Environmental and Resource Economics
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Natural Resources Economics and Dynamic Optimization Part - 2

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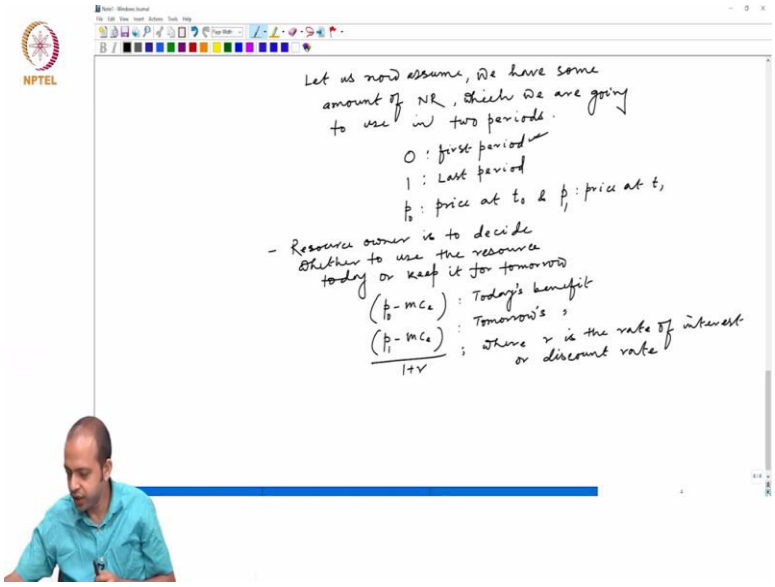

Now suppose, let us now assume, we have some amount of non-renewable resource which we are going to use in two periods, that is let us say the first period is called as 0, 0 is the first period and 1 is the last period. So, p0 is the price of the resource at t0 and p1 is price at t1, that is what. Now, if we the resource owner problem the resource, the resource owner is to decide whether to use the resource today or keep it for tomorrow. This is a resource owner problem resource.

Resource owner is to decide whether to use the resource today or keep it for tomorrow. Now, if the resource owner uses the resource today that means at first period then the benefit is p0 minus mc where mc is basically marginal cost of extraction, this is today's benefit. If the resource owner keeps the resource for tomorrow and extract the resource at t1 then the benefit would be p1 minus mce we assume that cost of extraction is same tomorrow's benefit.

Now, when the resource owner is thinking at t0 then tomorrow's benefit has to be converted into today's benefit. How do you do that? That would be 1 minus r where r is basically, r is the rate of interest or discount rate, you know it very well that if we have to compare tomorrow's benefit at present time period then we need to convert tomorrow's benefit into present time by discounting. And what is the discount rate? That is r, that is r.

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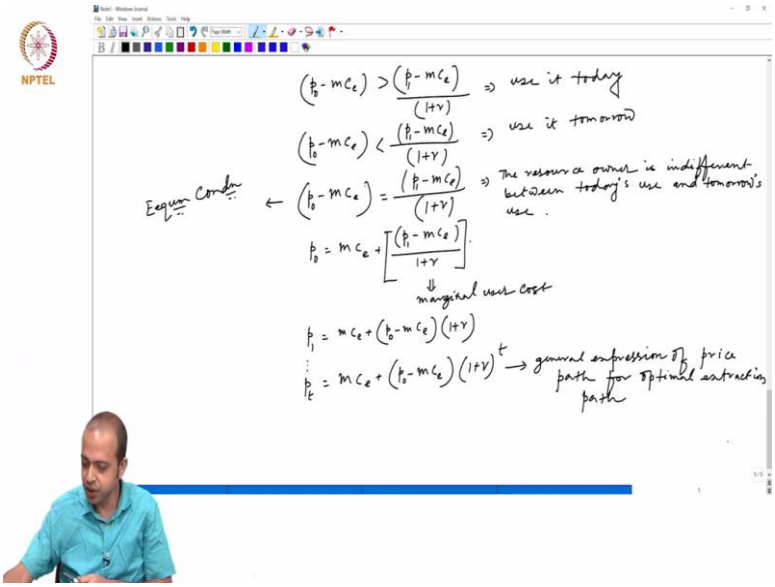

