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 - 53
Discovery of Natural Resources

Hello, I am Dr. Anwesha Aditya, your instructor for the course Petroleum Economics and Management that I am offering in the NPTEL. We are in module 11 of our course where we are discussing about the Management of Petroleum Wealth and this is lecture number 53 and third lecture in this module. So, in this lecture we are going to discuss our module of economic growth once resource is discovered. So, Discovery of Natural Resources.

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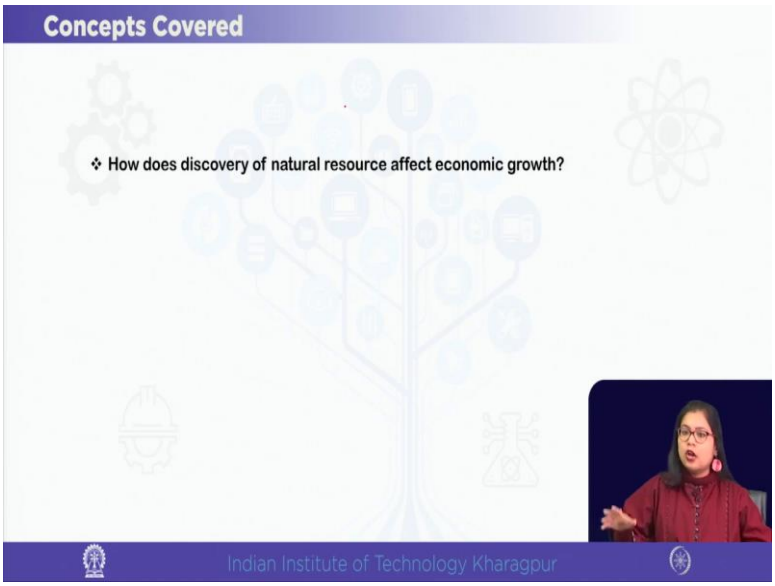

So, if you remember in module 11, we are discussing how to manage petroleum wealth or wealth from the natural resource in a model of economic growth. Because we have already discussed that it is not only important to be endowed with natural resource that may actually adversely affect an economy also if the economy runs into a crisis of Dutch disease and resource curse hypothesis if you remember.

So, we have already seen enough empirical evidences of resource curse and Dutch disease. So, it is not only important that we discover a resource, but it is more important of how to manage the resource. So, if we discover the resource and the resource wealth is only acquired by very few then the gain is not distributed. So, there will be huge inequality as we often see in the Middle East countries.

So, the policy maker has to also interfere and distribute the resource the wealth or the gains coming out from the resource to a large section of the society. So, we have seen that with empirical evidences that when resources discovered in developed countries like Norway or Netherlands. So, they may have run into a crisis or recession, but those were temporary and finally, they perform much better. So, it is really possible to cure a Dutch disease or resource curse, ok.

But, how to do that? So that is what we are discussing with a model of economic growth. Now, this is a bit advanced model. So, we are not spending we are not going into very detail of the solution of the model because you see for benefit of larger audiences, we have not kept any prerequisite, but those who are interested we have already provided the reference and you can also go for some advanced courses on say let say resource economics or to study more in depth about the theoretical models.

Because we are actually running out of time to discuss going to the very detail of the solution of the dynamic optimization problem. So, but what we are focusing on we are focusing on this particular lecture. The question that we are going to address in this lecture that how does resource discovery affect the economic growth?

So, if you remember in the previous two lectures of this module, we have structured our model of economic growth in a continuous time horizon infinite time horizon framework with a micro foundation of macro economies and we considered a planned economy.

We already wrote down the Hamiltonian and the necessary conditions to solve the maximization problem and if you remember we have compared the optimal capital stock under golden rule and modified golden rule. Now, more important more interesting for our purpose is the question regarding how discovery of natural resource affects economic growth. So, this is the subject matter in this particular lecture.

