Petroleum Economics and Management
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Module - 07
Petroleum Discoveries and Structural Changes
Lecture - 30
Theory of Production: A brief overview

Hi, everyone. Welcome to our NPTEL course Petroleum Economics and Management. I am your instructor Dr. Anwesha Aditya. So, if you remember we are in Module 7 of our course where we are discussing Petroleum Discoveries and Structural Changes. Now, I have already elaborated about what is Dutch disease, what is the hypothesis of resource curse.

Now, we will be studying a theoretical model and we will also explore some country experiences of a resource curse and capacity destruction and Dutch disease. But, for that we need some basic understanding of the concept of production and some other very fundamental concepts of economics. So, with this motivation I have designed today's lecture on a Theory of Production and overview. So, this is lecture 30 of our course. So, this is just we are at the midpoint of our course.

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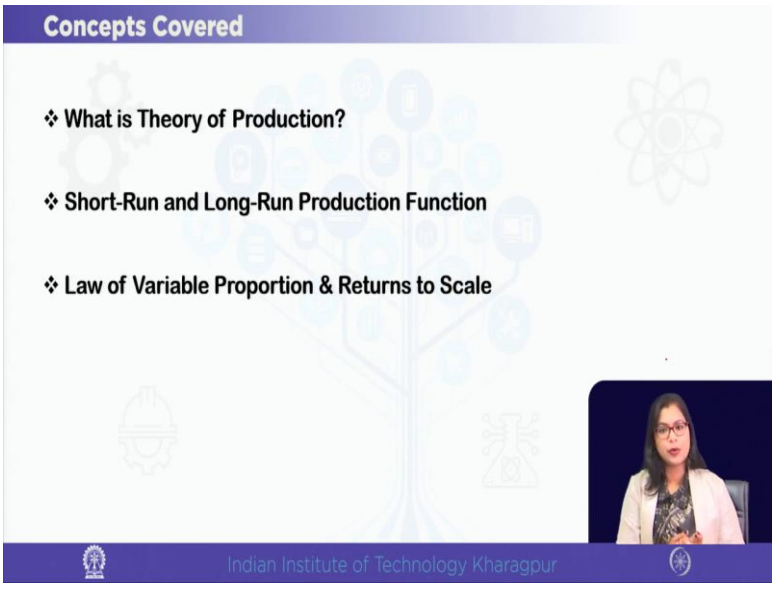

So, see the purpose is not to elaborate on theory of production because that is not the objective of our course. As I mentioned earlier also while outlining our course because we are not keeping any prerequisite, so that, the course is helpful and beneficial for students and faculties and industry professionals coming from various backgrounds, various disciplines so, that is why there is no prerequisite.

But of course, as you can understand if we have to study some theoretical model, if we have to also validate the theoretical model with some empirical evidences, we need to understand some very basic concepts. So, for that we are devoting three lectures in this module to understand the theoretical model. So, just this is required only to the extent for understanding the theoretical model ok.

So, first lecture on this basic of economics part again included in module 7 is regarding theory of production which is a part in microeconomics. Not only for this module, this will be helpful for some of your upcoming modules also like when you will be studying the oligopoly and game theory models, the price leadership dominant firm model in a theoretical structure because if you remember we have a module devoted to understand the world oil market, the theoretical structure of the world oil market.

So, they are also you need to understand the theories of production, the laws of production ok. So, with this idea in mind we have developed this we are devoting some of the lectures for basic understanding of more economics concept. So, first we will start with what do we mean by theory of production, why do we need to study a theory of production and then some basic concepts of theory of production like the concept of production function and isoquant.

And, then if a firm wants to change the output. How output will change, how the firm should proceed? Because we will see that the factors of production also, they vary in nature in the short run and long run. So, the production function also varies and hence the change in output in the short run and long run will also vary ok. So, there are two laws of production, the law of diminishing return to the variable factor and the laws of return to scale. So, we will be studying these two laws.

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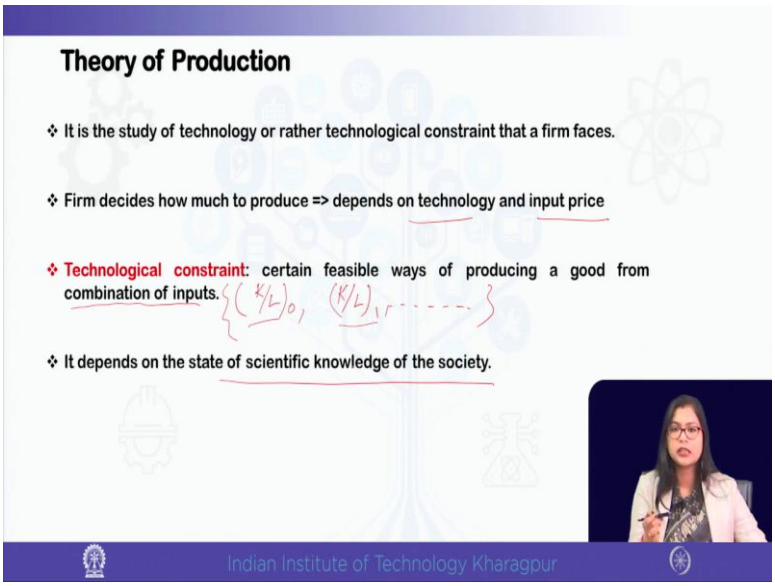

So, first and foremost we need to know what is theory of production. So, to in a very simple language theory of production is the study of technology or rather technological constraint that a firm face. So, I will explain with some examples then it will be easier for you to understand.

Now, you see a firm will decide how much to produce. So, that can be a good or that can be even service also. Services like say restaurants, saloon services, hotel tourism these are all examples of services BPO call center even education health these are all examples of services. So, firm will decide how much to produce that depends on what that depends on the given state of technology, right.

Because if you remember in supply in our very initial classes we discussed about law of supply and we also discussed what are the factors on which supply depends. So, there we discuss about the supply function and we saw that one of the very important determinant of supplies technology, right. So, how much the firm will produce it will depend on of course, demand firm will not produce beyond the demand if there is no take of the good that the firm is producing the firm will not produce, right.

Now, in a in an open economy or in a globalized world we are not necessarily concerned about the domestic demand because we can produce and sell beyond our domestic country. So, of course, demand is there, but firm also decides how much to produce given the technology ok and the input price because if the input prices increases, in one

of the classes if you remember we discussed about the cost of production, right. So, cost of production basically it is depending on the input prices.

So, if input price increases cost of production will increase the firm can now produce less because if the that depends on the revenue of the firm the fund that the firm has ok. Now, you see if you remember in earlier classes, we have taken examples that a particular good can be produced in a many different ways. And not only good even services can also be delivered in a in many different possible manners.

Let us say for example, in the conventional classroom teaching what we do? What we need? We have a face to face interaction where the teacher and the students are all inside one classroom and what are the equipments there? The equipments there is a black board or white board and chalk or marker, right and table, benches, chairs. So, these are the you can say the equipments right to deliver a lecture.

Now, the same lecture let us say I am delivering in online mode. So, in the during the pandemic more or less we are dependent on online education and now also its improvement in ICT infrastructure online education has become a very normal thing. So, you see the same lecture can be delivered in many different ways depending on the technology because you see the equipments are different.

In the online education we are more reliant on the techniques, the technology, we need an electronic device, we need electricity, we need internet connection on both the sides on the side of the instructor or the teacher and even on the side of the audience or the students, right.

So, you see the same lecture can be delivered in different ways in online mode, in physical mode, offline mode, in face to face interaction so, depending on the technology. Now, you see this online education was not imaginable before few years when we did not have that much sophisticated ICT infrastructure, right?. The internet communication was not available throughout the country, but now with the improvement in ICT infrastructure online education has become the new normal, right.

So, you see the same service can be delivered in many different ways. Even say telemedicine services is also now very common nowadays. So, the COVID-19 pandemic has led to a significant change in service sector as well. And, regarding the production of

goods we already can think of many examples like the same good can be produced in many different ways. Like in one of their classes I was taking the example of say one table.