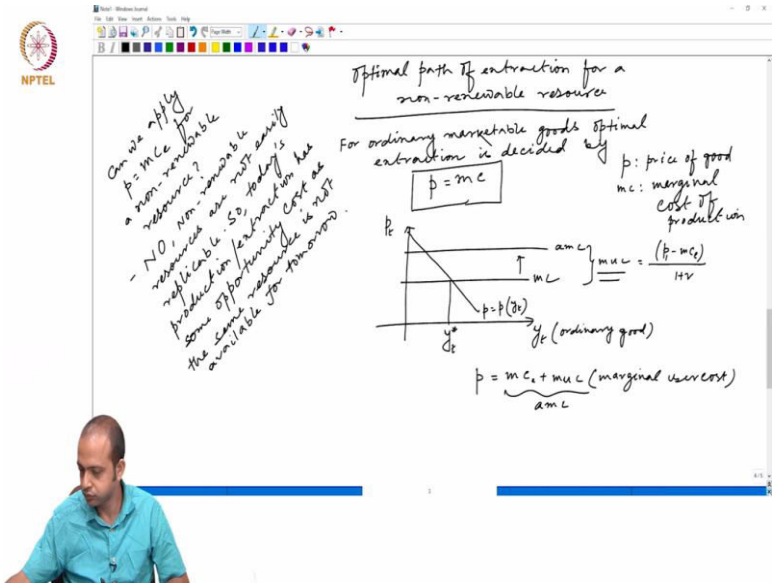

Now we can actually get three type of condition let us say that p0 minus mce, p0 minus mce is actually greater than p0, sorry, p1 minus mce divided by 1 plus r. So, that means today's benefit is greater than tomorrow's discounted benefit. So, obviously, it is better that resource owner should use the resource today. Similarly, if p0 minus mce is less than p1 minus mce divided by 1 plus r then use it tomorrow and when p0 minus mce is actually equals to p1 minus mce divided by 1 plus r then the resource owner is indifferent between today's use and tomorrow use.

And as you know the moment the resource owner said he is indifferent. So, I have no preference or today use, today's use over tomorrow's use then that is basically the equilibrium condition, this is also known as equilibrium condition. Now, we can derive different type of

intuition propositions from this optimality condition. So, from here what we can write is that if that means what I can say that from here what I can write p0 equals to mce plus p1 minus mce divided by 1 plus r.

Now, look at this condition previously we said that if the resource is nonrenewable then marginal cost pricing is not applicable something needs to be added over and above marginal cost of extraction and what is that something the something is basically this p1 minus mc1 divided by 1 plus r that means, the discounted tomorrow's benefit or marginal user cost. Now, this is actually called marginal user cost, this is known as Marginal User Cost or MUC user cost.

And mce plus this taken together is called Augmented marginal cost because I have augmented marginal cost of extraction by this marginal user cost, this is basically p1 minus mce divided by 1 plus r. So, that means in terms of the diagram, if you look at in terms of the diagram, this is what we say the difference between this mc and AMC is a marginal user cost and we have now quantified this marginal user cost as p1 minus mce divided by 1 plus r, we have now quantified this.

Now from this we can also get the condition that p1 would be then equals to mce plus p0 minus mce into 1 plus r, this is called the Price Path. Now, from this we can also get pt equals to mce plus p0 minus mce into 1 plus r to the power t. So, this is called general expression of price path for optimal extraction path. So, that means, the moment we say that we need to decide about an optimal extraction path.

So, that means, we need to decide about optimum extraction at each and every period and if you want to decide optimum extraction at each and every period, we need to get a price, optimum price for each and every period and the look if you connect all these that means basically instead of saying price for a particular point of time, we are saying it is a price path.

The path along which the price optimum price is decided at each and every point of time that is why it is pt it is not simply p, that is the difference between static optimization and the dynamic optimization slowly we are moving to.

So, you can easily understand this pt is basically a price path it is not the price which is relevant for a particular point of time rather this is the price path which decides optimum price at each and every point of time. So, this is the price path for optimum extraction. Now, from this p1 this equation what do we say that p1 is basically equals to p 1 equals to mc

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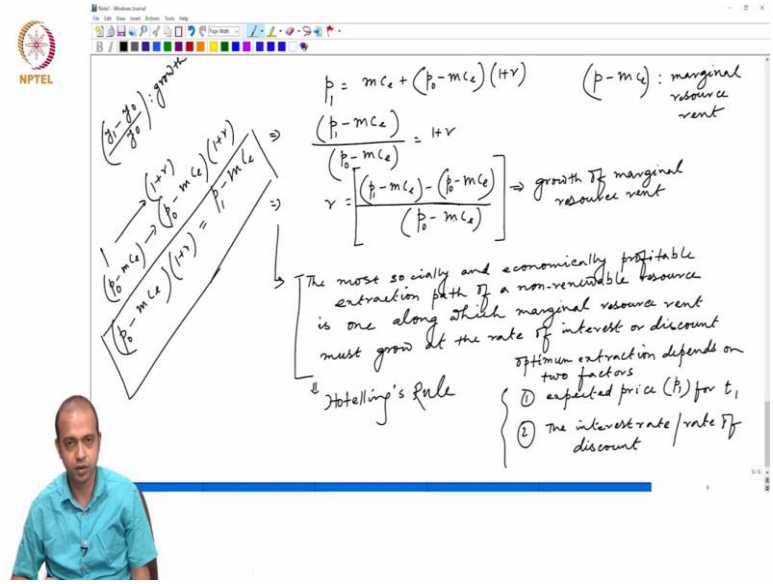

p1 equals to mce plus p0 minus mce into 1 plus r. Now, from here what we can get is that p1 minus mc1 mce divided by p0 minus mce equals to 1 plus r and from there we can write that r equals to then p1 minus mce minus p0 minus mce divided by p0 minus mce. Now, what is this if you look at this expression, this expression gives you an interesting economic meaning let us try to understand what is p minus mc?