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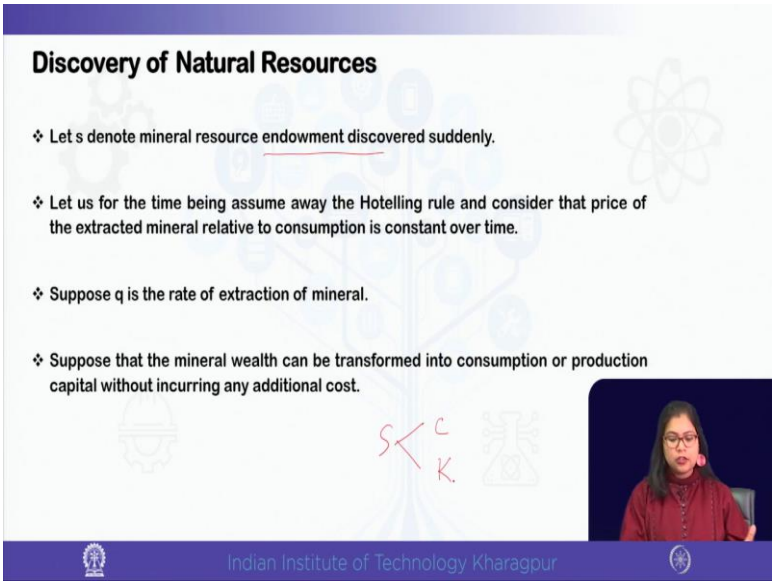

So, the other things mean we already have discussed pre-resource discovery. So, you can consider these lectures in this module these three lectures are interconnected. So, I am not elaborating again on the model pre-resource discovery. So, pre-resource discovery if you remember we worked with the utility function utility is a function of consumption and then we maximize the discounted sum of utility by using the rate of time preference r.

And we had a stock variable that is capital stock and we assume that capital stock is growing over time and that is given by the difference between the production, consumption and the depreciation of capital and capital depreciated at a constant rate a. So, if you remember graphically also, we have plotted the ak function and the production function fk and we compared the optimal capital stock under golden rule and modified golden rule.

So, golden rule corresponds to the maximum level of per capita consumption, but we saw that once we introduce the modified golden rule, we incorporate the social rate of time preference. So, the capital stock under modified golden rule was less. So, this far we have discussed.

Now, in this framework I am introducing natural resource. Suppose S denote the mineral resource endowment which is discovered suddenly ok suddenly. So, the structure of the rest of the economy that we discussed already it holds in addition. Now, we consider S

which is discovered suddenly. So, it can be petroleum or it can be other type of non-renewable mineral resource which is in fixed supply.

Now, let us for the time being assume that the price of this resource is constant over time ok So, if you remember in module 10, we discussed that the price of a natural resource which is in limited supply it increases over time. So, even if the cost of production was 0 price is positive and it increases over time and the rate of increase is given by the rate of time preference or the market interest rate and that is what that is known as the R-percent rule or Hotelling's rule.

But for the time being in this module for our purpose of solving the theoretical model, suppose that we are ruling out the Hotelling rule and we are considering that the price of the extracted mineral resource relative to consumption is constant over time. Now, in the next class of this module or the last class of this module I will be introducing uncertainty. How uncertainty about the future price of oil how that will affect the economic growth?

Now, suppose this we know what we will do with this mineral resource when it is discovered. Obviously, we will be extracting that because in module 10 also we discussed that means we have to think about the optimal use of the resource. We should not exhaust all the resource at the same time we should not keep the resource entirely for future use.

Then what will happen if you keep the resource entirely for future use as we pointed out due to some technological breakthrough the resource may become useless. There can be some alternative or cheap substitutes available in the market and the resource will become useless. So, if the country discovers the resource obviously, the country will extract the resource. So, suppose q is the rate of extraction.

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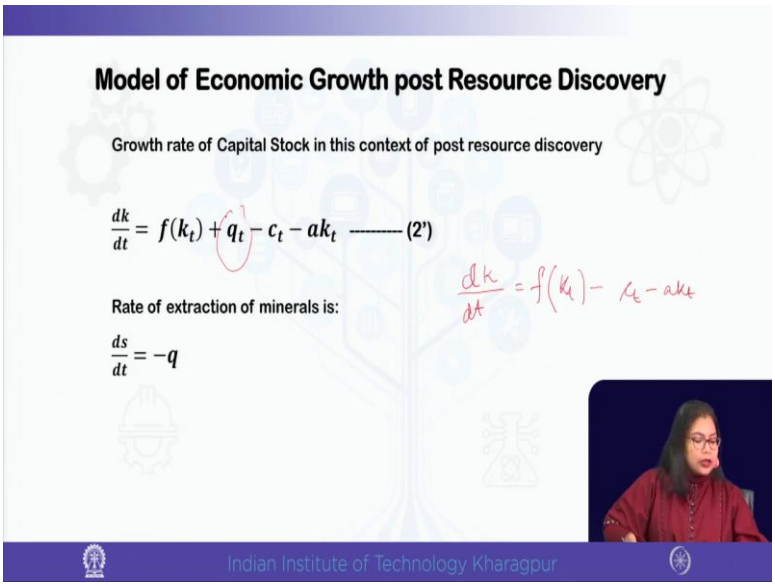