So, I am taking the class here I have a table here, the same table can be constructed in many different ways. So, that depends on the state of the technology of the country or the economy. Now, in a labour abandoned country mainly the developing countries are labour abandoned, they are mainly the wood will be converted into table mostly by the carpenters using some machine tool.

Now, in the countries where there is lack of unskilled, semi-skilled workers the developed countries like Japan they use lot of automated production technology. The OECD countries mostly they go for very capital-intensive technology intensive technique technology of production. So, there they may be converting the wood into the table using a very sophisticated automated technology only some workers will be required to operate the machine.

So, you see the same good can be produced in many different ways. In the labour abandoned countries given that the countries are developing countries and they do not have so much developed technology and also, they have excess supply of labour they have the problem of unemployment So, they will rely more on labour.

Whereas, the same good can be produced in the developed countries where they have better technology and they face scarcity of unskilled or semi-skilled workers. So, they will go for a more automated technology. So, same good can be produced in many different techniques of production or many different capital labour ratios let us say. So, when I am saying this combination of input what do you mean? Say the capital labour ratio, right.

Suppose this is one particular capital labour ratio say KL0 there can be another capital labour ratio say KL1. So, you can produce the same good in many different capital labour ratios. So, you can use more capital with respect to labour you can use more labour with respect to capital. So, when you are using more capital so, that is called a capital-intensive technique of production; if you are using more labour that is a labour intensive technique of production, right.

So, whether a firm will go for a capital intensive or labour intensive technique of production that depends on the state of technology also you see and of course, the input price. So, if the firm suppose is using a more labour intensive technique of production, but for some reason suppose wage rate increases, then the firm may also try to replace labour and go for more automated kind of production technology, right.

So, the firm will decide how much to produce that depends on the technology and input price. In earlier classes also we talked about in case of supply let us say we have talked about how technological improvement can enable a firm to produce more with the same amount of inputs, right. Suppose you can produce more with same amount of raw material you can produce more. So, you see it depends on the state of scientific knowledge of the society.

Now, in the developing countries in the underdeveloped countries the very sophisticated automated technique of production may not be available. So, those countries will have to rely on more primitive ways of producing the good or even the service also. So, in a nutshell what we can say is the theory of production deals with the study of technology that the firm faces, ok.

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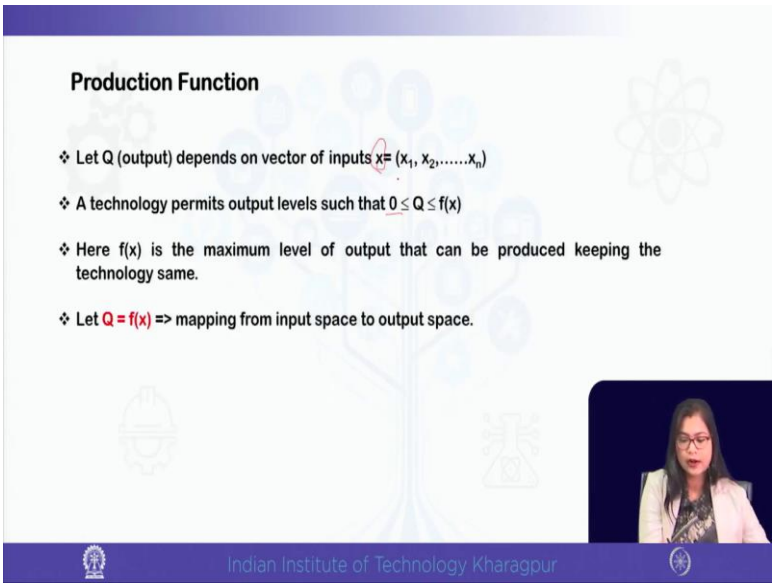

Now, here we have some important concept.

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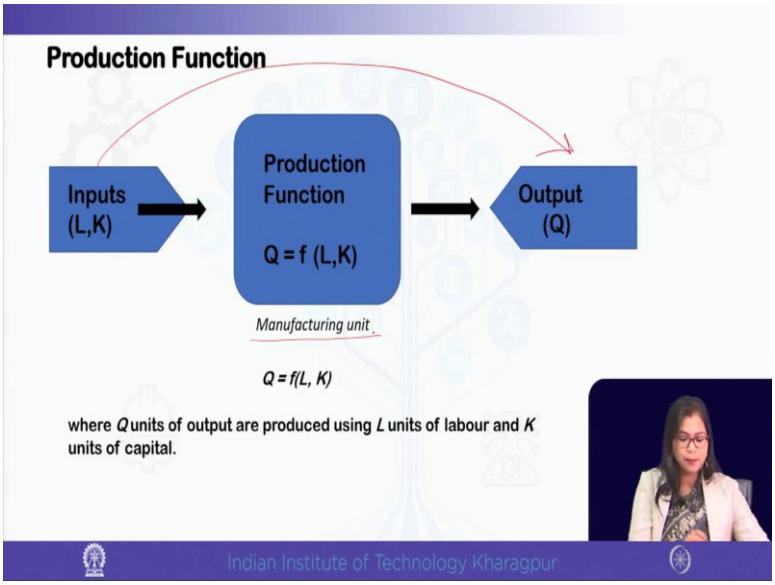

Now, you see when we are taking the example that the wood is converted into the table. So, we can think it in terms of this graphical exposition you see that will help us to understand when we visualize things. So, suppose for the time being we assume that some workers are converting the wood into table using some capital. So, mainly generally we consider two factors of production labour and capital. So, labour and capital are converting the wood into the final output Q using some technology, right.

So, this is if you see that the inputs are finally, converted into output. So, generally we can see the two inputs you can also bring the factors of production other factors of production. If you remember in very initial classes, we talked about four factors of production – land, labour, capital and entrepreneur. So, for our easy understanding we are just continuing with two factors of production labour and capital that is a convenient way. So, two inputs are combined using some technology and we get the final output.

So, output is a function of the inputs of production labour and capital. So, the conversion this converting the input into the output using some technology is being done in the manufacturing unit. Even you can think of this as some service sector also. So, the inputs are combined. So, let us say this lecture. So, we are using the electronic devices, electricity, ICT infrastructure ok and the labour or the human capital and that is converted into the final lecture. So, that is a service we are delivering.

So, anyway whatever with the case it is a service or any manufacturing or agriculture so, the inputs are combined to get the final output. So, you see it is a mapping. It is as if a mapping from the input space to output space. So, this relationship is called the production function. Ok.

So, the standard or conventional notation for output is Q. So, let Q or output depends on a vector of input where we are denoting the vector as small x and we can have many inputs of production. So, x can range from X1 to Xn. Say x 1 is labour, X2 is capital, X3 is land, X4 is say the raw material say suppose it is the textile industry. So, X4 is suppose the cotton textile, right. So, in this way say we have n number of factors of production.

So, the technology permits the output level such that the output level can be running from 0 to some up to some maximum limit, right. So, with a given state of technology with some particular amount of input of course, we cannot produce infinite level of output. There will be some upper limit of producing the output, right. So, you see the minimum amount of production is 0 means if you are not using any input then you would not be able to produce any output.

So, starting from 0, but of course, we will be considering the positive level of output. So, if you are now adding the input output will also become positive, ok, but we do not have any infinite limit because we have an upper limit, right. So, with a given technology with given input some particular amount of input will enable the firm to achieve a maximum level of output. So, this fx is basically the maximum level of output that can be produced keeping the technology same.

Because with a technological improvement the same amount of input can deliver higher amount of output. So, that is why with given technology fx is the upper limit or the upper boundary. Ok. So, Q equals to fx (Q = fx) is as we just have seen visually. So, this is like a mapping from the input space to output space. So, this is called the production function output as a function of the inputs of production. This is called the production function. Ok.

