Petroleum Economics and Management
Prof. Anwesha Aditya
Department of Humanities and Social Sciences
Indian Institute of Technology, Kharagpur

Module - 11
Management of Petroleum Wealth
Lecture - 51
Model of Economic Growth-I

Hi everyone, I am Dr. Anwesha Aditya, offering the NPTEL course, Petroleum Economics and Management. So, welcome to our course, now we have come to module 11 in our course, where we are discussing the Management of Petroleum Wealth. So, this is our first lecture in this module and overall, this is the lecture number 51 in our course. So, in today's lecture we will be discussing a Model of Economic Growth.

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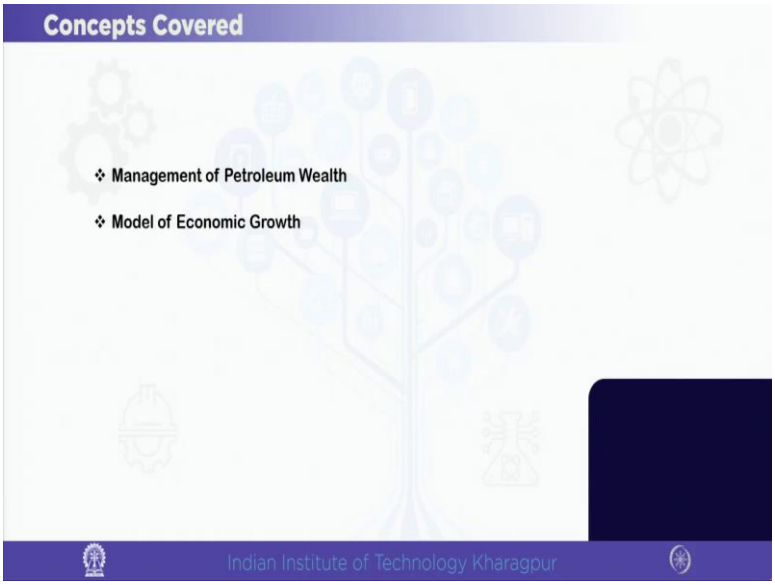

Now, if you remember we have already discussed in depth how sudden discovery of resource, how that leads to a change in the structure of the economy. So, we have discussed it both theoretically, empirically, intuitively we have discussed the phenomena of Dutch disease and resource curse.

So, it is not only important that resource is discovered, but how to manage the resource because we have seen from empirical evidences that often the countries become rich overnight by discovering resource like it happened for the case of Saudi Arabia.

So, Saudi Arabia was a very poor province we know that and when oil was discovered there was very limited domestic demand for oil in Saudi Arabia. So, Saudi Arabia started exporting oil because there was huge demand for oil outside Saudi Arabia and it earned huge amount of oil rent and it became rich because by selling or exporting outside. So, you earn in terms of dollar or that means, the foreign exchange and you can buy the goods for which are needed for your consumption?

So, Saudi Arabia and other OPEC countries even the Non-OPEC suppliers who are endowed with oil. So, they became rich once oil was discovered or even other mineral resources. So, we have already studied the phenomena of Dutch disease which the name of Dutch disease was due to it occurred when natural gas was discovered in Netherlands and hence the name Dutch disease.

And we have studied the theoretical model also in a two, in a traded good sector and non-traded good sector. How discovery of resource actually leads to a shrinkage of non-resource tradeable activities. Because we have already studied what will happen when the country starts exporting the resource.

So, the country will earn a foreign exchange so, which will lead to increase supply of the foreign exchange. So, the domestic currency appreciates and that leads to reduced competitiveness in the market for other goods and services if the country is exporting other goods and services.

So, ultimately the resource sector dominates the economy and in the very extreme case it emerges as a mono economy means there will be huge dualism ok. And the non-resource sectors since the prices are determined within the domestic economy for the non-traded sectors and for the traded sector the prices are determined outside the country. So, what are the implications in the labour market we have already discussed in module 7 the petroleum discoveries and structural changes right.

Now, so; that means, it is not only important that natural resource is discovered ok. So, it is very important that the resource should be used prudently otherwise we have already seen with the experience of Venezuela that how Venezuelan economy was very much dependent on oil and it did not could not develop the other sector. So, it was financing its import demand from exporting oil.

But when it almost depleted oil or the price of oil started falling after the shale oil revolution. So, Venezuelan economy also suffered even Indonesia also depleted its reserve, but Indonesia tried to diversify itself. So, it is not only important that we discovered the resource managing the return run earn from the resource is very important and we have already studied whether Dutch disease is curable or not.

So, if you remember the answer to the question is whether Dutch disease is curable or not? We have studied that yes; Dutch disease is curable because we have seen that Netherlands also perform better. Netherlands is one of the OECD countries, rich countries and the human development index is also good even we have compared the experiences of Norway and Denmark.

In Norway also there was a balance of payment crisis during 1987, but Norway also could come out from the balance of payment crisis afterwards with intervention with proper policies and Norway did well and Norway also ranks very high in the almost in the top position in the human development index. So, that means, with the experience of Norway and with the experience of Netherlands what we can say is that once resource is discovered in an economy which is already developed.