So, we write down the rate of extraction is dsdt. So, how the resource s is extracted over time? So, ds dt is equal to minus q, why minus? Because it is not adding up to the stock; so, dsdt is not increasing right because if you are extracting the resource s. So, the resource endowment is falling. So, S is your endowment of the resource and you are extracting the resource. So, it is falling at the rate q. So, the rate of extraction is q.

So, your endowment is falling right. So, hence we have this a negative sign. You remember in capital stock what happens capital is added, but here you are exhausting this is in fixed amount. So, you are exhausting ok. Now, we are making another assumption that suppose the mineral wealth this S can either be used for consumption or it can also be used for production capital without incurring any additional cost ok.

So, this S can be used either for consumption purpose or for formation of capital without incurring any additional cost. So, that means, in a cost less way. So, you have to decide how much of this S to be consumed and how much of this S to be invested in capital stock.

And growth rate of capital stock if you remember we already discussed in the previous lectures, but now it has changed a bit ok. So, we are using this with two dash because earlier we have written the growth rate of capital stock if you remember in the previous lecture the growth rate of capital stock was like this dkdt was fkt minus ct minus or if you are writing it in first bracket it will be like this ok.

So, you can remove the bracket also. So, this was the growth rate of capital stock without the resource discovery, but now we are rewriting the growth rate of capital stock because as we mentioned that with the resource discovery a part of the resource can also be used for capital for stock formation.

So, now you have this additional term qt. So, how your capital stock will change now it will be now the difference between the production and how much of the resource is now used for capital stock formation. And then you are taking the gap you are subtracting the value of the amount of production and the depreciation of capital ok.

So, earlier it was just the gap between the production and consumption and depreciation. Now, it is the gap between production and the rate of extraction of the mineral resource and consumption and depreciation. So, this qt term is the addition is the change in the capital stock formation. So, you see our earlier model is now gradually being changed.

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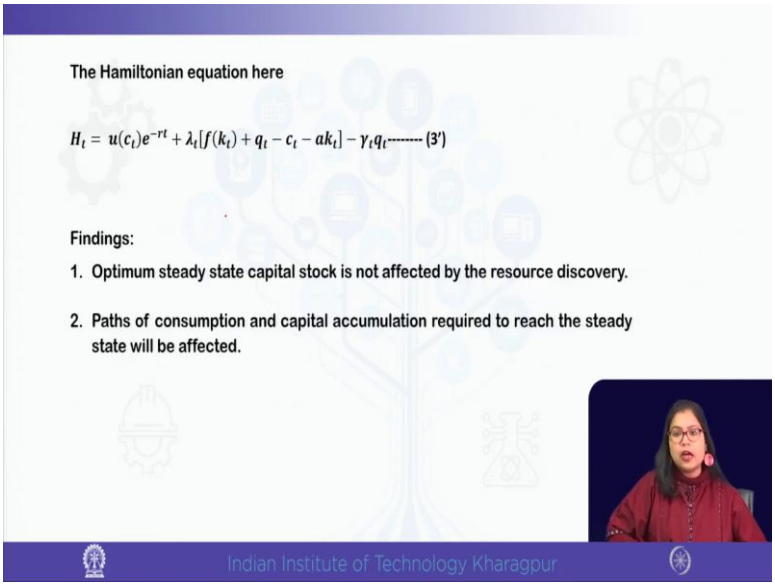

So, you have to also rewrite our Hamiltonian. So, in the Hamiltonian now you have as usual the objective function this is the objective function in the Hamiltonian this is the ucte to the power minus rt. So, there is no change in this one because our discounted sum of utility that is same. So, this one is same the second one was the auxiliary variable lambda t multiplied by the growth rate of capital stock.