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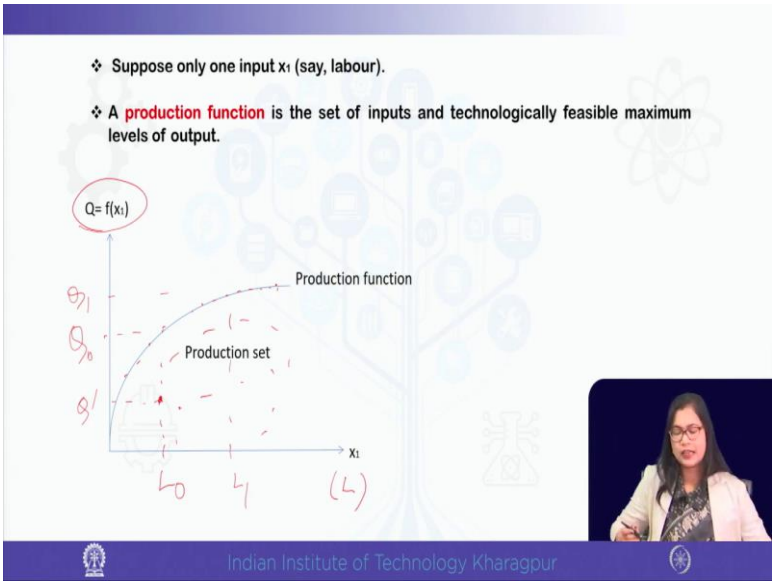

Now, suppose for our graphical illustration let us say we consider only one factor of production say x1. Suppose x1 is labour. So, your plotting labour or x1 on the horizontal axis as you can see from this figure. So, this x1 you can consider it as labour. And so, using some technology should labour will be translated into the output, ok, Q. So, the output is plotted on the vertical axis.

So, you see with some particular amount of labour say L0, there will be a maximum amount of output that the firm can produce suppose this is Q0. And of course, if labour is 0 output will also be 0. Then, if suppose the firm now employs more labour say it is L1 so, output will be greater Q1, right. So, what is this corresponding to Q0 if or corresponding to L0 you can see that Q0 is the highest possible level of output with some given state of technology.

L0 can produce greater amount of output only if there is a technological improvement. But, let us now consider that the technology is given at a particular point of time ok. Even with L0 you can produce less amount of output, right? With L0 you can also produce say output Q dash. But the maximum limit is Q0, ok. So, we can define the production function as the set of inputs and technologically feasible maximum level of output, ok.

And all the points over here you see all these points constitute what we call the production set. Because these are feasible output levels that the firm can produce with

the given amounts of different amounts of input and given technology. So, all the points over here constitute the production set and the upper boundary of the production set is called the production function. Unless there is a technological improvement the firm cannot go beyond the production function, right. So, this is how we are defining and illustrating the production function.

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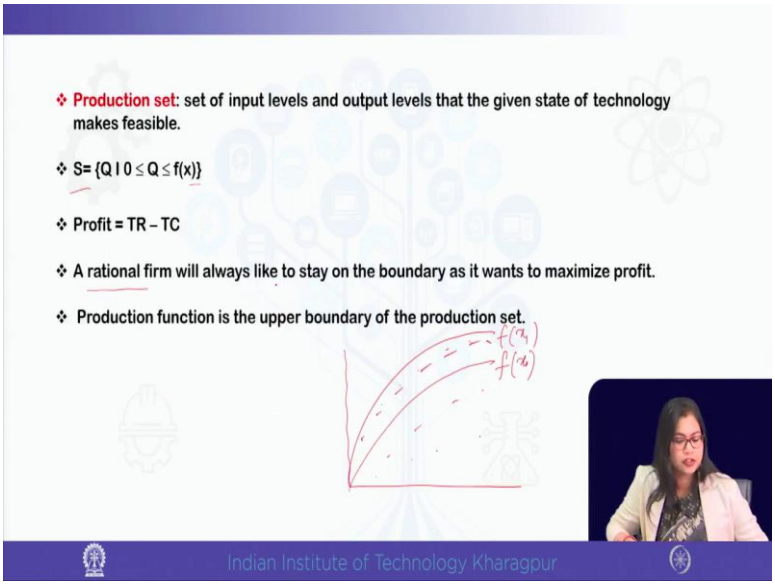

So, you see we have also defined the production set. It is the set of input levels and output levels that the given state of technology makes feasible. Now, if there is a technological improvement so, you can understand what will happen, this upper limit will expand, right.

So, that means, now more and more points now become feasible. But, with given technology you see with given technology your production function the existing production function is the upper limit. With a technological improvement now, your production set expands. So, now those points which are not feasible earlier suppose this was f of x0 this is the and this is say f of x1 you can say. With the technological improvement this is your new production function.

Now, these unfeasible points also become feasible because technological improvement allows the firm to produce more. Now, you say that is how we are defining the production set the it is the set of output Q such that output is in the range of 0 to f of x where fx is the upper limit or this is the production function, ok. Now, you can also

understand from here that a rational firm rational means rational economic agent is the one who wants to maximize his or her self interest.

So, you already know that what is the objective of a firm; objective of the firm is to maximize profit, right. So, a rational profit maximizing firm so, when I am writing rational firm that implies that the firm is a profit maximizer. So, what the firm will do then? Now, you remember we have already defined profit as the difference between total revenue and total cost.

So, of course, if the firm wants to maximize profit, the firm would like to maximize the gap between total revenue and total cost so, that means, the firm would like to maximize the total revenue. So, how the firm will do that? The firm will try to always be on the upper limit of the production set that means, what is the upper limit of the production set that is nothing but the production function.

So, a rational profit maximizing firm will always try to operate on the upper boundary of the production set that is on the production function, ok so, which is fixed without any technological improvement.

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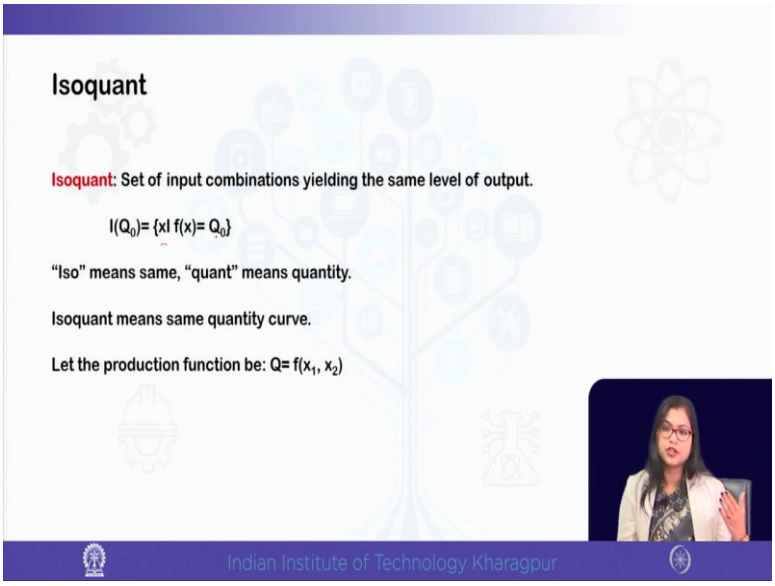

Now, with this we also define another very important concept that is called isoquant which is nothing but the graphical representation or the locus of the production function

you can say. So, what is isoquant? Iso means same and quant means quantity. So, isoquant is the set of input combinations which give us the same level of output, ok.

So, isoquant I of Q0 is defined as the set of inputs x such that those input combinations give the same level of outputs say Q0, ok. So, isoquant means same quantity curve. For example, suppose we consider this production function Q is a function of capital or labour or going by our general generalized notation of x. So, we can also write the production function Q is a function of f of x1 and x2 say x1 is labour and x 2 is capital, ok.

