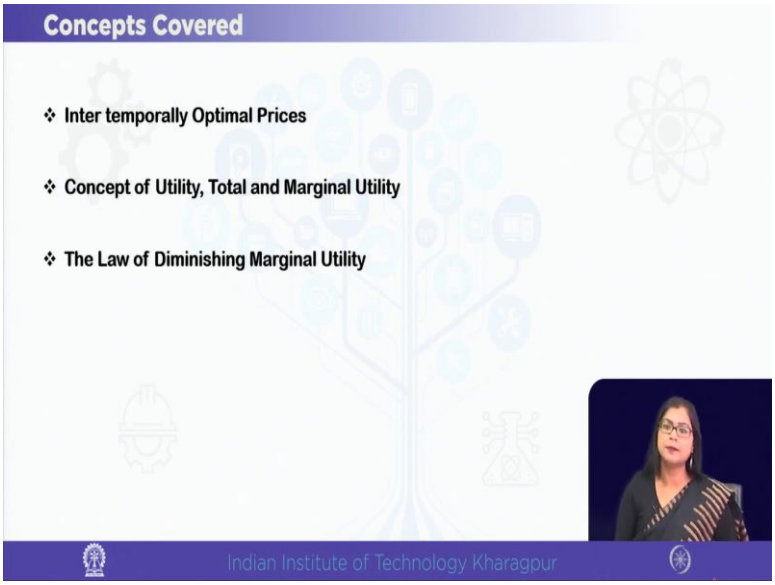

So, if we motivate the module, if you remember we are going to discuss the pricing of petrol. Say we have already studied in detail the global oil industry, how the price is formed by the OPEC countries and what is the role of the Non- OPEC countries. We have also studied in depth the price movement of oil from the development of oil industry to the very recent time of the COVID-19 pandemic and the Russia, Ukraine war.

Now, coming to the theoretical aspect of how pricing should be done. Now, you see oil is something we have already discussed, we have seen the use of oil from the point of view

of environment and sustainability. So, we already have seen that oil is basically fossil fuel. So, it is formed from the savings of the past millennium and that is one of the changes that industrial revolution have brought in human civilization.

So, before industrial revolution we were dependent on primitive sources of energy like cow dung and wood. But after industrial revolution we started using coal and petroleum and these are basically the fossil fuels or these are the savings from the past century. So, the current rate of formation at present also, so this type of resources are being formed, but you can understand that the rate at which we are currently using these resources, its much higher than the rate at which these resources are formed, right.

Because our human civilization nowadays is so much dependent on oil and other type of natural resources. So, before industrial revolution we are dependent on primitive sources and after the industrial revolution we are more dependent on coal and oil and they have increased our productive capacity many times. So, and we have already discussed the indispensable nature of oil I am not going to detail out.

We have seen that how we are dependent on oil for electricity and transportation. However, in electricity we could make some replacement of oil from mid 1980 onward the new power stations are built using coal and natural gas because oil price was increasing so much, but transportation sector heavily depends on oil till now. We do not have any close substitute of oil in transportation right. So, so our day to day life is completely dependent on these type of resources and mainly on oil.

But the supply of oil is limited and that too of uncertain amount because we are not sure how much oil is left right. We have already studied the concept of proof reserve and the related concept of extractable resources. So, we are not sure how much of oil is left underground and whether that will be means usable or what will be the cost of extraction because as we go deeper into the ground our cost of extraction will increase.

If the quality of the crude oil is not good our cost of refining will increase and if the market price is not that high because recently we had some experiences where during the lockdown oil price decline. So, or due to the shale oil revolution also in 2014 oil price declined. So, if the market conditions are not very favourable and then the cost of extraction and refining increases. So, it may not be worth it to extract oil from those fields.

So; that means, there is lot of uncertainty involved in the pricing of oil. So, the rate at which we are using oil is much faster than the rate at which it is currently formed. It is a limited supply at a particular point in time, it is also in uncertain amount. So, these issues complicate the pricing of oil and also not only to oil, but also other type of mineral resources like coal or natural gas.

So, we are not sure how much is left. So, this idea in mind will be starting a simple theoretical model in a very simple framework of how to decide the price of oil or other mineral resources which are in limited supply and also how to distribute the allocation over time because you see we are using this particular resource over time. So, how to use, whether we should use the resource currently or whether we should use the resource means we should keep the resource for future for our future generation?

See human beings we consider we care for our future generation. So, should we use it now more or should we keep it for our future generation. So, this decision we should make. So, with this idea in mind we will be starting this theoretical model of how to set the price optimally in an inter temporal setting means over time setting and how much should be the quantity consumed over time. So, we will be starting a simple two period model.

So, I will outline the model in today's class, but before we proceed further we will see that we need some concept some very basic concept of economics called utility and the related concept of total utility and marginal utility and how marginal utility changes when we consume more of a good. So, these are the concepts to be covered in today's lecture.

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So, suppose we consider a very simple model where we assume that the supply is fixed of an unknown magnitude. So, we do not know how much is there at a particular point in time. So, at particular point in time also oil is being formed or that particular resource is formed, but you see the rate of formation is very less.

So, at a given point of time we may consider the endowment of the resource to be more or less fixed. So, and this model is a generalized model which can be applicable to other type of mineral resources, but of course, I will be taking the example and instances of oil.

But the same model is applicable for other type of mineral resources which are non-renewable in nature these are in limited stock and the rate of current use is much greater than the rate at which these are formed and we also have lot of uncertainty regarding how much of the resource is left at present.

So, in this setup how to decide the price and how to decide how much to consume at the present and how much to keep for future consumption. And see now finding out new reserve is also very costly. If you remember we have already discussed we have devoted one module in deciding means in discussing the concept of depletion, the cost of discovery, so we set out the what are the steps.