When we are extracting one unit of resource the cost of extraction is let us say this is e cost of extraction is mc and the price is p that is why the difference between price and marginal cost of extraction is called as Marginal Resource Rent. A concept used by the economists in the context of non-renewable resource. This is called Marginal Resource Rent the difference between price and marginal cost of extraction.

If this is marginal resource rent obviously, p1 minus mce minus p0 minus mce divided by p0 minus mce, what does it mean? This entire expression basically indicates one thing which is called growth of marginal resource rent which is very easy to understand you can convert this let us say this is if you say that y1 minus y0 divided by y0 is nothing but growth, that is nothing but growth y1 minus y0 divided by y0 same thing we are doing p1 minus mc minus p0 minus mc divided by p0 minus mc equals to growth of marginal resource rent.

So, from this, what we can say that this particular rule is he saying that along the optimum path of extraction marginal resource rent should grow, along the optimum path of extraction marginal resource rent must grow at the rate of discount. So, that means we can say that the most socially and economically profitable extraction path of a non-renewable resource is 1 along which marginal resource rent must grow at the rate of interest or discount.

So, this is basically a rule which is given by, this is called the Hotelling's rule famous economist Hotelling. He first came up with this type of rule in the context of US economic. So, look at this I have derived this condition from this, which is basically optimum path of extraction. So, that is why the rule say the most socially and economically profitable extraction path of a non-renewable resource is 1 along which marginal resource rent must grow at the rate of discount. Now, what is the economic meaning of this?

See, a resource owner has two alternatives. Either I use the resource today, I extract the resource today and my rent is p1 minus mc, if I use the resource today and get p1 minus mc then tomorrow what I will do with the rent? I will keep that money, rent is nothing but the money, I will keep the money in a bank and bank will give me a rate of interest which is given by r or I can extract the resource tomorrow and tomorrow's benefit would be p1 minus mc.

So, at optimality my principle plus rate of interest should be equals to tomorrow's marginal resource rent that means p1 minus mc which is very simple to understand that is why this Hotelling's rule says that optimum extraction path means a path along which marginal resource rent, marginal means rent out of 1 unit, marginal resource rent must grow at the rate of discount or interest rate. These are the two alternatives either I extract today get the money keep it in bank and bank will give me interest for r. So, 1 rupee if I keep tomorrow it will be 1 plus r.

So, 1 rupee becomes 1 plus r tomorrow and if I get p0 minus mce. So, tomorrow it will become p0 minus mce into 1 plus r. So, that should be p0 minus mce into 1 plus r that should be equals to p1 minus mce. This is very simple to understand. Principal are added with the rate of interest would be equals to tomorrow's benefit p1 minus mc that is actually the meaning of this. So, that means if you look at, what are the deciding factor of then this optimum extraction.

So, optimum extraction depends on two things, two factors. What are those? First of all, tomorrow's price is unknown to the resource owner tomorrow, what would be the price of the resource tomorrow that I do not know today. So, that means the resource owner while deciding about whether to use the resource today or tomorrow, what the resource owner will do? Resource owner will use expected price. So, this p1 is basically the expected price.

So, expected price which is p1, price for t1 p1 please keep in mind p1 is tomorrow's price that is not known today. That is why what is my expectation about tomorrow's price that is going

to be one of the deciding factor and secondly the interest rate or rate of discount. This rate discount rate, what should be the appropriate discount rate that actually varies from person to person. If a person is heavily present biased, that means the person is going to use heavy discount rate for future benefit.

I want to enjoy it today that is why I will always use a heavy discount for any future benefit. And if I do not have such present bias, they are not I will do it we will try to keep the resource for tomorrow, that is why present bias individual will always use a higher discount rate than the other individual who has future bias.

For example, those who are smoking they also know that smoking leads to cancer, but then why are they smoking because the present satisfaction or benefit out of the smoking appears to be quite larger than any future pain what he or she is going to suffer after 10, 20 or 30 years. So, I am using a heavy discount rate for the future pain.

So, in at present that pain appears to be very low, same logic is applicable here. If I use a higher discount rate, then obviously future benefit of keeping the resource will appear to be very low to me. And as a result of which I will try to extract the resource as much as possible today.

On the other hand, if my discount rate is low, then future benefit would appear to be higher, I will keep the resource for tomorrow's use. So these are the two important factors. Expected price and interest or interest rate or rate of discount that basically determine whether to use the resource today or tomorrow or basically the optimum extraction path. Thank You.