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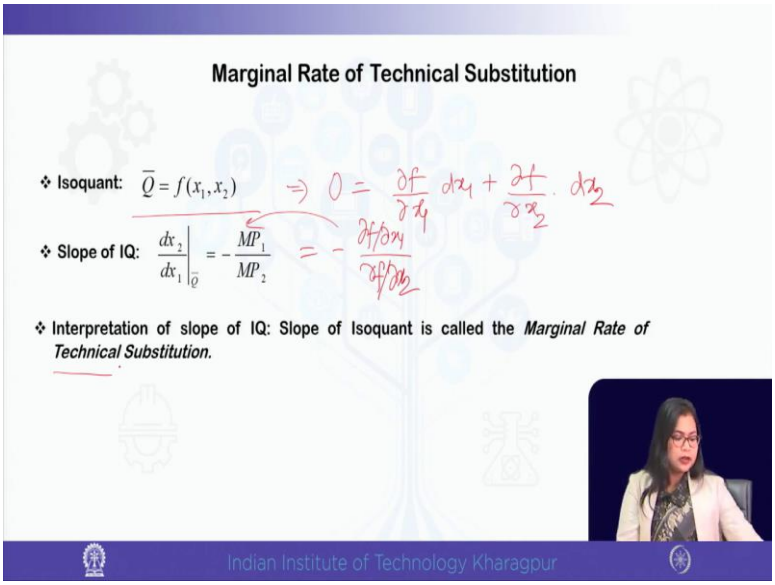

So, now we can define the isoquant as we fix the level of output.

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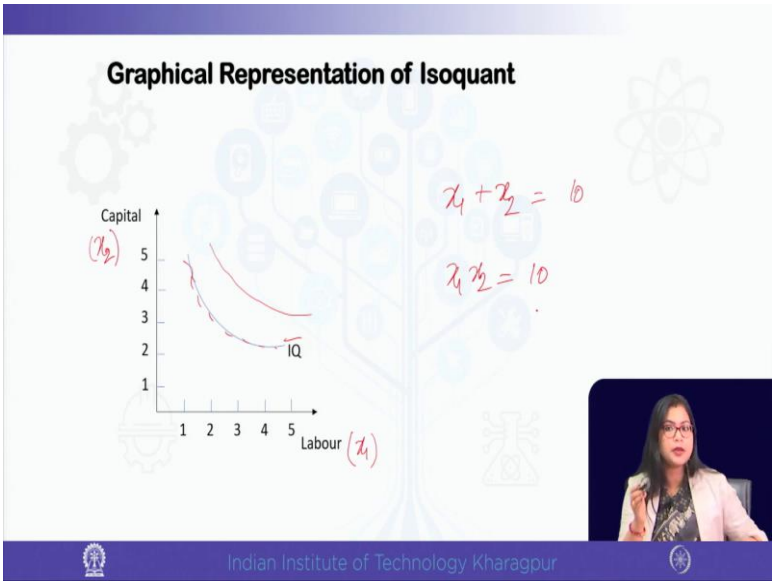

Now, suppose we are plotting the two inputs, ok. Say x1 is labour which is plotted on the horizontal axis and x2 is capital which is plotted on the vertical axis. So, what is isoquant? So, suppose we fix the level of output, so, isoquant is the combination of input which will give you the same level of output right, ok. Say for example, say x1 your isoquant say the production function is x1 plus x2 is equal to say 10. So, we know that there are different combinations that we can get 10.

It can be 10 plus 0, it can be 0 plus 10, it can be 5 plus 5 or it can also be like another example can be say x1, x2 equals to 10. So, it can be 10 and 0, 0 and 10, 5 and 2, 2 and 5. So, you see you fix the level of output and you find out the different combinations of input which will give us the same level of output, here you can see, ok. So, your output is fixed along a particular isoquant; iso means same. It is the same quantity curve ok.

So, you fix the level of output and you find out the input combinations which will give you the same level of output. So, this is the definition of the isoquant. So, you see the difference graphically in isoquant what we are plotting in the two axes? We are plotting the two inputs of production capital and labour and we are getting the output level. So, different combinations which give us the same output level is called the isoquant.

And, in the production function figure what we plotted in the production set and production function figure we plotted output on the vertical axis and input on the horizontal axis, but because this production function is showing the relationship between

how the input is converted into output. And, the isoquant is showing the relationship between how the 2 inputs can be combined to get a same level of output, ok. So, Q bar equals to f of x1, x2 is a particular isoquant.

See we can consider another level of output say x1 plus x2 equals to 20. So, that will give you another isoquant for example, or x1 into x2 equals to 20 so, that will give another isoquant and as long as the inputs contribute to output level. So, if you add one more unit of input output also increases. So, marginal productivity is a positive then higher isoquant means higher isoquant means the output will also be high on that higher isoquant.

Higher isoquant will correspond to a higher level of output, ok. Now, you see the it is interesting to interpret the slope of isoquant. So, how do you get the slope of isoquant? Suppose, we totally differentiate this equation of isoquant so, if we totally differentiate what this becomes d the left-hand side becomes d of Q bar. Now, see along the isoquant we are keeping output fixed.

So, d of Q bar will be 0 is equal to what? In the right-hand side, it will be del f del x 1. See along the isoquant means you are changing the two inputs to get the same level of output. So, the left-hand side d Q bar will be 0 in the right-hand side it will be del f del x 1 into dx 1 plus del f del x2 into dx 2. So, I think this we can get the slope of the isoquant.

So, dx 2 by dx 1 along a particular isoquant Q bar is equal to minus of you see del f del x 1 by del f del x 2. So, how do we interpret del f del x i? Del f del x i means if you change i-th input by 1 unit let us say how output will change? So, del f del x 1 is basically it is called the marginal productivity of the first factor of production which here we have written it as MP 1.

So, del f del x 1 is marginal productivity of input 1. If we change input 1 by 1 unit how output will change? Similarly, in the denominator we have marginal productivity of input 2. Ok. So, the slope of the isoquant is called the ratio of the marginal productivity or we can also tell this as the absolute value of slope of the isoquant is the ratio of the marginal productivity. Now, this is called the marginal rate of technical substitution.

That means, the rate at which we want to substitute one input for another input, so that output remains unchanged and of course, this rate of substitution this will given by the technique because we can have different types of techniques of production the two inputs can be perfect substitutes, two input can be perfect complements there can be limited ways of combining the inputs and depending on that the slope of the isoquant will also vary.

But, for the time being we are not going into that detail because that will divert our attention. Just I just wanted to interpret the slope of the isoquant, ok. So, this is the marginal rate of technical substitution which is the absolute value of the slope of isoquant.

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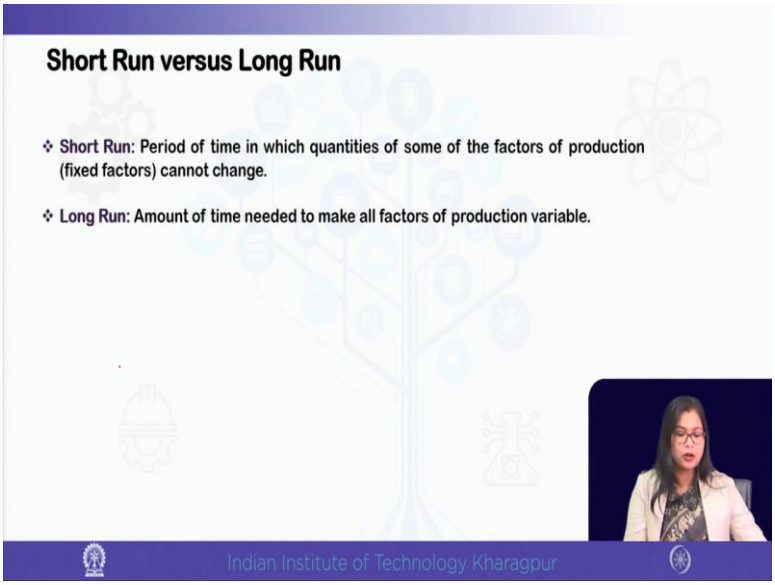

Now, you see coming to a very important aspect of production is the distinction between short run and long run because if you remember we discussed that one of the very important determinants of supply is time, over time supply can change. Now, suppose from a firm's perspective if the firm wants to produce more so, how the firm will go? The firm will like to increase the in output.