If you remember so, first a nationwide broad mapping is carried out by either directly by the government or the government funded agencies like the research institutes to identify

the potential oil fields and then the private firms in the next step they come in and they explore the oil field to set up the extractable resources and next in the next stage the probe reserve is established right.

So, these are the steps and so, its time taking as well as it is very costly. So, all these issues so, fixed amount of supply which is on unknown magnitude along with costly new reserve. So, these issues make the pricing of oil so complicated.

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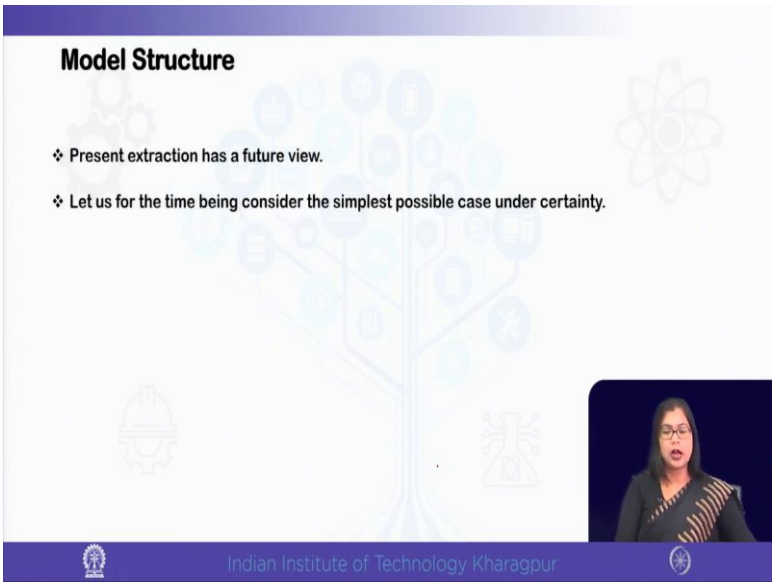

So, let us start with discussing the structure of a theoretical model. See so, when we are deciding about how much to extract of that particular resource let us say oil at present we should have a futuristic view, is not it. If we use too much of resource then we will be not leaving the resource for our future generation.

So, we should not be doing that we should also think about the use of the oil by the future generation. So, that actually is a sustainable development we should not exhaust the resource completely until and unless we have some easy cheap substitute good substitute very close substitute and that is available for a large section of the world.

It is not like a nuclear power or say shale oil which is only available to few countries let us say shale oil it is mainly available to US or nuclear power also is mainly available to the developed countries man and there are other adverse consequences of nuclear power and shale oil is not available to the developing countries or the poor countries.

So, we have to also think about the poor countries or the developing countries who are actually till here to reach the more advanced stages of economic growth and development they are in the process of industrialization. So, their energy requirement is also high. So, therefore, we should be using the resource in such a way that we should not exhaust the resource completely. So, with this idea in mind let us go into the detail of the theoretical model.

So, for our purpose we are starting a very simple theoretical model with two period, period, ok period 1 and period 2. So, period 1 is the present and period 2 is the future and let us for the time being consider a very simple case under certainty. So, suppose for the time being that we know how much amount is there ok.

So, this is a simplistic assumption because when we start a theoretical model often we start with a simple assumption and then we as proceed we can complicate we can bring more complications we can make the model more realistic. So, let us for the time being assume that we know how much of oil is left in the ground. So, with this knowledge we are now deciding how to allocate the resource over time and what should be the prices the current price and the future price.

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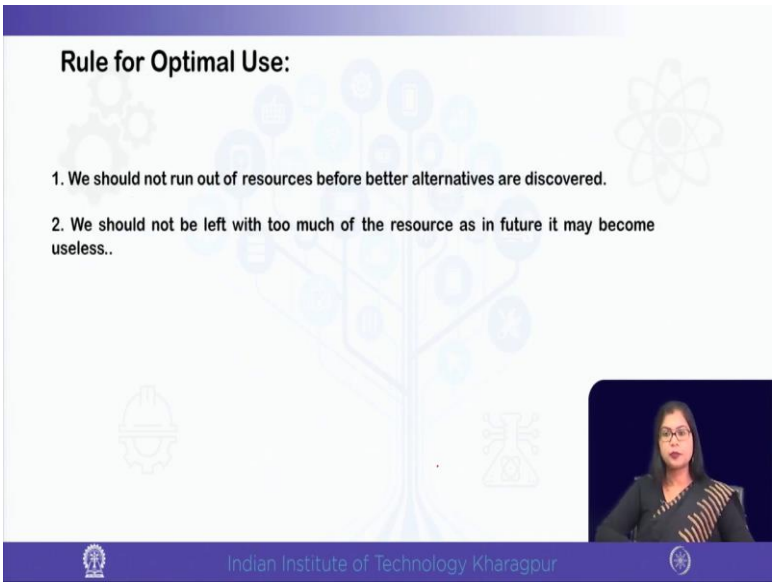

So, what should be the rule that will follow for optimal pricing of oil? First is that we should not run out of the resource before close alternatives, cheaper alternatives are

discovered. That means, if we use the resource too much and if it is in limited stock of course, at some point of time the resource will be depleted.

We have already studied the concept of depletion. Thankfully our empirical observation revealed that for oil at least we have not preached the stage of depletion, but we have also seen the experiences of some countries like Indonesia which have almost depleted its oil reserves. So, we should learn from the experiences and we should not run out of the resource because we have to keep the resource for our future generation. Now, that does not mean that we should not be using the resource at present.