So, the resource wealth can be managed properly, but we often see that the Middle-East countries the OPEC countries mostly they could not do so, because these countries were not developed when the resource was discovered. So, and many times the resource wealth or the rents arising out of the resource is captured by very few. So, these countries suffer from increased inequality and the human development index parameters are also not quite good in these countries.

These countries also have lot of domestic violence and they engage into war. So, the political stability is lacking. However, we have seen that in the 21st century they have also started diversifying, but they have also a lot of scope for improvement. So, that is why they are earning huge amount of rent, but these countries do not feature in the list of the developed countries as classified by the World Bank ok.

So, it is not only important to discover a resource, but it is very important to use the resource wealth prudently. It should not be captured by only few. So, that the benefit is not percolated or distributed across the larger section of the society. It is the wealth

should be used for improving the standard of living of the mass people improving the health infrastructure education.

So, how to manage the petroleum wealth? That becomes a very important issue. It is not only the task of the policy maker does not end by discovering the resource rather you can say that if the task actually begins after discovering the resource. Now, see the problems are different for a country like India the problem is we have to import a lot of oil, but what about the countries which are endowed with oil.

So, for them also it is not that they are very lucky because they have to use the resource otherwise, we can see that there can be repetition of experiences like Venezuela. So, how to use how to manage the oil wealth or the resource wealth so, that is what we are going to study in this module using a theoretical model. So, we will be studying a model of economic growth in which we will be studying how to use means what happens when resource is discovered.

So, we will start with a model of economic growth without a resource discovery ok. So, we will be first comparing the model of we will be structuring the model of economic growth without a resource discovery and then we will see how resource discovery affects the economic growth in that model.

And then lastly, we will be bringing out the role of uncertainty because you see in the course outline also, we have discussed about uncertainty and we have already many times with empirical data we have seen that the global oil market is so, uncertain we cannot predict what will be the price.

So, we have seen many ups and downs like the recent case of COVID-19 pandemic where the WTI price became negative. So, the market is subject to lot of volatility and uncertainty. So, in the context of uncertainty it is important to know or it is important to explore that how the model of economic growth will be disrupted when we bring uncertainty with respect to the future oil price.

So, this module is distributed into four lectures in the first two lectures I am going to elaborate the model structure without resource discovery. In the third lecture of this module, we will be bringing out we will be introducing the resource discovery and

finally, in the last lecture we will be talking about the uncertainty related to oil price how that will affect the economic growth.

Now, before proceeding further I would like to point out a few things that you see our course is distributed and balance in such a way that there are some components which are more oriented towards microeconomics. Like our first initial modules of basic of economics public policy and then the modules on game theory oligopoly part because those were the decisions of individual economic agent.

Either the producer or the consumer or the firm right or the government in the public policy part it was the individual the decision of the policy maker; whether to interfere or not and in which way to interfere.

So, these are all the aspects from individual economic agent and come under the purview of microeconomics. And you see there are certain modules like your module 10 and module 11 where we are discussing the issues at the macro level. So, these are these have a macro perspective.

So, if you remember in the very initial lecture, we have categorized economics into two broad branches microeconomics and macroeconomics. So, microeconomics deals with the individual economic agents and macroeconomic deals with the aggregate economy. So, like inflation, savings rate, unemployment rate, investment rate, interest rate. So, these are all the macroeconomic aspects.

So, you see our module 10, 11 even the last module, module 12, these are these modules have a macroeconomic perspective because these are for the aggregate economy as a whole. Even you see the module 7 where we discuss the theoretical model on resource discovery and structural change that was in a general equilibrium framework where we discussed how the allocation of resource will be affected or labor allocation will be affected after the resource discovery.

So, I just wanted to point it out that we have distributed the course accordingly some topics have a micro perspective and some topics have a macro perspective. So, module 10, 11 and 12 have a macroeconomic perspective because we are discussing about in the module 10 if you remember we discussed about the inter temporal allocation and pricing of oil in module 11 we are discussing the model of economic growth and in module 12

and the last module we will be discussing about the exchange rate. So, they are for the aggregate economy.

Now, you see another important point the second point I would like to draw your attention to this module 11 we are studying the model of economic growth we will be using a micro foundation of macroeconomics. Now, the traditional approach of studying macroeconomics is to start with the aggregate economy.

But and that is called the tops down approach you start from the aggregate say you discuss about the inflation, savings rate, interest rate, but the latest approach to study macroeconomics is to start from the individual economic agent.

Why? Because see suppose he was studying about the labor supply now who makes the labor supply decision it is the individual households who make the labor supply decision how much time to devote for work and how much time to enjoy as leisure right. Again, you see the savings behavior that also comes from the choice of the individual household. So, how much to consume and how much to save right.

So, the latest approach to study macroeconomics is not to start at the aggregate level, but we should start from the button and then we should add up means we should go to the top ok. By aggregating the labor supply decision of all the individual households in the economy or by first studying the individual economic agents decision on labor supply or say savings then we add up and we get the aggregate.

So, this is called the bottoms up approach; that means, we start from the bottom and then we go up. So, we will be using this micro foundation of macroeconomics. So, you see initially micro economics was divided into these two broad categories microeconomics and macroeconomics, but then again you see there is a convergence between the two because we are studying macroeconomics even with a micro foundation ok.