How the firm can do so? The firm has to employ more when more factor of production is not it with a given technology which is constant at a particular point of time. So, the firm can produce more only by hiring more factors of production otherwise how can the firm produce more.

Now, you see there are certain factors of production which cannot be changed in the very short run let us say capital. Suppose, you consider a manufacturing unit where the machine is imported, ok and that is not available in the domestic market. So, if the firm wants to produce more the firm has to buy the machine, import the machine and that can be time taking.

Even say the manufacturing units which take inputs from for example, you can think of pharmaceutical industries which use a particular chemical to produce a particular medicine and the chemical has to be imported. So, these are time taking even you see expanding the factory space. If the firm wants to increase the factory space, build a new factory, so, that is also time taking.

So, there are some factors of production which are fixed in the short run. So, these are called the fixed factors of production. So, generally capital is considered to be the fixed factor of production which cannot be changed in the short run. Now, you see the concept of short run and long run I have already told you that varies from context to context in microeconomics and macroeconomics.

So, in microeconomics when we are dealing with the particular individual economic agent a firm's perspective, a few production periods can be a long run. So, short run is very short time say 3 months, 6 months. So, it depends on the context. So, in the short run if then the firm wants to change output the firm can do so, only by hiring more and more of the variable factor which is nothing but labour.

So, labour is considered as the variable factor of production variable why? Because the amount of labour that the firm can hire or even layoff that is possible to change only in the short run; in short run capital is fixed. However, you see the main distinction between short run and long run is then in long run all the factors of production can be varied.

Now, if the firm sees that there is a growing demand for the product, so, the firm will now make arrangement to import the capital or the machineries, the say chemical that is used in the pharmaceutical industry. So, in the long run no factor of production is fixed all the factors of production are variable.

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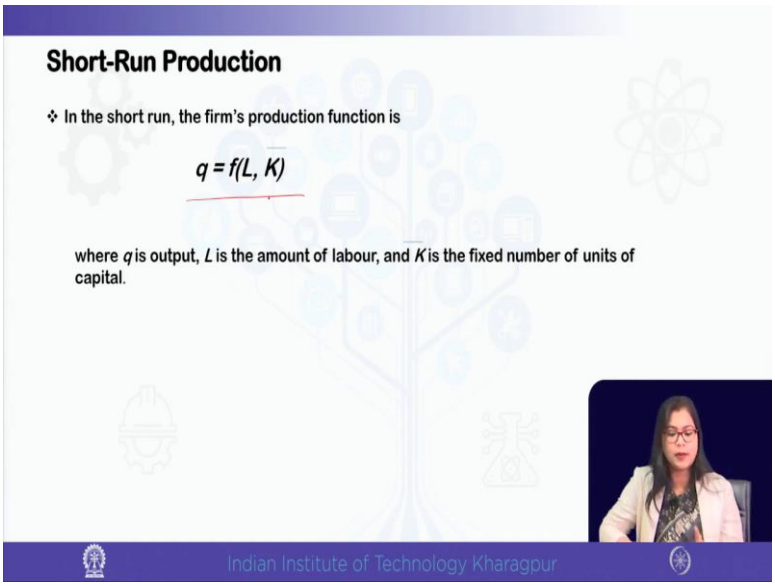

So, this is very important to understand because our laws of production will also depend on how the firm can change output by changing the inputs in the short run as well as in the long run. So, in the short-run then what happens? In the short-run we can write the production function as Q is a function of labour and capital which is fixed so, that means, the firm can change output Q only by changing labour, ok.

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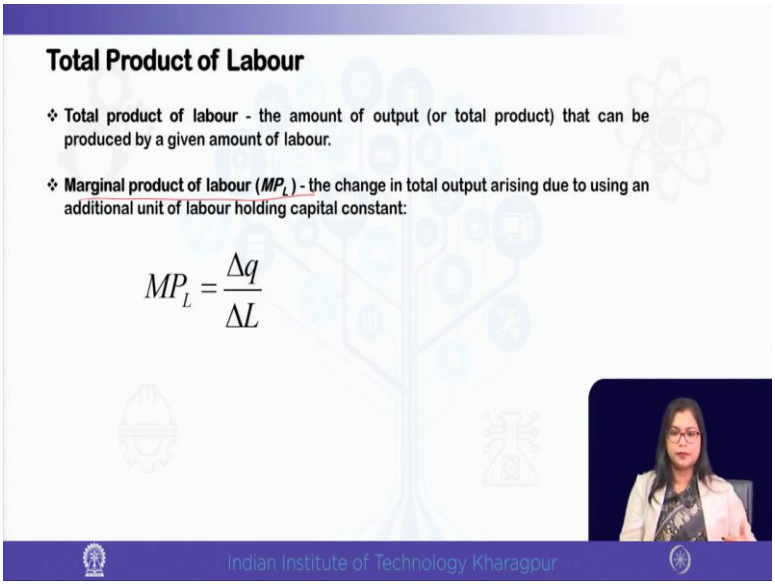

So, here comes very important concept of total product and marginal product. So, what is the total product? Total product is the amount of labour which can be produced by sorry

total product is the amount of output that can be produced by using a given amount of labour, ok. So, if you are using some labour how the output what will be the output, that is of course, the total product.

An average product you can understand that will be total product divided by the amount of labour, ok. So, that will be the per unit output is the average productivity of labour. And, once again you see in economics, we are very much concerned about what is happening in the margin. So, we have the concept of marginal productivity of labour.

What is marginal productivity of labour? So, that is the changing total output which arises due to using one extra unit of labour holding the other factors of production like capital constant. So, that means, it is nothing, but del q del L, ok. If labour changes how output will change.

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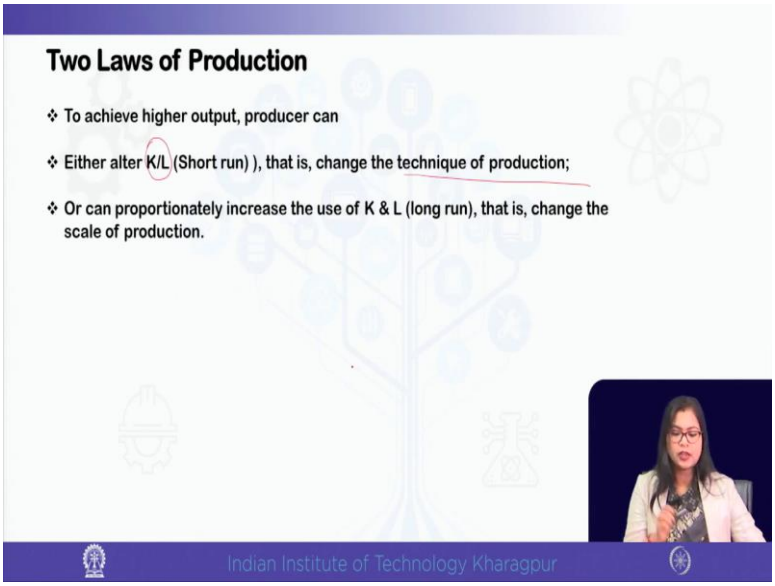

So, with this we have come to the point where we discuss the two laws of production. So, to achieve higher output the producer has now two ways of doing that. The producer can now use a more labour that can be possible only in the short run because in short run capital is fixed. So, if capital is fixed the producer can change the capital labour ratio because, K is fixed. So, only way of changing the output will be by changing L.

So, what will happen? The capital labour ratio will change. So, that will be the case under short run and K by L as I mentioned initially that is nothing but the technique of

production. You see I have already shown you that there are different techniques of producing a particular good K by L0, K by L1. So, these are the techniques of production.