So, there is also a risk that if you do not use, if you become too miser and if you do not use the resource for present, if you keep a larger amount of resource for future, it may happen that in future you have a technological breakthrough. So, you remember in supply we discussed that technology is very important in case of supply. So, the technological breakthrough come up with new technologies and that can replace that particular resource.

So, often you see the technological advancements are I mean sometimes they are so unimaginable. You see think about this online education even few decades ago it was not believable right, but with the improvement in ICT infrastructure now online education or even telemedicine these have become so, common.

So, technological advancement can bring new substitutes which are better substitutes which can be less costly and that can be made accessible to a larger section of the society and then if you do not use that particular resource so, the resource will become completely useless. So, we should not do that. So, that means, we have to use the resource prudently and there should be a balance. We should not use it at a faster rate that we are running out of the resource and we should not also use it at a very slower rate.

So, that in future it is completely useless. So, if you come up with some technological improvement and this technological improvement also you see its uncertain you do not know. We have already seen that how US came up with shale oil revolution and the peak oil hypothesis the proponents of peak oil hypothesis who were very pessimistic regarding the future of oil they were completely means they changed their opinion, they had to

change their opinion regarding the future of oil because they did not know about the research and development going on for shale oil.

So, you see if there is some alternative so, the pricing trend also reverses. Now, we should not keep more resources for future use because it may become useless. So, you see lot of uncertainties involved not only with respect to the endowment, but also with respect to alternatives of that particular resource. So, these are the two rules we should keep in mind for optimal allocation and pricing of the resource in an inter-temporal setting inter-temporal means over time.

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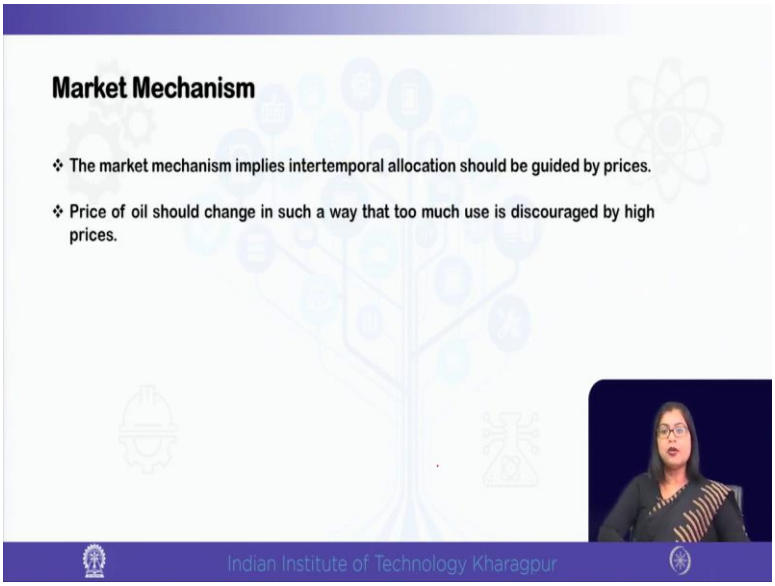

Now, if you are leaving it to the market. So, the market will decide how much to be used at present and how much to be used in future. So, the market mechanism implies that inter-temporal allocation should be guided by the pricing mechanism. So, what do we mean? That means, the price should act as a signal of how much to consume now and how much to keep for future use.

So, that means, the price of oil should change or behave in such a way that too much use should be discouraged by high prices. So, that means, what; that means, if price of oil is very low at present. So, what will happen? You will use the resource at a faster rate. If you say if you remember in public policy module, we have discussed about different types of tax policies.

And we have seen that with the tax, the quantity of consumption falls compared to the without tax level because with the tax there occurs the divergence between demand price and supply price. So, the net price that the consumers are paying that increases, the net price the sellers are receiving that falls.

However, we have also discussed that means who bears the burden of the tax that depends on the elasticity of demand and supply. I am not going to that part. So, that means, tax reduces the quantity whereas, we also discussed that subsidy or which can also be interpreted as negative tax that leads to a greater use of the resource. Now, here we are not bringing any third party, but if we leave the market to only the forces of demand and supply.

So, price should act as a signal. So, if price falls, current price falls. So, what will happen? The consumers will buy more. So, you will be left with less oil for future. If price increases in the present period, then you would not be able to consume that much. So, you will also be having some resource for future use. So, that means, the price should be done in such a way that it will govern the allocation of the important resource over time ok. So, price is taken as a signal if you are leaving everything to market forces.

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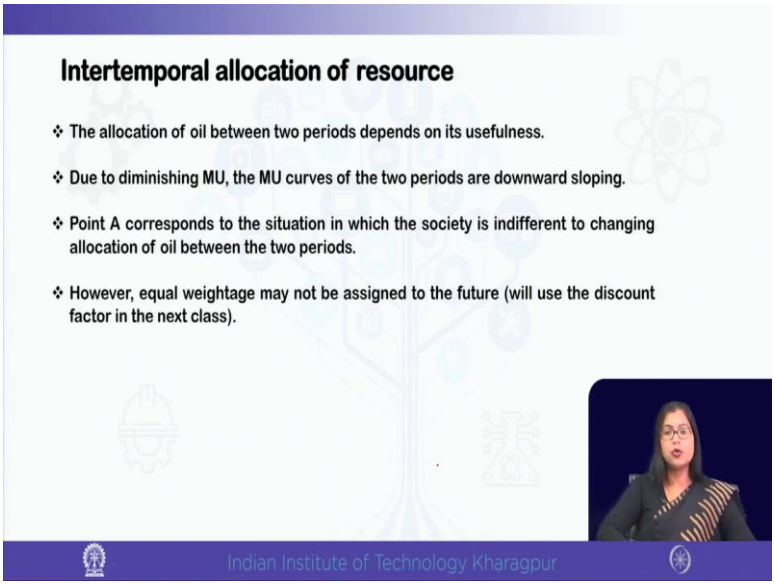

So, you see, now if you come to the inter-temporal allocation of resource, how much to use currently and how much to keep for future use. So, we can see that the allocation of oil between the two period, it will depend on the usefulness or the utility of oil. So, here

comes the concept of utility. So, before we proceed further, we need to have some basic ideas. So, I will come back to this part, but before that we need to know what is utility.