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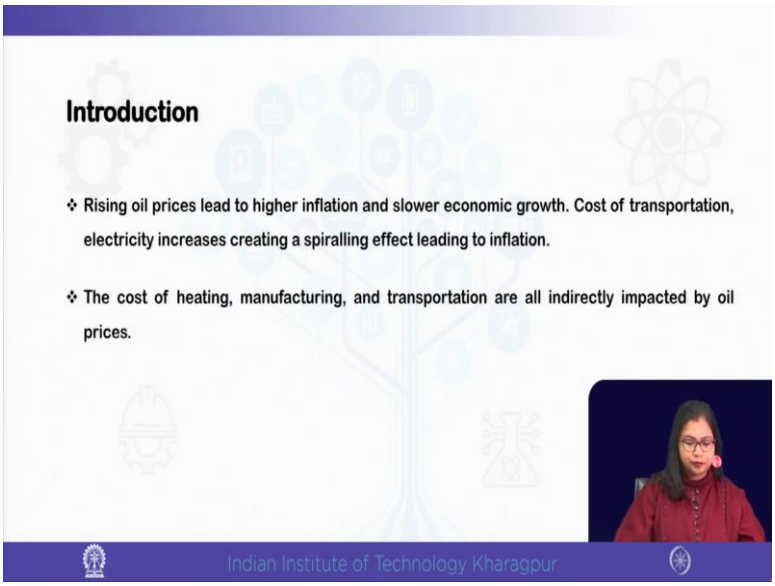

So, let us now proceed in our lecture. So, we already know that increasing oil prices have a spiralling effect because when oil price increases cost of transportation increases because transportation mainly depends on oil, we have discussed it many times.

Cost of power generation increases and all these will lead to inflationary pressure in the economy because your cost of manufacturing, agriculture production services everything will go up. So, rising oil prices it has it will impact the entire economy. So, cost of manufacturing, heating, transportation all are either directly or indirectly affected by rising oil price.

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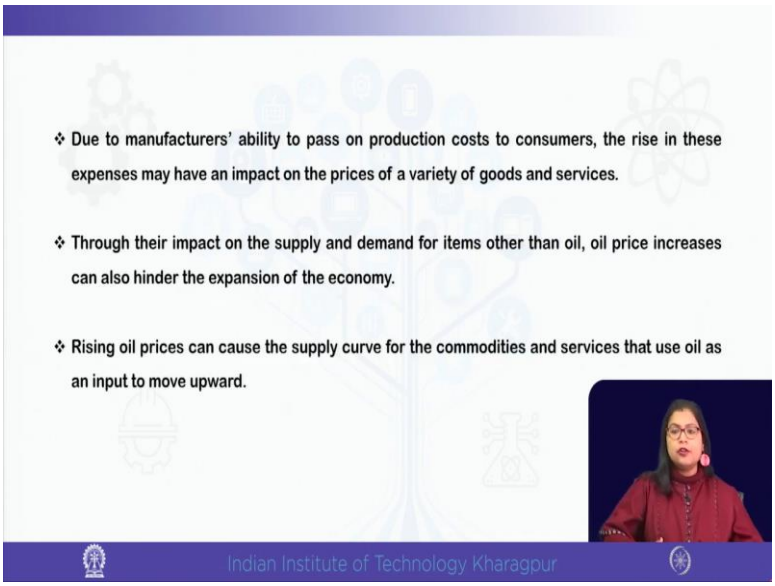

And because oil being inelastic the producers can also pass on the increasing oil price on the consumer. So, often you see even if the oil price in the global markets say the crude oil price falls, but in domestic economy we have to pay high price. So, we already know that oil is a very reliable source of government revenue being inelastic in nature and the sellers can also pass on the increasing oil price on the consumers because the oil the price elasticity of demand is less ok.

So, the increase in the cost of transportation, electricity, power generation they have impact on the price of lot of goods and services ok. So, oil price can also the increase in oil price can also hinder the expansion of the economy because for the countries which are, we are talking about these first two slides from the perspective of the oil importing countries like India.

So, we have to spend lot of amount for importing oil and given that oil is inelastic if oil price increases the import demand or import bill also increases ok. And supply curve of other commodities and goods and services and which are used as inputs of production as well as the final goods the supply also falls ok.

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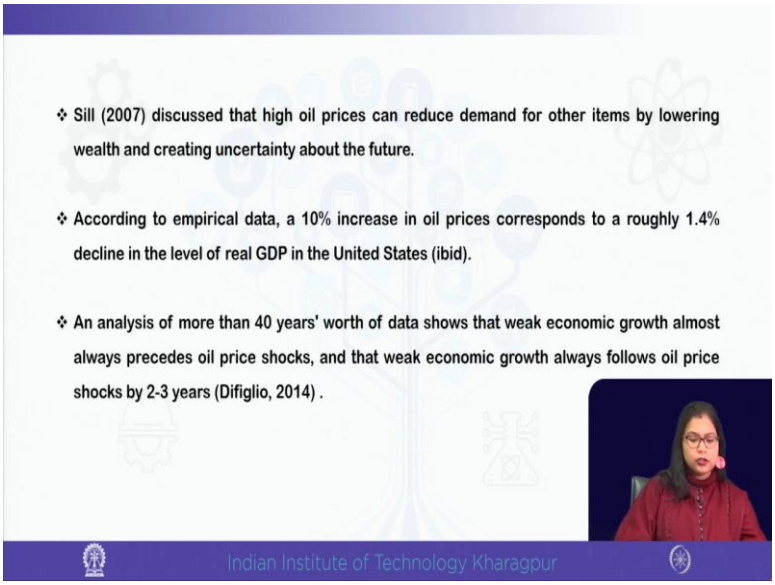

So, these things we have also already discussed many times. So, if we now look at the literature on the impact of rising oil price on economic growth, we find that Sill (2007) discuss that high oil prices can reduce the demand for other items by lowering the amount of wealth in the economy and creating uncertainty about the future.