So, in the short run K is fixed only way the firm can change output Q is by changing L. So, K by L ratio will change in the short run. So, this is called the law of variable proportion. I will come to the statement of the law, but what is the other law? Other law is the one which is operated in the long run because in the long run now you see what happens?

The long run the firm is no longer constrained by the fixed factor. All the factors of production can be varied. So, in the long run the firm can proportionately increase the use of capital and labour, that is the firm can change the scale of production. So, this is called the law of return to scale.

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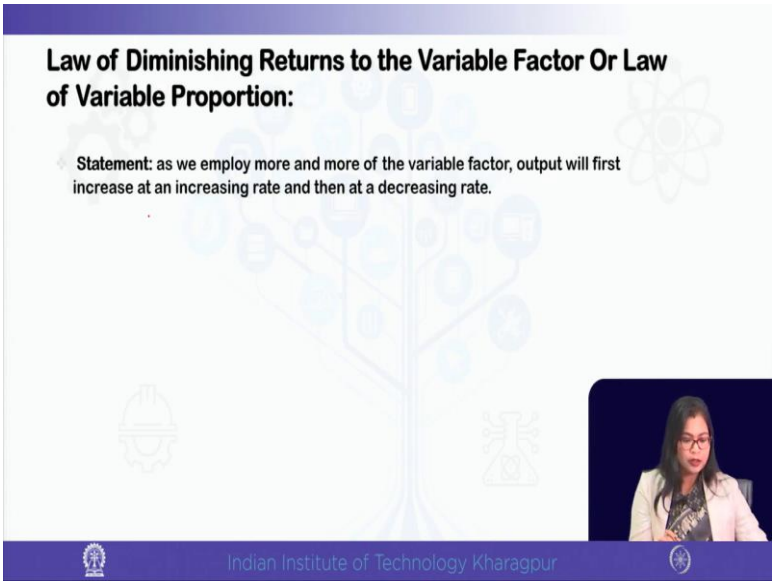

So, I will just show the two laws of production here because these are very important for our theoretical models and for some of our upcoming modules also. So, what happens in the short run? Let us first start with the short run. In the short run to change the output the firm is changing the amount of labour. So, what will happen? Suppose the firm wants to produce more the firm will then hire more labour.

So, the what happens as the firm hires more and more of the variable factor that is labour, output will first increase at an increasing rate and then at a decreasing rate. So, this is called the law of diminishing return to the variable factor or the law of variable proportion. See output increases, but first it increases at an increasing rate and then it increases, but at a decreasing rate.

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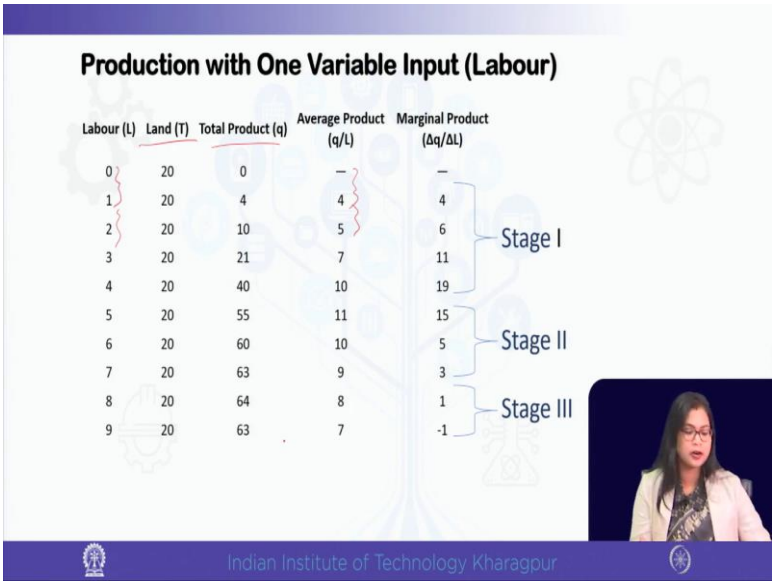

So, you can see the very simple example where suppose we consider land as the fixed factor. So, you can see the amount of land is fixed and then in the first column we have plotted the amount of labour and in the third column we show the total product. So, you see of course, if the labour is 0 even with land output is 0.

Suppose you consider agriculture production. So, if there is even with land if there is no labour we cannot get any agriculture crop, right. So, output is 0, but then as labour increases total product also becomes positive, but it increases, right. Now, in the fourth column we have presented the average productivity of labour, ok. So, that is the per unit output. So, we divide the third column by the first column we get the average productivity of labour.

And, the last column is of our interest where we are plotting the marginal productivity of labour or you can also interpret it as the contribution of labour, ok. If the firm is changing one more unit of labour how output is changing? See if the firm is going from 0 to 1 how output is changing? Then 1 to 2 how output is changing? – So, these changes

are given by the marginal productivity. Ok. So, you can see the marginal productivity of labour. Ok.

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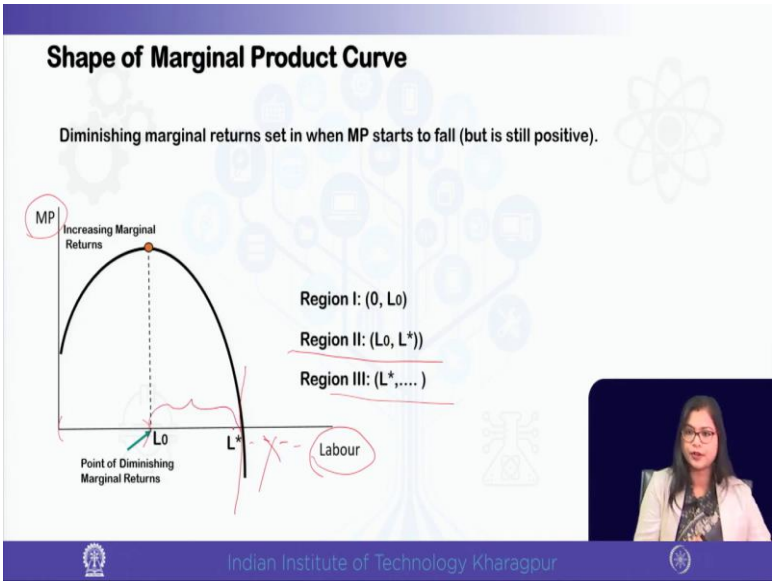

Now, you see by the statement as output increases sorry. As labour increases marginal productivity of labour will first increase at an increasing rate and then at a decreasing rate. Ok. So, that is our statement. So, here you can see what happens to the marginal productivity. So, it is first increasing and then it is decreasing, ok and then a stage comes where it becomes negative, ok.

So, in the first stage what happens? You can see if we plot marginal productivity of labour in the vertical axis against labour on the horizontal axis, we see that marginal productivity of labour first increases, then it reaches maximum and then it starts declining. Ok. So, that is what we can see over here that as we go on increasing labour, marginal productivity first increases, first is it increasing at an increasing rate in the stage 1.

You can see stage 2 where marginal productivities are positive, but it is falling. Ok. See output is increasing, but at a decreasing rate. So, this is called the stage 2 and in the last stage what is happening? The marginal productivity is become negative because output starts falling. So, of course, you can understand the firm will never hire labour where marginal productivity of labour becomes negative because by that what happens? If the firm hires more labour, output will become negative. Ok. So, the no firm will do that.