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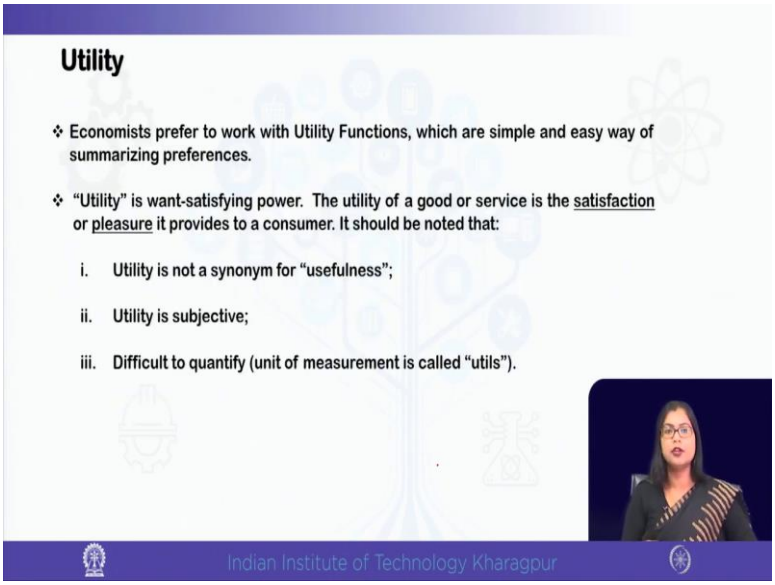

So, often we the economist we want to work with the utility function and these are simple and easy way of representing our preferences or our choice; that means, our likes and dislikes. So, what is utility? Utility is the one satisfying power of a good or service; that means, a product overall. So, if we if you are hungry, if you eat something a food product that will give you some utility, right. So, it is the one satisfying power.

So, utility of a good or service, it can be defined as the satisfaction or pleasure that it provides to the consumer who is consuming. But we should keep in mind that utility is not same as usefulness ok and utility is also subjective because it may vary from context to context. So, the same person will not derive, may not derive the same level of utility from consuming the same amount of a particular good. It may vary.

See for example, your umbrella has greater utility in the rainy season, right as compared to the winter. So, you see so it varies from ah means for a particular person also it varies from time to time. Whereas, it also varies from person to person because the same good may not yield same level of satisfaction to all the consumers in the market. So, it is a subjective concept, it is difficult to quantify.

So, often we use graphical analysis or axiomatic approach to represent utility or the utility function where we do not need to quantify utility, but we can represent the ordering. There are different approaches of utility.

The traditional approach of utility is to quantify utility and there is a unit called utils, but that approach is subject to lot of criticism that it is difficult to quantify utility as it is subjective, it varies from individual to individual for the same individual also it can vary from context to context. Now, utility is itself is a vast area in economics, we are not going into that detail. We are just studying a theoretical model in this module right where we need some basic, very basic concept of utility.

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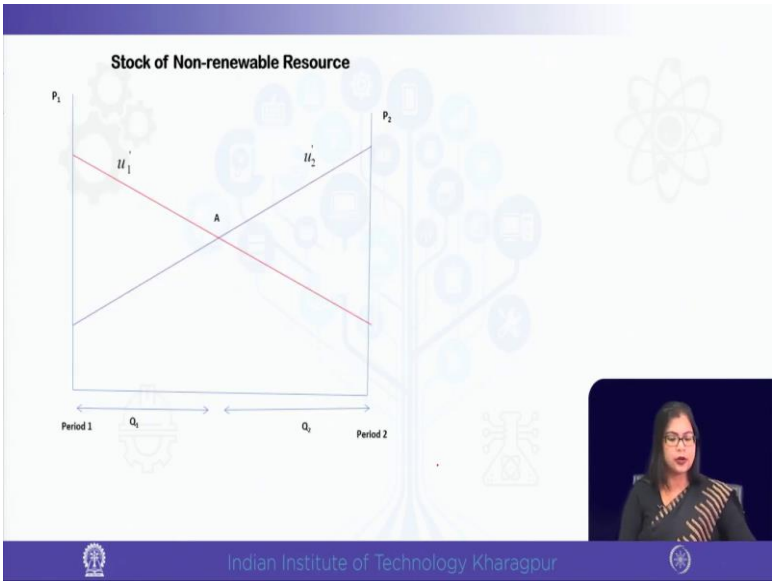

As you can see the way we are representing the allocation of resource, we have to show the marginal utility curve. So, we should know what is marginal utility and the downwards shape or slope of the marginal utility curve. So, that is the purpose of including the very basic concept of utility. So, as I also mentioned that it is difficult to quantify also. So, often we represent we work with the utility function or we work with the preference ordering.