Now, there as we just now mentioned that it has changed like this. So, you have the new addition qt term and then we have to now we have now another stock variable right. So, we have to use incorporate this stock variable. So, we incorporate another auxiliary time varying function gamma t. So, this is now gamma tqt because now you have a negative sign because as we just mentioned that this is the resource is when you extract the resource the resource endowment deflates. So, we have a negative sign over here.

So, the third term in the Hamiltonian is minus gamma tqt. So, now you have another stock variable apart from capital stock in the pre resource discovery capital stock was the only stock variable, but now you have the mineral resource also as the stock variable ok.

Now, what we can find out is that if you now again solve for if you proceed in the similar fashion which I am not able to do again because we do not have that much of time. We are just focusing on how resource discovery may change our solutions our model so, our capital stock formation.

So, if we now solve the model like in the initial classes. So, you can find out these two very important conclusions. 1st is that the optimal steady state capital stock. So, that means, if you remember that was k1 and k2 ok the modified golden rule and golden rule those two are not affected by the resource discovery.

So, the optimal steady state capital stock is not affected by the resource discovery. 2nd conclusion is that the path of consumption dcdt and path of capital accumulation required to reach the steady state those will be affected. So, we are focusing on these parts.

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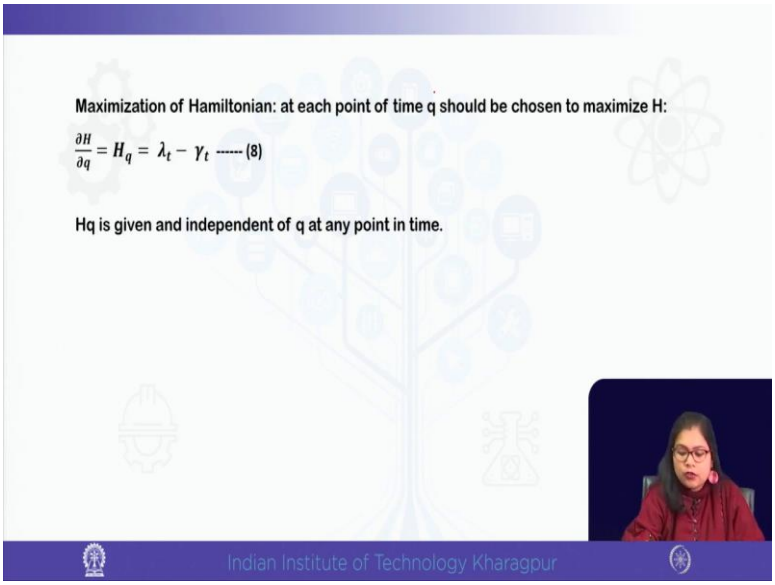

So, now, if you write down the maximization of Hamiltonian the necessary condition so, now earlier we have written the conditions with respect to consumption and capital stock, but now we have to also bring we have to use the stock variable also means the mineral resource. So, what is the problem of the policy maker? We have to choose at each point of time the q or that means, the rate of extraction should be chosen so, as to maximize the Hamiltonian.

So, the condition becomes del H del q that means, you can write it as Hq is equal to you can go back and see that del H del q will be what? Lambda T minus gamma T so, that is what you are writing in this equation. So, Hq is given and it is independent of q at any point in time. So, you have to find out. So, see here the question is what should be the optimal q? So, that H is maximum.

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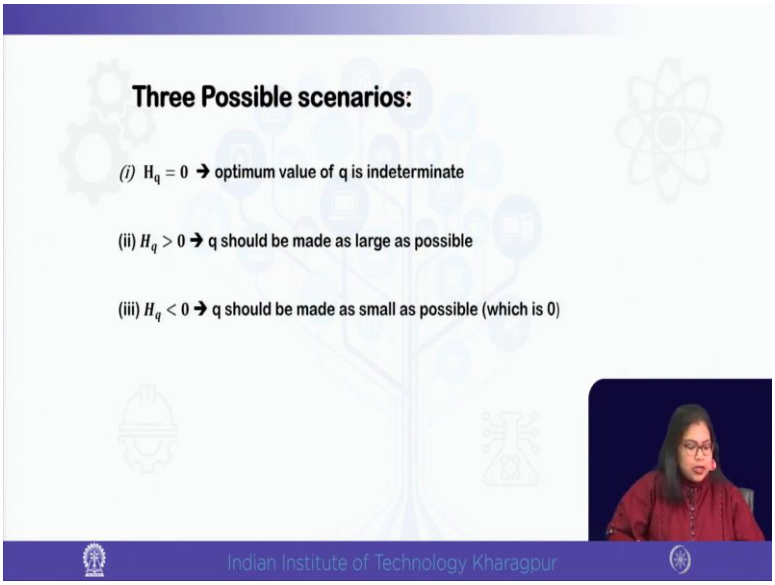