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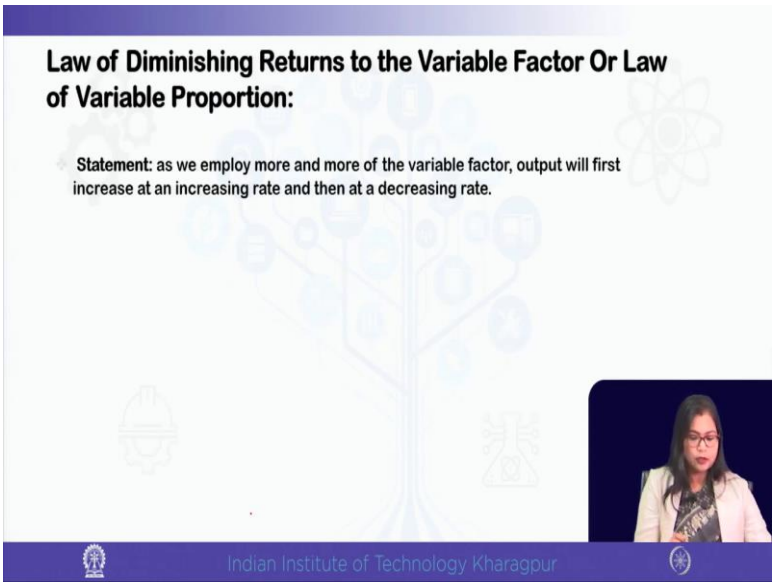

So, for the law of variable proportion we are sticking up to stage 2. See we have here shown the three stages of production in stage 1 you see output increases. In stage 2 output increases, but at a decreasing rate so, you can see over here output is positive, but decreasing. So, the rate of change in the marginal productivity is falling. So, this is graphically represented in stage 1 which ranges from 0 to L0, marginal productivity is increasing.

In stage 2 which operates till the region L0 to L star marginal productivity is positive, but decreasing, but beyond L star marginal productivity curve has entered the negative quadrant. So, no firm will go beyond employing L star amount of labour right because if the firm hires workers output will fall means output becomes negative. So, the firm means output you see output starts falling marginal productivity becomes negative. Firm will never operate in stage 3, this region 3.

Now, the question is. Will the firm operate in region 1? No, the firm will also not operate in region 1 because, what happens? A rational profit maximizing firm if the firm is hiring worker the contribution of the worker is positive and it is increasing. So, the firm will not stop by hiring up to L0 amount of worker. The firm will definitely enter the stage 2 the because the contribution of the worker till L0 will be positive. So, the firm will keep on hiring more and more workers.

So, you see we are left with only region 2 which is also called the region of economic operation because here what happens? In the range of L0 to L star if the firm hires more worker, you see marginal productivities are positive, but it is diminishing. So, this is also called the region of economic operation. So, we can conclude that diminishing marginal returns set in when marginal productivity of labour starts to fall, but it is still positive ok.

So, you can see that we have plotted these three stages of production. This is very important for our upcoming not only for today this lecture, but for the subsequent lectures also understanding the law of diminishing marginal productivity. So, this is how we are representing the marginal productivity curve which is inverted U shape, ok. So, this is our region of economic operation, right.

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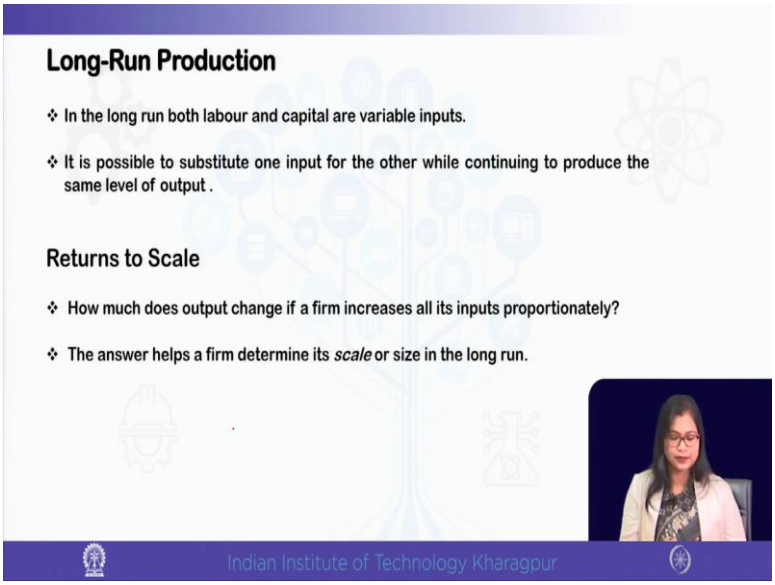

Now, you see over time then the firm what the firm will do? In the long run, the firm is no longer constraint the firm has the option of producing more by changing both labour and capital. Now, suppose we assume that the firm can change labour and capital in the same proportion. So, that is called if the firm is suppose increasing labour and capital in the same proportion that is called an expansion in the scale of production.

So, if the firm is expanding the scale of production how output will change? That is the question. Answer is given by the laws of return to scale. Now, you see here we do not have an only one answer because if the firm is changing the scale of production, output can change in three different ways, ok.

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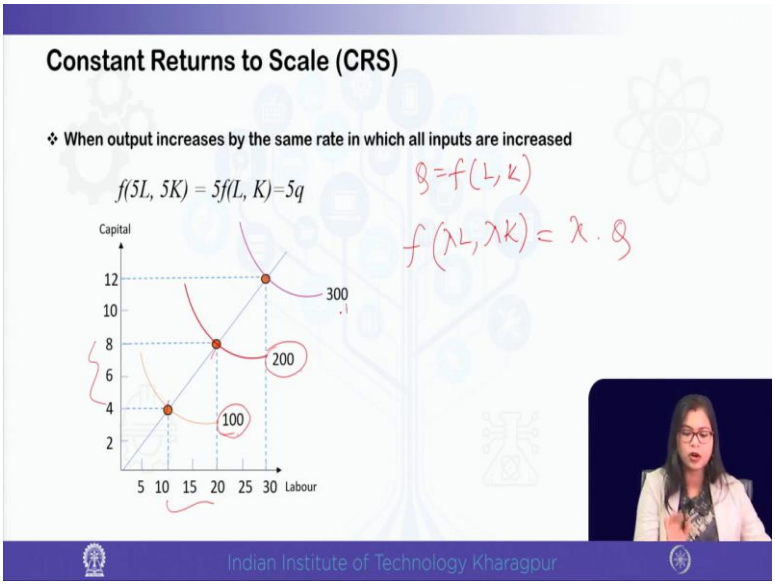

So, there are three types of return to scale. So, the first case is where say the firm is changing the scale of production, output also changes by the same rate ok. Suppose the firm is changing both labour and capital by some rate lambda.

So, the initial production function is suppose Q is equal to f of L, K. If the firm is raising both capital and labour by the percentage lambda; lambda is some positive constant and so, output also changes by lambda percentage by the same percentage. So, this is called constant return to scale technology.

So, output increases by the same rate in which all the inputs are increased. Suppose the firm doubles labour and capital output is also doubled, say lambda is equal to 2. So, this is called constant return to scale CRS technology. So, you can see the map of isoquant. So, if the firm wants to go from isoquant 100 to isoquant 200, isoquant 200 means it corresponds to output level 200.

So, the firm is changing the rate of change of both the inputs you see. This means the firm is changing the scale of production in the same rate to go from isoquant 100 to 200 to 300, ok. The we have exact proportionate change same proportionate change. If input is changed by a particular percentage, output will also change by the same percentage. This is called return constant return to scale.

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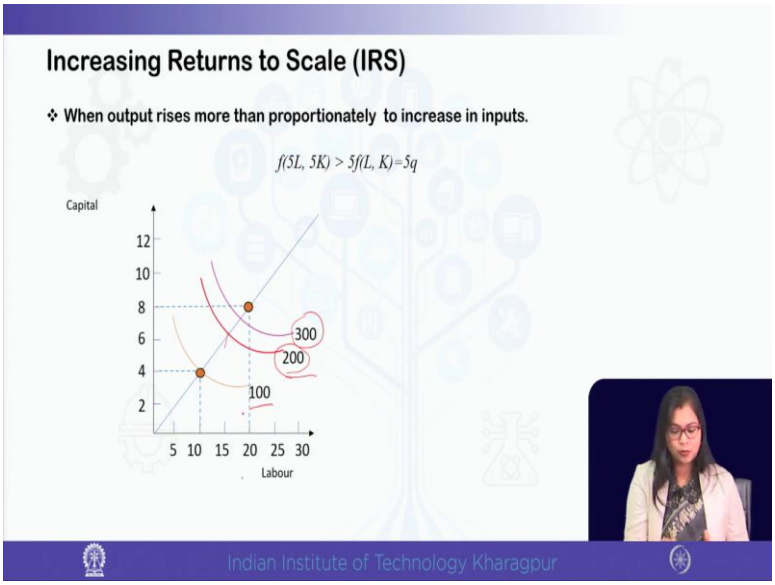

But there are cases where the input can increase more the output can increase more than proportionately. Suppose, the firm doubles the inputs labour and capital it can happen that output more than doubles, ok. The production technique is such that if the firm doubles labour and capital, output is now say it is increasing 5 times, ok.