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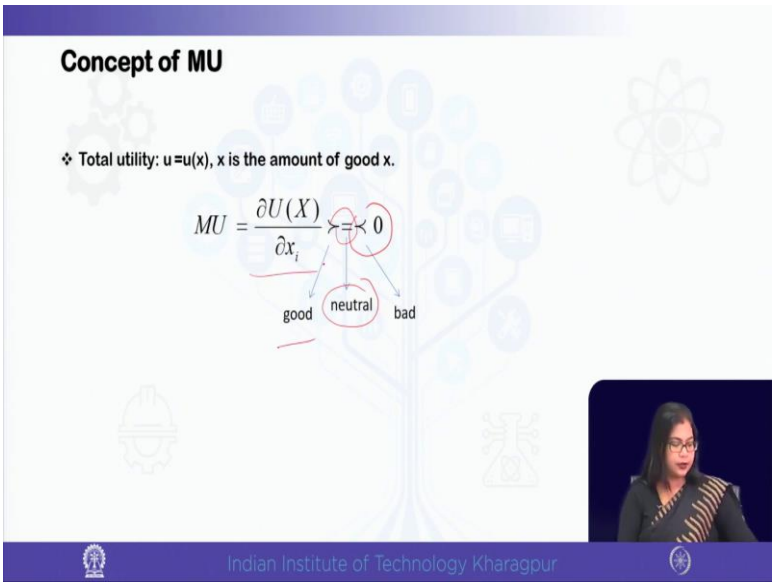

So, we define the total utility or utility function which depends on the amount of consumption of a good. So, U is a function of X where X is the amount of consumption of good X. Now, if you So, this is the total utility you derive from consuming any particular good X. Now, how your utility changes if you change if you consume on additional unit.

Now, you see by this time you know that economists are often interested to see what is happening at the margin. So, often we work with the you have already seen you have come across with the concept of marginal many times, a marginal revenue, marginal cost. So, similarly again in case of utility also we are often interested to see how the total utility will change if we consume one more unit of a good.

So, that is called the marginal utility. So, change in total utility with respect to change in consumption of one unit of a good. So, $\frac{\partial U}{\partial x}$ is the marginal utility of good x. Now, you see generally marginal utility is positive because if you consume one more unit that will give you a greater level of satisfaction right.

But it may not always be the case. So, marginal utility is positive for the good commodities. But there are some commodities like for example, marginal utility can become negative also let us say pollution. We want less of pollution, is not it? Because if you have more of pollution, your utility falls right.

So, this you can think of pollution as a bad commodity. So, marginal utility is negative for bad commodity. There are some goods also in your consumption basket to which you may be means you are just indifferent to the amount.

You need some minimum amount, but if that good is given to you in more quantity. So, that may not add to greater level of satisfaction. Let us say salt, we all need salt, but greater amount of salt is not required or even say toothpaste also. So, we start our day with toothpaste, but you do not need a large amount of toothpaste.

So, these are some examples of neutral goods for which marginal utility takes a value 0. So, this addition to another packet of salt or another toothpaste tube will not add to your utility ok. But mostly we see that marginal utilities are positive. So, for our purpose we are just concentrating ourselves to the goods or services that yield a positive marginal utility ok.

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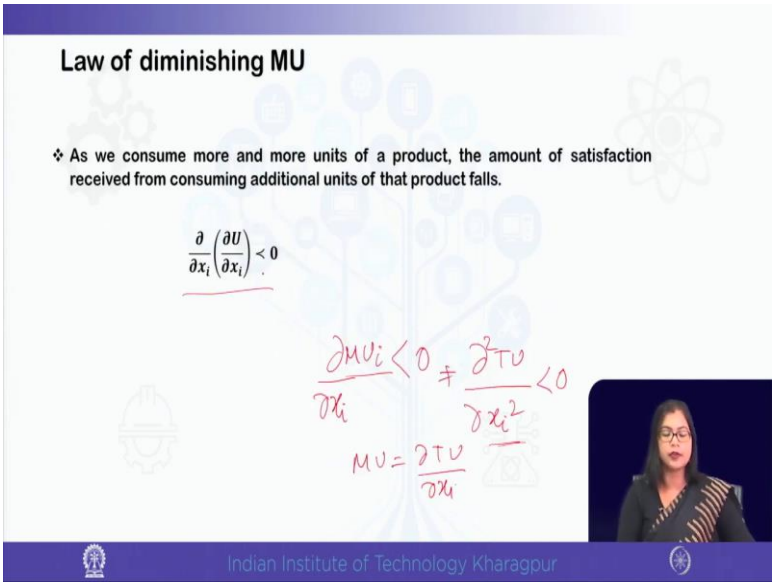

Now, suppose you are too hungry. So, you could not have a proper breakfast to attend your lectures. So, after the lecture you will be having some food, so you will be too hungry. So, if you suppose you have one plate of say breakfast item and then you are not full, you will order the second plate.

So, how your utility will change? So, if you go on adding more and more units of consumption of that particular i th good. So, here comes the very important or famous

law of diminishing marginal utility, which tells how your utility changes as you consume more and more units of a product. So, what we see empirically is that as we consume more and more units of a product, the amount of satisfaction or utility received from the additional unit of the product falls.

So, that means, the rate of change of marginal utility is falling as you are consuming more and more unit of i th good. So, that means, see $\frac{\partial}{\partial x_i}(\frac{\partial MU_i}{\partial x_i})$ is negative or you can also write it as $\frac{\partial^2 TU}{\partial x_i^2}$ is negative. So, that means, the total utility change in total utility as you are consuming more and more of good x. So, and what is MU? MU is just now defined that it is basically $\frac{\partial TU}{\partial x_i}$ So, in place of $\frac{\partial TU}{\partial x_i}$ you can write MU, so it will become $\frac{\partial MU_i}{\partial x_i}$

So, the law of diminishing marginal utility tells that if you go on adding more and more units of consumption of that particular good, so the rate of change of utility is declining. So, utility marginal utility is positive, we are just concentrating on the case where marginal utility is positive, so we are not considering these cases for our purpose.

So, even within the range of the good commodities for which marginal utility is positive, how marginal utility changes if we keep on adding more and more unit of good x. So, that we see that that is declining. So, this is called the law of diminishing marginal utility.