So, of course, we know that oil market is subject to lot of volatility and uncertainty. So, according to empirical data as analyzed by Sill 2007, a 10 percent increase in oil price corresponds to roughly 1.4 percent decrease in the level of real GDP in the US ok. So, nominal GDP divided by the price level. So, real GDP also falls if oil prices increase.

Again, you see another study by Difiglio (2014) points out that over analyzing a data of almost for years Difiglio 2014 concluded that weak economic growth almost always precedes oil price shock and that weak economic growth also always follows oil price shock by 2-3 years. So, if there is an oil price shock before that and after that economic growth is relatively weaker. So, these are very interesting observation from the literature from the point of view of mainly the oil importing countries.

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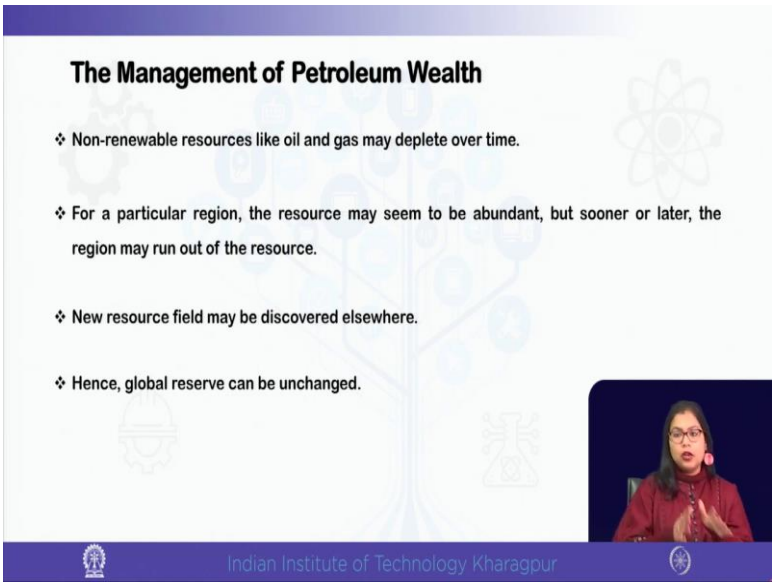

Now, coming to the oil endowed countries or oil exporting countries. So, how to manage the petroleum oil that is what we are going to discuss in the present study. Now, you see we have already discussed we have distinguished between renewable and non-renewable resources.

So, oil and gas and coal they generally come under the non-renewable resources category and they deplete over time. So, if you continue to use these resources. So, at the current rate of formation is very low. So, therefore, at some point of time or other you will exhaust the resource.

So, for a particular region the resource may be abundant, but at some point of time the region may run out of the resource because if you are not replacing the use of the resource if you are too much dependent and you are in using of the resource at some point of time you will exhaust the resource. Now, at the same time as we know that new resource field will always will be discovered elsewhere because we have studied the process in our module 6, how prove reserves and extractable resources can be established.

We know that nationwide mapping is done by the government or the government funded agencies and in the next step the private firms come up. So, you are using resource from particular region and also you are finding out resource in the new regions because we

have seen in our previous module in the module in which we discussed the inter-temporal allocation.

We have seen that most of the resource fields are extracted only around 20 percent because if we go deeper then cost of extraction and cost of refining may also increase. So, after 20 percent of the resources extracted generally the companies or the owners they switch to extract to the new fields if that is more cost effective. So, you are extracting the resource from a particular region and you are also finding out or discovering resource elsewhere.

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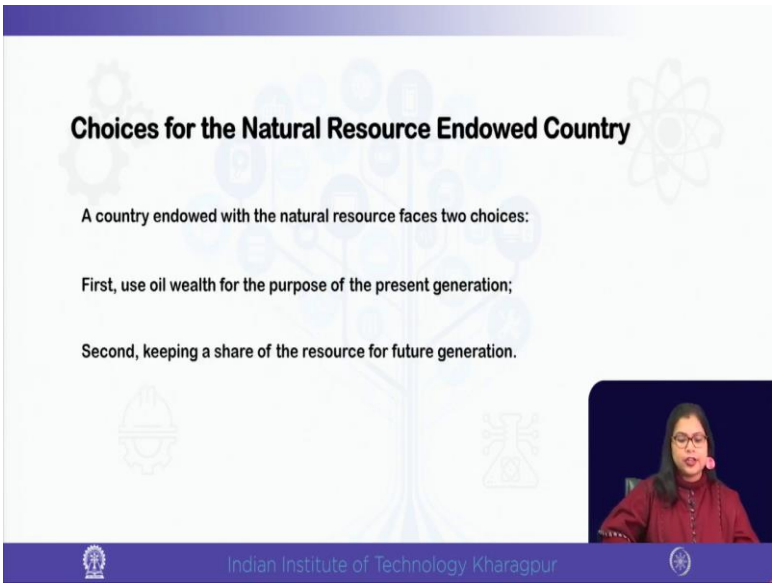

So, global reserves can be unchanged. So, in this context what is the choice for the natural resource endowed countries? So, we see that these countries which are endowed with natural resource they have mainly two choices. First, they have to use oil wealth either for the purpose of the present generation. So, this is one choice and second is keeping a share of the resource for future ok. So, either the country can use of the resource for the present.