So, we have increasing return to scale and you can see the what happens to the map of isoquant. Now, you see as you are producing more and more you are expanding the scale of production and by the increasing return to scale as you are employing more and more factors of production output increases at a faster rate. Now, we have a more than proportionate change. So, now the isoquants are getting even closer as you are increasing the output.

See from increasing the output from 100 units to 200 units, the amount of input increase and you see if you now want to go from 200 units of output to 300 unit of output you need the input to change less. Because now the inputs can contribute more because, if inputs are changed in the same way output will change more than proportionately that means, if we put it other way round to have a given change in output, we now need to increase the input at a lesser rate.

Because if we increase the input at the same rate output will increase more and more that is why you see when you are just increasing the output from 100 to 200 to 300 to 400

unit less increase in the amount of input and that is why in the isoquant map the isoquants are very closer.

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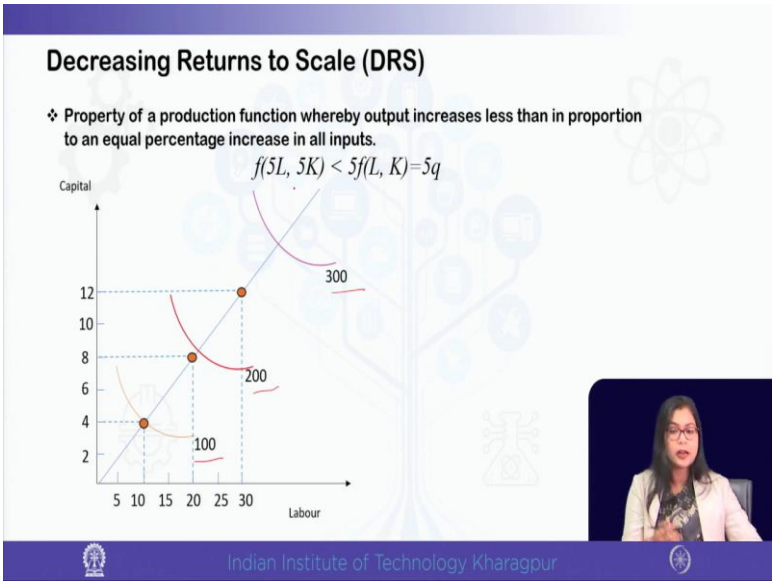

Now, we can have other situation also other possibility; that means, we can also have a decreasing return to scale. The production function can be such that if the firm is increasing capital and labour suppose the firm is doubling the capital and labour output also increases, but it is less than doubled. So, now there is a less than proportionate change. So, that is called decreasing return to scale.

Now, you see the graph of isoquant map, now the isoquants are far apart. Why? Because if the firm wants to increase the output from 100 to 200 to 300. Now, as the firm wants to increase more and more output the firm needs more and more input right because the return to scale is now decreasing. So, if the firm wants to means change the scale of production, it increases the scale of production output increases, but less than proportionately, ok.

So, that means, if we now just summarize in the short run we can tell if the firm wants to produce more the firm will hire more variable factor labour, but then output will increase at a faster rate initially, but then output will increase but at a decreasing rate. In the long run if the firm wants to produce more the firm will hire more labour and capital, but how output will change we cannot say definitely it depends on the return to scale that the

production function follows. So, we can have constant return to scale increasing return to scale and decreasing return to scale.

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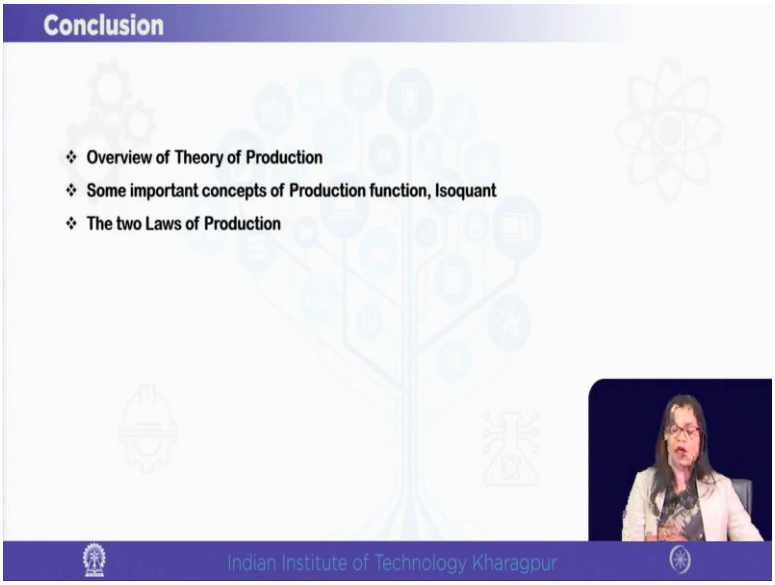

And, I have also shown you graphically the law of diminishing marginal productivity and also the isoquant map for the three types of return to scale. So, if we just summarize today's lecture, we discussed we gave a brief overview of what is theory of production and we discussed very important concepts of production function, production set and isoquant.

So, production function is the mapping from input to output space or it is also the upper limit of the production set with a technological improvement only the firm can expand the production set. With given technology the production function is the upper limit of production set.

Now, if you fix the level of output the input combinations give us the isoquant. If we plot the input combinations corresponding to a particular level of output that is the called the isoquant and the slope of the isoquant is marginal rate of technical substitution. And, then we discussed about the laws of production which I just now summarized. So, we have two laws in the short run and the long run. So, the law variable proportion in the short run and the law of return to scale in the long run. Ok.

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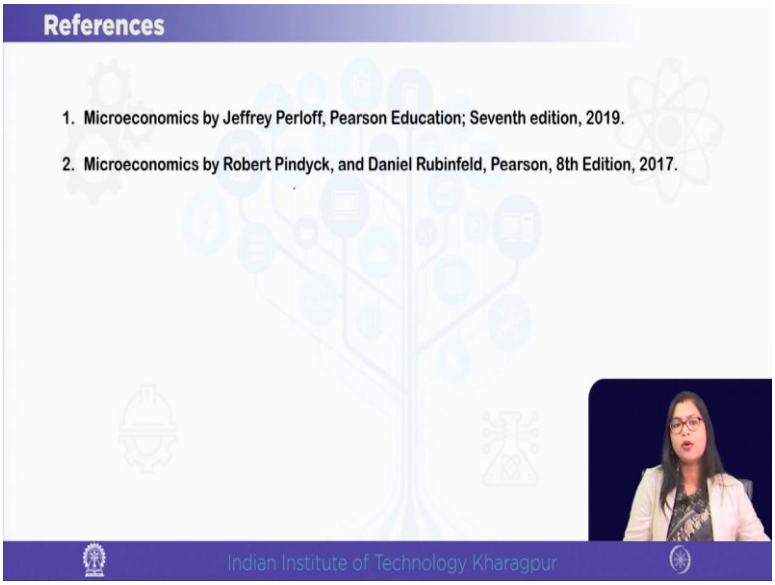

So, we can follow any standard microeconomics book for studying the theory of production and the laws of production part.

So, thank you very much. I look forward to see you in the theoretical model discussion.