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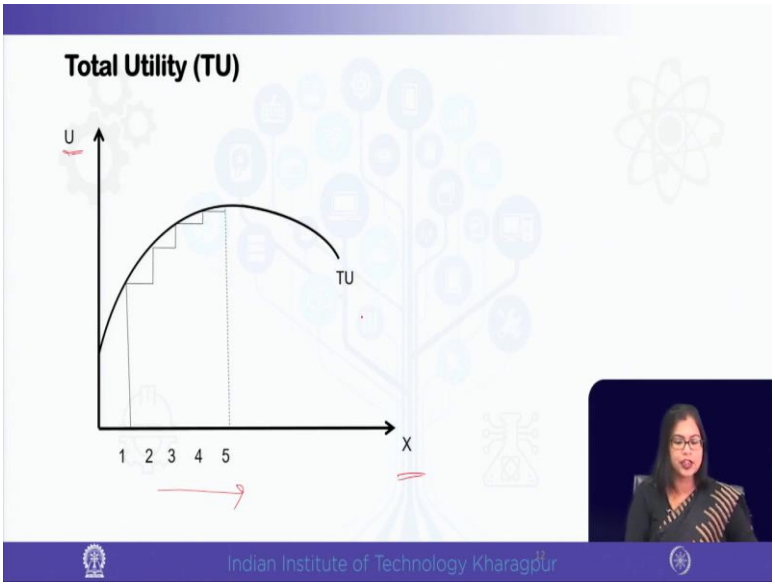

So, we can plot the total utility schedule. So, of course, you can see that here utility is a function of the amount of consumption of good x and as the amount of consumption of good x increases, see total utility increases. But it is first increasing at an increasing rate, but then due to the law of diminishing marginal utility. So, total utility is positive, but it starts declining. So, it is like a inverted U shape.

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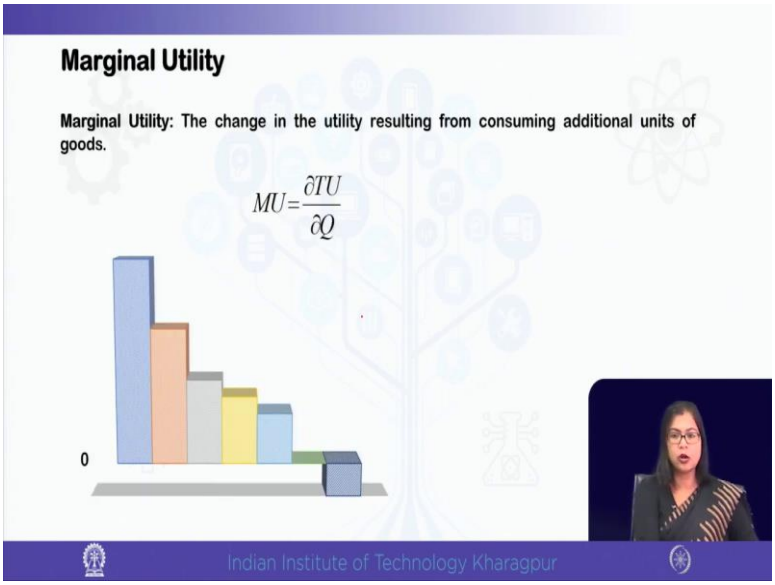

So, you can also plot the marginal , so marginal utility is declining. You see the change in utility resulting from additional unit of consumption of that particular good. So, MU is equal to $\frac{\partial TU}{\partial Q}$ that is falling you can see. So, after certain point, it can also become 0 like you have seen that for bad commodities it is 0, it is negative and for neutral it is 0, but we are not considering those cases. So, we are not considering the cases where the marginal utility is 0 or negative for neutral on the bad commodities.

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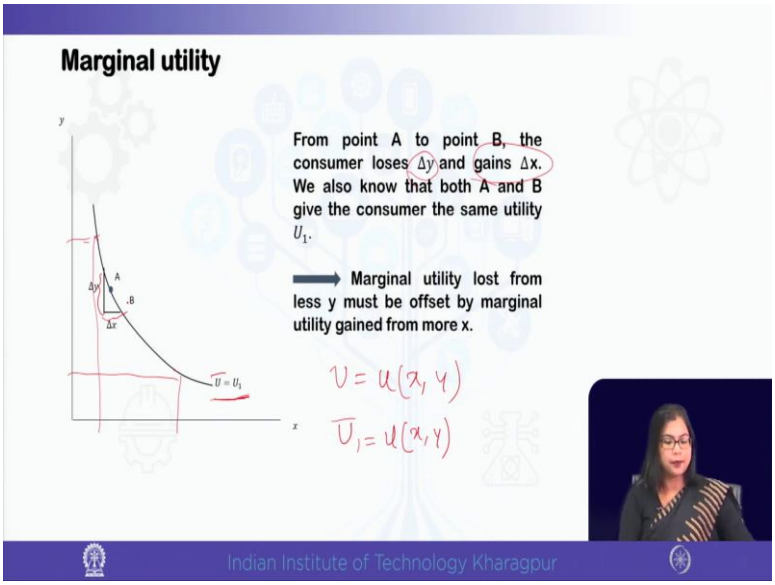

So, if you now plot these two products say x and y in the two axis. Here you see in the previous figure you have plotted utility against the amount of consumption of good x. Now, suppose your consumption basket has two goods x and y. So, you can basically write your utility function; utility is a function of consumption of good x and y.

So, if you plot this ok. So, if you now fix the level of utility say U_1 as we have already denoted. So, this is the combination of different combinations of consumption of quantities of good x and good y, which gives you the same level of satisfaction say $\overline{U_1}$. So, this is what we call the very famous indifference curve.