So, you we can have three possible scenarios either this Hq can be. So, Hq first you see it does not include any q term it is given. So, it is the difference between these two auxiliary variables lambda t and gamma t. So, it does not depend it is not a function of q. So, three possible scenarios Hq either equals to 0 or positive or negative.

Now, what are the implications? If Hq is equal to 0 then we cannot determine the optimal value of q. So, we are not considering this case because we want to find out that optimal level of q which will maximize H. The second possibility is that Hq is positive. So, that means, in that case q or the rate of extraction should be made very large.

Third scenario is Hq is negative. In that case you see q should be made very small. So, the smallest possible q; that means, q is what q is the rate of extraction right. So, what is the smallest possible q? Of course, it can be 0, right; that means, in case q is 0; so, even not extracting any mineral resource.

Now, does it make any sense? No, because if you are not extracting any mineral resource, you are leaving everything for future it may become useless and you are not using the well for current consumption also. So, that is basically entirely meaningless right. So, this cannot be the possibility that q is made very small the smallest possible q being equal to 0 so, that the planner will not do right.

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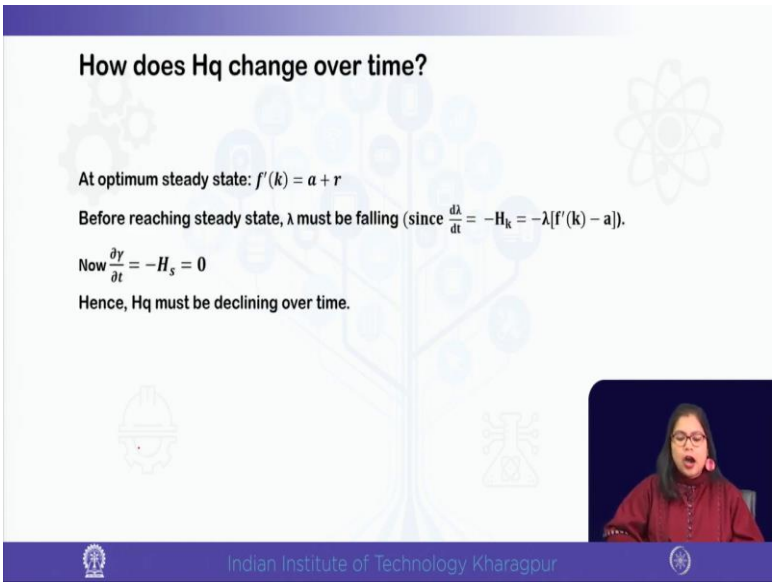

Now, let us see how the Hq will change over time. Now, you see already we have mentioned that the at the optimum the steady state condition remains the same even the resource discovery will not change. So, if you proceed in the similar fashion, we combined in the previous lecture I am referring to we combined equation 5 and 6 to derive this one.

So, if you proceed in the same way I request you to do that because of time constraint we are not able to solve the model. So, you do and you get the same condition. So, as I already mentioned that this is one solution this is one very important conclusion that the optimum steady state capital stock is unaffected by resource discovery.

So, you see f prime k the marginal productivity is capital is equal to the rate of depreciation plus the rate of time preference. So, this is the same modified golden rule capital stock that you are finding out in the pre resource discovery situation.

Now, before you reach the steady state what will happen to lambda? So, lambda must be falling ok. Now, since d lambda dt is equal to minus Hq is equal to minus lambda f prime k minus a. So, this is from our last class. So, please refer to the last lecture. So, you can see that d lambda sorry d gamma dt from here you see, d gamma dt is what? Is equal to minus H s is equal to 0. So, that means, Hq must be declining over time. So, over time H q should fall.