Now, you see it is not that the owner is private firm even if the rent is supposed owned by the government means the oil fields or the natural resource sector is owned by the government then also the government may have temptation to use the oil wealth or the resource wealth because the government has to spend in lot of social welfare schemes.

So, the government also has to resist the temptation because if the government uses the resource wealth for the consumption of the present generation. So, it will not be left for the future generation's consumption. So, the choice for the policy maker is how much to use for the present generation and how much to keep for the future generation.

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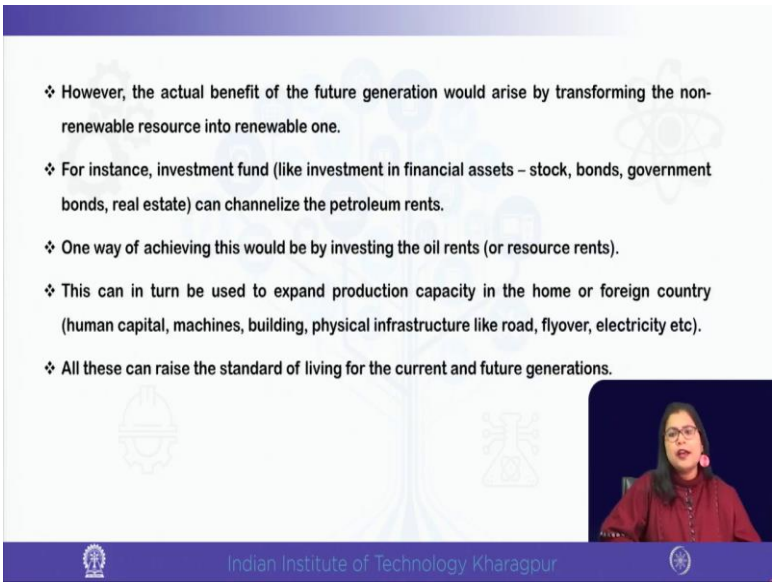

However, as we know that this type of resources, mineral resources overall they are exhaustible in nature. So, the benefit of the future generation would arise if the policy maker can transform the non-renewable resource into renewable one. Now, you may think that how is it possible because non-renewable means you are you have the resource in a fixed stock. So, how can we transform the non-renewable resource into renewable one?

So, one way of transforming the resource I am not mentioning about transforming the resource in physical form, but what we can do is that we can invest the resource wealth in investment fund. To channelize the petroleum rent or the rent earned from selling or exporting the natural resource.

So, that means, whatever is the owner of the resource whether it is the government or the private firm. If the owner is selling the resource abroad and earning the revenue, the owner should not be spending it entirely for the current consumption. The owner should keep a part of future consumption.

So, how can the owner do so? The owner can invest the return earned from the oil wealth or a petroleum rent or even resource wealth in investing in investment funds like investment in financial asset like stock, bond, government, bond and real estate.

So, that the you earn return from that investment. So, the future generation can also be benefited from the oil wealth. So, in a way you are as if transforming the resource in from a non-renewable one to renewable one because the future generation can be benefited from the resource wealth. So, the resource may have been extracted, but the future generation is benefited from the investment. The return coming out of the investment that the policy maker or the owner overall has made in the previous period.

Now, one way of achieving this would be by investing the oil, oil rents or resource rent and this can be used to expand the production capacity. So, when you are investing the oil wealth in one period in future you are earning return. So, what you can do the owner of the resource can invest that means can use the investment return for increasing the production capacity or it can also use the resource rent or the investment return from the resource rent for creating the physical infrastructure.

Like say for example, road, railway, flyover, over bridge, creation of human capital, physical capital and machinery, building, real estate creating facilities for electricity production and say irrigation facility. So, overall physical infrastructure can be created and even the owner of the resource can even invest in foreign country so, in the form of foreign investment right.

So, it is not that necessary that you will be investing in the domestic country, you can invest in foreign country if by doing so, you earn a higher return. You can also invest in formation of human capital like skill formation. So, you can set up school educational institute school college or see you can provide a training to means acquire skill for your unskilled workers.

And you will see all these will have a long-term impact and this can improve the standard of living because if you are investing on human capital creating the facilities for education and health. So, that will have overall improvement in standard of living not only for the present generation, but also for the future generation.