So, locus of quantities of consumption of the two goods, which give the consumer the same level of satisfaction. So, I am not going into that detail, we really do not have time to discuss all this. So, this is you can say that the indifference curve is the graphical representation or the locus of the utility function.

So, you see along this particular utility function that we have plotted that means, the indifference curve U_1, so the level of satisfaction is same. So, this is basically the locus of different bundles which give the consumer the same level of satisfaction, these are the different combinations. So, we have taken to bundles let us say A and B. See, if we move down along a particular indifference curve, if we move from point A to B, we see that we are reducing the consumption of one good.

So, the consumer is losing the opportunity to consume this good y by the amount Δy and the consumer is now consuming more of good x. That means, the consumer is gaining by the amount Δx and the consumer receives the same amount of utility along all the points on this indifference curve on this locus U_1. So, marginal utility lost from less of y, it should be offset by the marginal utility gained from more of x ok.

So, if you are going down, so you are losing this Δy amount, but you are also gaining this Δx amount. But these should be compensated, so loss in y should be compensated by the gain in x, so that the consumer should receive the same level of satisfaction from point A and point B.

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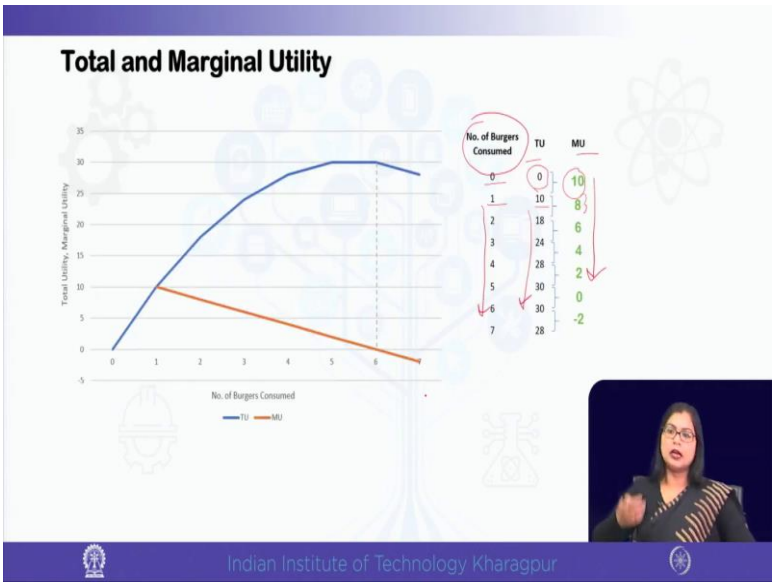

So, you can also plot together total utility and marginal utility. So, here we have taken an example of number of burgers consumed by a consumer. So, what are the total utilities and marginal utilities? So, of course, if the quantity of consumption is 0, the consumer will not receive any utility, so total utility is 0. Now, then you see as the number of burger consumed increases. So, total utility is increasing. But what about the rate of change? So, you see, the marginal utilities are positive, but declining.

For the same reason we discussed because initially you are too hungry. So, if you are not consuming any burger, you are not receiving any satisfaction. So, you are too hungry, so for the 1st unit, your total utility of 1st unit of burger is 10. So, your marginal utility from

0 to 1 unit of burger is 10. The gap between the total utility received from 0 to 1 unit of burger.

Then if you have one more unit of burger, see if you are not completely satisfied with one burger, you are still hungry, you have the next burger. But is the next burger giving you the same level of satisfaction the first burger gave? No, because now you are less hungry.

So, you see your change of total utility is now 10 to 18. So; that means, your marginal utility is now 8. So, in this way, see as you go on adding more and more burgers, your total utility its positive, but the rate of change of total utility is declining. So, this is the law of diminishing marginal utility.

So, you have plotted both total utility and marginal utility, so you see total utility is positive. Initially it is increasing, but then it starts declining and marginal utility is decreasing due to the law of diminishing marginal utility. So, we needed this law of diminishing marginal utility and the concept of marginal utility to discuss our theoretical model.

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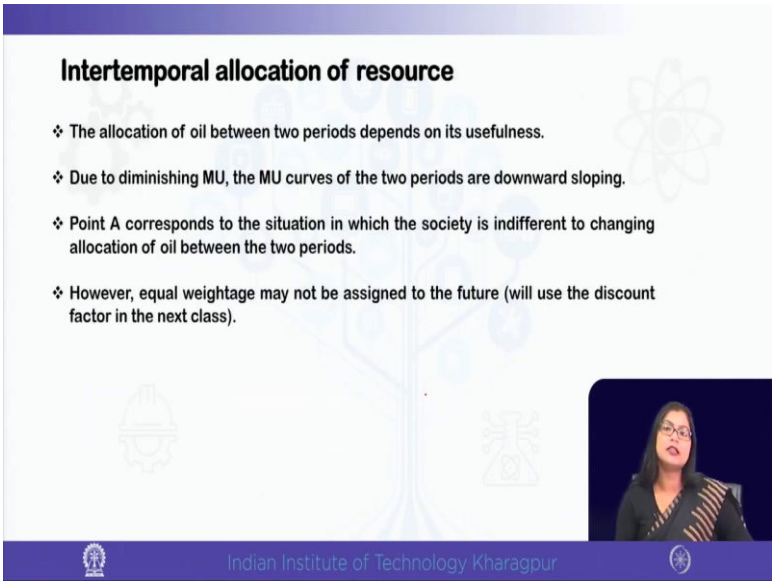

So, if we now go back to the inter-temporal allocation of steady source in the theoretical model that we are going to study.