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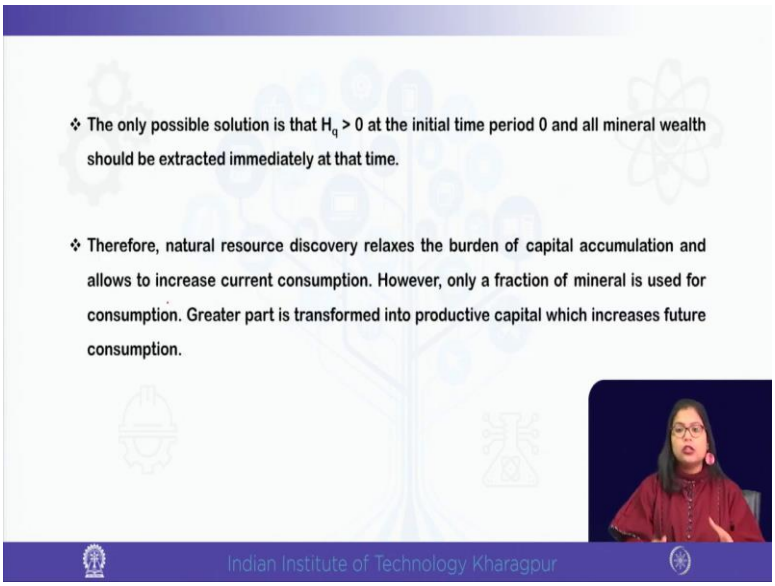

So, the only possible solution because we pointed out three possible scenarios, we can now find out that the only possible solution is the second solution means the second possible scenario that Hq is positive; that means, q should be made as large as possible ok. Hq must be declining over time. So, the implication is that only possible solution is that Hq is positive at the initial time point 0.

So, at present the initial time point 0 means at present you are calculating your maximizing your utility from present for the future ok infinite time horizon. So, at present Hq should be positive. So, that means, what is the implication if Hq should be positive q should be made as large as possible.

So, that means, all largest possible q means you extract all the mineral wealth now. So, all the mineral wealth should be extracted immediately at that time. So, that means, what now if you compare the paths of consumption and capital accumulation in the post resource discovery situation to reach the steady state what we can conclude.

We can conclude is that the discovery of the natural resource S term it relaxes the burden of capital accumulation and it allows to increase current consumption. However, only a part or a fraction of the resource can be used for consumption a greater part can be used for transforming into production capital, which will increase future consumption ok.

So, we should not use all the natural resource for increasing the current consumption rather we should invest it so, that we can increase our future consumption as well. So, natural resource discovery it actually relaxes the burden of capital accumulation and allows us to increase our current consumption.

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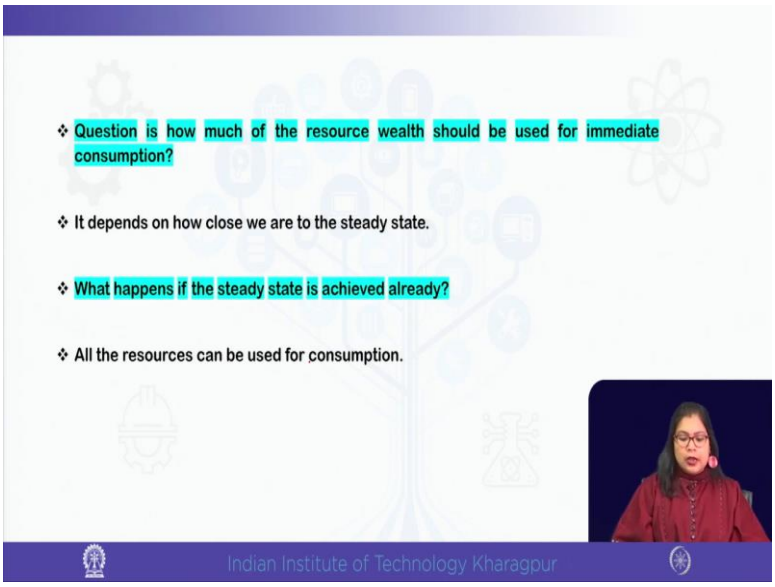

Now, question is how much of the resource wealth should be used for immediate consumption? Now, the answer depends on how close we are to the steady state have we reached the steady state or not?

So, if we suppose we have reached the steady state if we have already reached the steady state and if you remember how we define the steady state steady state is a situation where your per capita consumption is already its maximum. So, the level variables are growing at a constant rate and per capita variables they do not grow.