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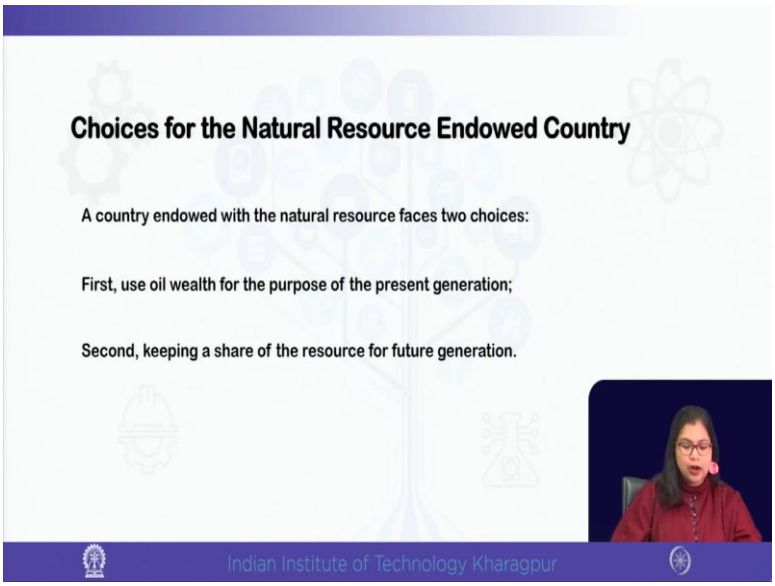

So, that is why you see the choice of this policy maker out of these two issues that we discussed whether to use all the oil rents for the present or to keep a part for the future. This is very important. So, we should not be using all the oil wealth for consumption of present generation.

We should be using a part for investing and that investment return will be can be used for the future generation and that will lead to improvement in the standard of living for the current and future generation and as if your resource becomes renewed right.

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So, in these circumstances you see now what is the important issue? Important issue is how much of the oil rent should be deposited in the investment fund. Are we going to deposit all the oil wealth and then how much will be consumed for means present consumption ok? Now, you see the answer to the question depends on the following three things.

What is the expected population growth? What is the economic growth of the country? And also, what is the level of affluence of the country? So, that if the country is already affluent then a large part means it can be used for say investment right because the standard of living is already high ok. So, we see as we proceed, we see we in the theoretical framework we will be trying to giving answer to these questions ok. That how much of the resource wealth should be consumed and how much to be deposited?

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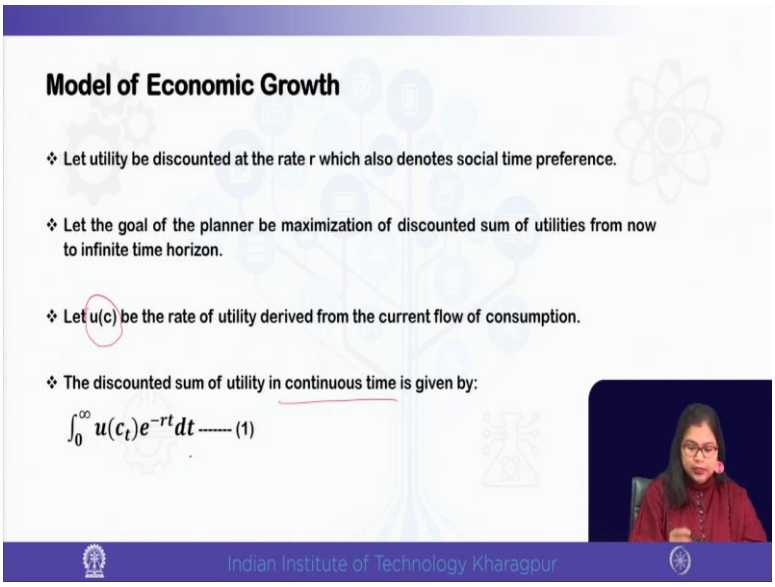

Now, in these circumstances we are starting our model of economic growth the theoretical framework. Now, you see these are some advanced topics and since we do not have any prerequisite and we target a wide audience should be benefited from our course. So, we will not be going into the very detail of the theoretical model because then I need more time. But we are already short of time we have only nine more lectures left and one complete module on exchange rate part is already left.

So, we will not be able to devote much time because this module the theoretical model that we are going to study in this module is bit advanced. So, how what I will be doing is

I will be introducing the model I will be giving you the brief overview, but we will be focusing more on the results part the implication of the results part and I will be giving you the appropriate references.

So, those who are interested for studying for going into more advance or even more detail analysis they can follow they can study the references that we will be mentioning ok. So, now in the module of economic growth suppose we consider now again as I mentioned that we will be using a micro foundation of macroeconomics. So, we are studying this for the entire economy means how much to consume of the oil wealth at present and how much to save.

So, that is a decision made by the policy maker that is for the entire economy, but we will be starting the model from the individual household or individual economic agents choice and that is the micro foundation. So, we start with the utility function. So, you see why our some of the lectures on the basic of economics was so important? Because we already discussed what is the utility function it is a numerical representation of the preference ordering.

So, utility is a function of or it depends on the amount of consumption of the goods and services, but here you are not talking about the current utility. We also considered the utility of the means lifetime we consider the lifetime utility function.

So, what we will do we already know from our previous module that we have to introduce the discount factor because you are calculating the present value the discounted sum of utility in a continuous time frame. So, we are bringing the discount factor which is denoted by the rate AR. So, suppose we discount utility at the rate R which also denotes the social rate of time preference.

And suppose the goal of the policy maker or the planner is maximization of discounted sum of utility from now to infinite time horizon. So, this is an infinite time horizon model which makes sense because in reality it is actually infinite time horizon, we do not know what will be the last stage ok. As I also mentioned in the modules on game theory so, this is we are talking about a planned economy. So, that means, the planner or the policy maker; that means, the government actually decides.