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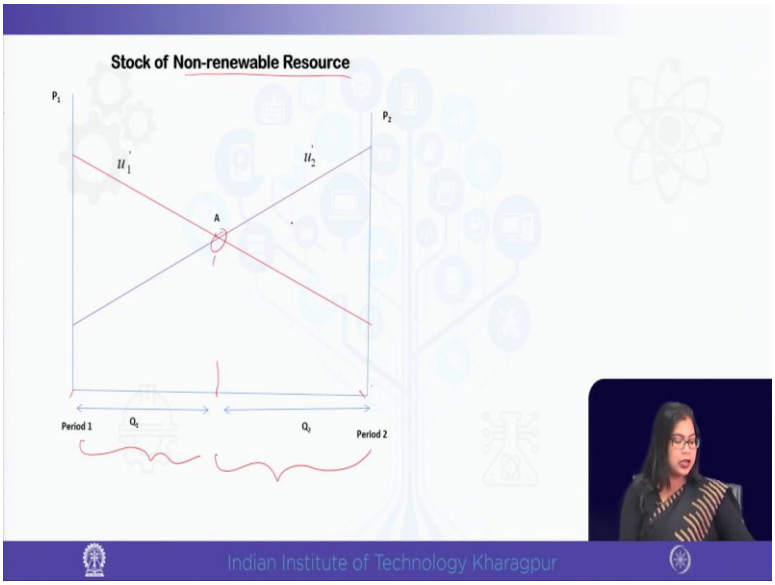

So, suppose we draw, we plot both the periods, period 1 and 2. So, how much of the resource to be allocated in the two periods? So, it is a very simple framework of two period. It can be extended for more number of periods. So, basically we are seeing a trade-off between the present and the future.

So, this left origin basically correspond to the 1st period and the right origin corresponds to the 2nd period. And what we plot over here is the marginal utilities of consumption of oil or that particular resource that we are considering and that resource is the non-renewable resource is in fixed quantity.

So, we are plotting the marginal utilities of the stock of non-renewable resource of period 1 and period 2. So, period 1 we are using the left origin and for period 2 we are using the right origin. If you remember we have used similar type of box type of diagram while discussing the allocation of resource when we studied the theoretical model of structural change and resource discovery and Dutch disease.

So, we are using a similar framework. So, here we have plotted the marginal utilities and so, u_1' is the marginal utility of consumption of the resource in period 1 and u_2' is the marginal utility of consumption of the resource in period 2. And by law of diminishing marginal utility we know that the marginal utility curves are downward sloping because as you go on consuming more and more units of the resource your utility falls the rate of change of total utility is falling ok.

Now, you see what we are plotting over here in the horizontal axis. In the horizontal axis we are plotting the allocation of oil, means the total amount of oil. And in the vertical axis we are plotting the prices and the utilities ok. So, we will be using this diagram to show what will be the optimal pricing policy and what will be the allocation of that resource in the two periods ok.

So, this is just the beginning this is not the final allocation we will bring the discount factor. But before that suppose if you value if the consumer puts equal weightage on present and future. So, period 1 and period 2 utilities are treated equally then we can see that these 2 marginal utility curves are intersecting at point A.

So, we can see that point we can conclude that point A is the situation in which the society is just indifferent to between changing the allocation of the resource between the two periods. So, that means, more or less equal amount of resource you are using. So, you are dividing the resource in the two periods more or less equally. However, now the caveat is that equal weightage may not be assigned to the future because often we value our present more than what we value our future.

So, we will be using the concept of discount factor. But if you put equal weightage on present and futures so, almost similar amount of resource is used for the two periods you see. And the price will also be the same P_1 will be equal to P_2 and same number this total use of total resource Q will be divided almost equally between period 1 and period 2.

So, capital Q will be equal to Q_1 plus Q_2 and the price will be same ok. However, this will not be the optimal allocation. So, I will discuss the optimal allocation and optimal pricing in the next class. So, in this class what we have done? We have just set up our theoretical model.

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We have specified the structure of the theoretical model and then we went through the very important, but basic concept of total utility, marginal utility and we also discussed the law of diminishing marginal utility.

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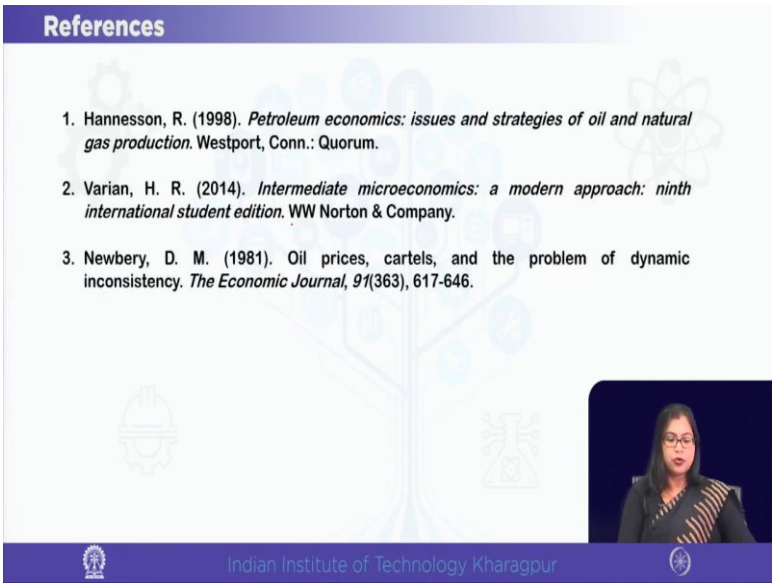

So, we are mainly following for the utility part it is the very good book by Hall-Varian Intermediate Microeconomics which is for the beginners. So, one can follow this part for the utility function and indifference part that I discussed in this class. And the theoretical

for the theoretical model you can follow the petroleum economics book by Hannesson and also one paper by Newbery.

So, thank you see you in the next class.