So, at the steady state so, the economy tries to converge in the long run that is the importance of the steady state. If you have already reached the steady state so, what happens then then all the resources can be used for consumption because you have already achieved that optimal capital stock.

Then you can use the entire mineral resource for consumption, but that is hardly the case because this is the situation where any economy would try to reach in the long run. So, that means, in that case you cannot use for you cannot use all the resources for

consumption, but if you reach the steady state you can use entire resource for consumption.

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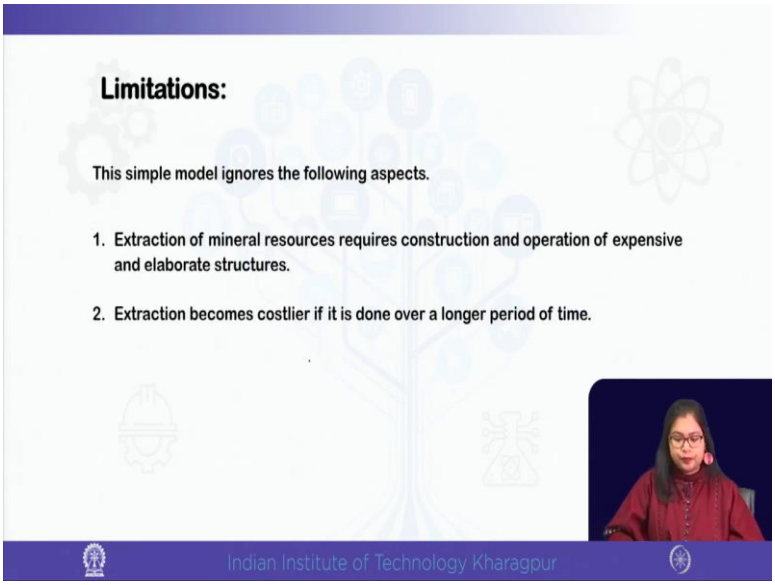

Now, there are some limitations of the model also. First of all, this simple model ignores the fact that the extraction of mineral resources may require construction and operation of expensive and elaborate structure. So, we have not included any cost of extraction and 2nd is extraction can even become costlier if it is done over a longer period of time.

So, when we are saying that we are not extracting all the resource we can keep some of the resource for future extraction. So, we should also take into account the increasing cost of extraction for in the future ok, but anyway. So, in spite of the limitation the model is very model has very important implication regarding the resource discovery.

And you see what happens many believe that the governments those who actually are in favour of that they are sceptical about what the government will do even the government can also feel a temptation of using of the resource right. So, according to them it will be better that the government should only extract the resource which is required for present.

What is not required for present should be kept underground? Because what happens often. Suppose so, by the theoretical model we see that the rate of extraction should be very high and it should be extracted immediately. And then you extract the resource

immediately and then you invest the return for future consumption, but you see once you extract the resource means you feel tempted even the government.

I am talking about from the policy from the policy makers point of view the social planner or the government can also be tempted to spend on social welfare projects or creating physical infrastructure human capital formation, but then you are not leaving for the future generation. So, we have already seen the experience of Venezuela.

So, according to those who feel that the policy maker may not resist the temptation to invest a larger part of the resource for future consumption; according to them, only a part of the resource should be extracted. And what is not required for increasing the present consumption should be better kept underground. Because once you extract the resource then it maybe it may become difficult to invest a larger part.

So, you should extract only the part which is required for the present consumption and for future consumption purpose you should keep a large part of the resource underground. So, this is the view of those who feel that the policy makers also may be tempted.

So, what we can see over here is that the natural resource discovery it relaxes the burden of capital accumulation and it allows to increase the current consumption, but however, we see that the optimum steady state capital stock remains unchanged. So, these are very important results ok.

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So, as I already mentioned that we have followed the book of Petroleum Economics by Hansen, but those who want to go into the detail and you should; obviously, study the Macroeconomics and Economics Growth related book by like the book of Barro and Sala-i-Martin and the book of Abel and Bernanke.

So, these are very important books and for the solution of the Hamiltonian we must study the book of Dynamic Optimization by Chiang. So, these are the references that we have followed in today's lecture for completing the discussion on the impact of resource discovery on the economic growth in an economy, in a resource dependent economy.

So, thank you. And see you in the last next lecture of which will be the last lecture in this module.