So, the objective here is to maximize the discounted sum of utility from the present period to infinite time horizon and say uC is the rate of utility derived from the current flow of consumption. So, this is our utility function uC ok. So, utility is a function of current consumption, current flow of consumption.

So, we have to maximize the discounted sum of utility. So, what is the discounted sum of utility in continuous time? So, it is not a discrete time it is a continuous time analysis. So, this is the first dynamic model we are studying in the previous lecture we studied inter temporal allocation into periods. Now, this is infinite time horizon model. So, this is the difference. So, you see this is the discounted sum of utility is given in equation 1 or condition 1.

You see not the equation the expression is mentioned in 1. So, it is uCt integration of uC te to the power minus rt dt where the integration runs from 0 to infinity ok. So, period 0 to infinite time and r is the social time preference. So, you are integrating over time and uC is the utility derived from the current flow of consumption.

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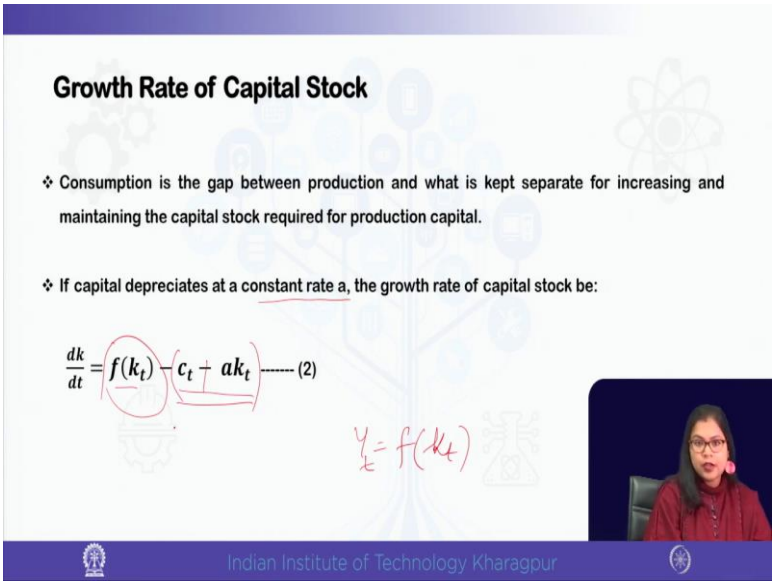

Now, in the dynamic framework you also have a stock variable. So, that is your capital stock. Now, what is actually consumption? Consumption is the difference between the production and what you are keeping separately for increasing and maintaining the capital stock required for production capital right. So, this is the gap the consumption is the gap between these two.

How much you are producing and how much is left for maintaining the capital stock increasing and maintaining the capital stock ok. So, consumption is the difference between this production and capital. So, the rest is rest amount is consumed. Now, suppose we consider that the capitals depreciate at a constant rate.

We know that there is wear and tear because if you are using a machinery. So, over time it will be depreciated. Suppose the capital depreciates at a constant rate. So, a is constant. So, what will be the growth rate of capital stock? So, capital stock will change by the amount of this is what fkt; fkt is basically y is equal to fkt if you remember this is nothing but the production function right.

We have already discussed in one of the modules in the concept of production possibilities a production function isoquant. So, what is the production function? It is a mapping from input space to output space. If you remember, so, if we use some inputs by using some technique of production, we combine the inputs and we get the final output right. So, this is your production function; that means, your value of the output ok.

So, that is the capital stock is changing by the amount of the output less the amount of consumption and less the amount of depreciation right because at each period the capital is depreciating at the rate a. So, the rate of growth of capital stock will be the gap between the production, consumption and the depreciation right.

So, this gap actually you can write it in this way, this gap by this rate the gap between this the first term and the sum of the second and third term. This is the rate by which the capital stock will change over time.

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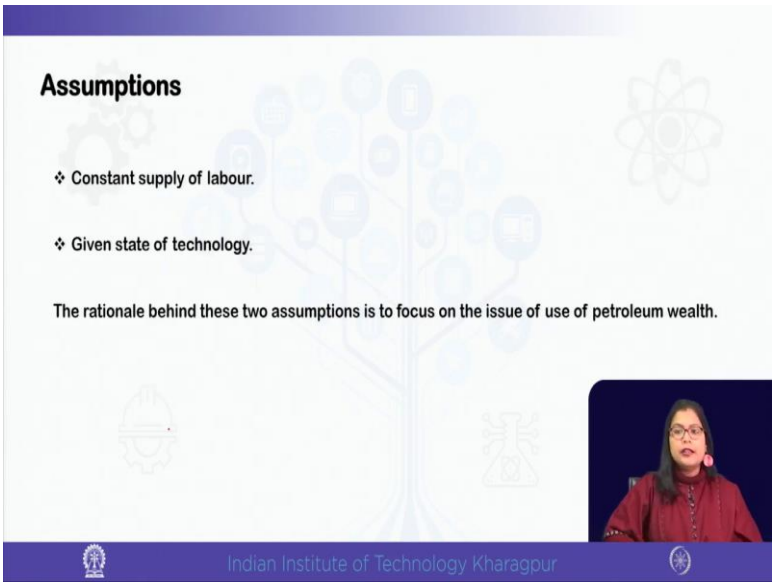

Now, in this framework we make some simplistic assumptions because we want to focus on the use of petroleum oil. So, to focus on the use of petroleum wealth we assume that the supply of labor is constant because if labor supply increases, then economic growth will also be changed. So, we do not want to do that because our objective is only a very specific to see how petroleum discovery or discovery of a natural resource will lead to a change in the economic growth.

So, we assume constant supply of labor and we also assume that there is no technological progress. So, that means, we work out the model with a given level of technology because we have already discussed that if there is a technological improvement the same level of input can give us higher level of output. So, we are ruling out that. So, we are assuming given state of technology.

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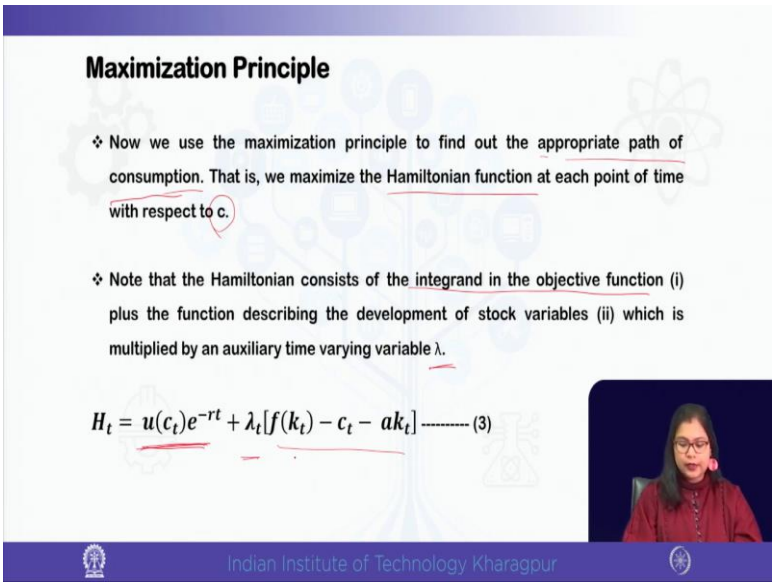

Now, in this context now we are writing the maximization problem of the policy maker or the planner. So, we use the maximization principle to find out the appropriate path of consumption. Path of consumption means how consumption changes over time ok. Because here we are focusing on the means what is happening over time.

So, how much to be consumed now and how much to be consumed later. So, we are studying the we are actually trying to identify the path of consumption, path means over time change ok.

So, to do that we maximize the Hamiltonian function at each point of time with respect to our consumption c now, what is the Hamiltonian? So, if you remember in the context of utility maximization, we use the Lagrange. So, that was in a static framework in a dynamic framework we use the Hamiltonian function to maximize this discounted sum of utility ok.

So, for this in the dynamic framework we use the Hamiltonian function this is used in optimal control theory and dynamic optimization so, those who are interested for more in-depth analysis please refer to the book of Alpha Chiang on Dynamic Optimization. Now, you see how we define the or how we construct the Hamiltonian. So, the Hamiltonian consists of the integrant in the objective function. So, what was the integrant in the objective function? This one, right?

So, ucte to the power minus rt ok plus the function describing the development of the stock variable. So, this was our stock variable right. So, this function dkdt this we are using and this is multiplied by the auxiliary time variable lambda. You remember in case of Lagrange also use the Lagrange multiplier the auxiliary variable here also you are using the auxiliary variable, but now it is varying over time. So, we have a subscript t everywhere right.

So, you see this is a dynamic model this Hamiltonian Ht consist of the utility function the discounted utility function plus the auxiliary variable lambda t. Now, this is time varying unlike the previous case of Lagrange multiplier which was not time varying, but this is time varying and this is the rate of change of capital stock dkdt. So, this we are writing as fkt minus ct minus akt. So, this is our Hamiltonian.

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So, in the next class we will be solving the model without the discovery of resource and then in the third lecture of this model we will bring the resource discovery. So, if we summarize this particular lecture, we discuss the importance of managing petroleum wealth.

So, it is not only important to be endowed with the resource or petroleum we have to use the resource prudently. So, the choice of the owner of the resource or the policy maker is how much to use for present consumption and how much to invest for future consumption.

So, we are discussing we are studying a theoretical model in a continuous time frame in an infinite horizon. So, in this lecture I gave you some evidences from the literature and we discussed about the importance of investment fund and then we started discussing the economic growth model. However, it could not be completed in one lecture. So, the rest of the model before resource discovery is to be discussed in the next class.

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So, as I mentioned that those who are interested you can obviously, you should look at the book of Dynamic Optimization by Alpha Chiang the fourth one and also you can look at other relevant books on Macroeconomics and Economic Growth like the book of Barro and Sala-i-Martin or Abel Bernanke. So, these are the relevant books for the economic growth models.

And of course, we are actually our model. So, these three books I mentioned 1, 2 and 4 these are the these are required for the backgrounds and the model that we are studying is largely from the book of Hannesson the Petroleum Economics book by Hannesson that we are following throughout our course mostly.

So, thank you very much. See you in the next lecture where we will be discussing the rest part of the model of economic growth.