Energy Economics and Policy
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Week - 02
Energy Demand – Part I
Lecture – 03
Decomposition Analysis and Parametric Approach

This is the third and final lecture of the second week and this week in this lecture, we are going to talk about Decomposition Analysis and Parametric Approach.

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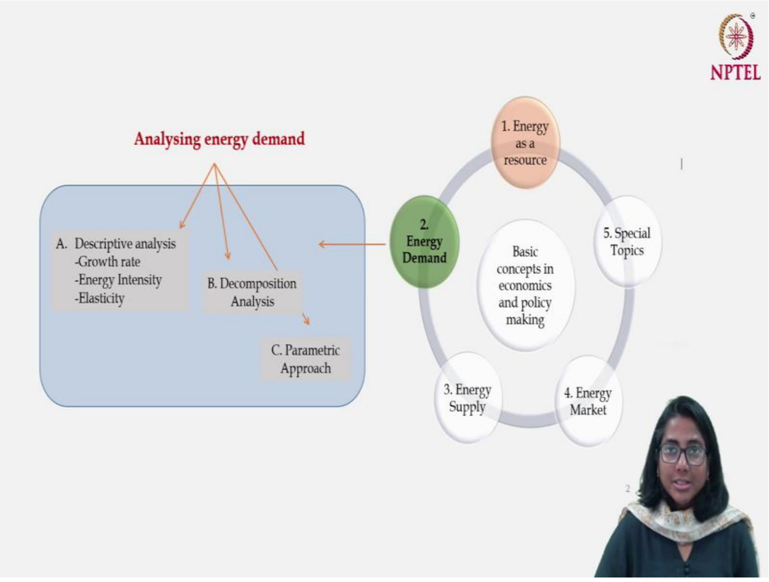

In the previous lecture, we already have discussed certain descriptive analyses involving the growth rate, energy intensity, and elasticity to analyze the growth in energy demand or generally to understand the energy demand. In this lecture we are going to discuss two things: one is the 'decomposition analysis' and the second is the 'parametric approach'.

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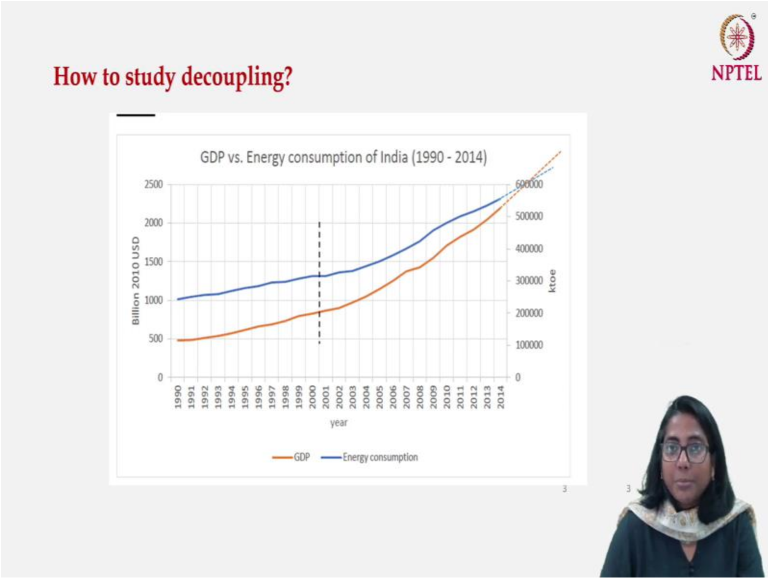

We begin with the decomposition analysis. Before we go to the analytical framework let us look at this diagram. The question that it tries to address is how to study decoupling? Now, what do we understand by decoupling? Decoupling here essentially means the decoupling of growth in GDP from the decoupling of growth in energy demand. If you look at these two curves, the orange line tells you the growth of GDP in India over time measured in billion US dollars.

And, this blue line is telling you the growth in energy consumption over time, which is measured in terms of a kiloton of oil equivalent. This blue line incorporates the use of all kinds of fuel. If you look at this diagram you see that initially, both blue line and orange line, the rate of growth was almost similar, they were running parallelly. Beyond a point of time, you see that orange line is growing much faster as compared to the growth in the blue line. As a result, after a point of time, you may get this kind of a situation.

What is essentially happening? It’s like this: up to this point in time, you see both these curves are going parallel. It means that the rate of increase in energy consumption is almost equal to the rate of increase in GDP. Therefore, if you think about the energy intensity of GDP there was almost no change in energy intensity of GDP up to this point of time. However, if you go beyond, the GDP is increasing at a higher rate compared to the increase in energy demand which is lower. Over this period you can expect that the energy intensity of GDP is falling, it’s not staying the same.

Now, the question comes that if there is an increase in energy efficiency which is reflected in the decline in energy intensity of GDP, will we be able to reach a situation where our GDP will grow, however that will not require an increase in the total energy consumption. With the pool of the same energy, we will be able to produce more GDP. This point is called the decoupling of GDP from energy demand. And you can kind of answer this question to understand up to which year this kind of decoupling can take place?

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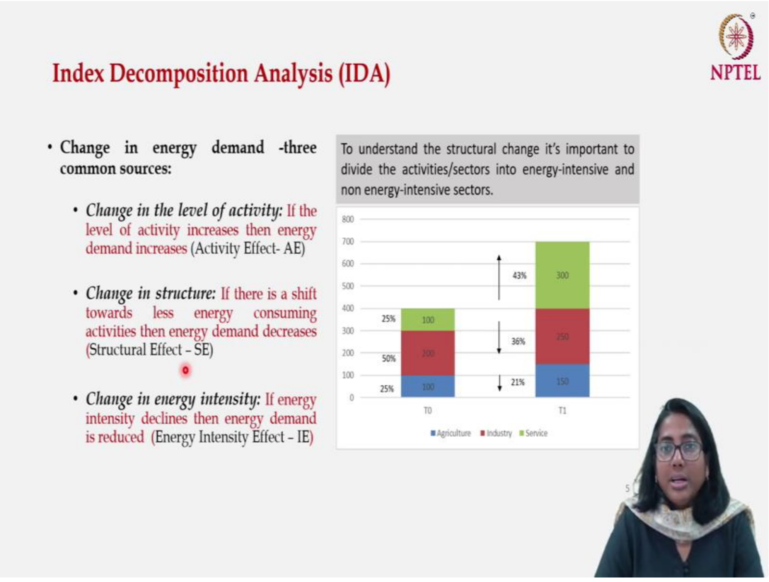

One of the things that become very handy is called the Index Decomposition Analysis. We are going to look at this method very briefly and see some of the applications of the Index Decomposition Analysis. In the basic framework let us assume that change in energy demand has three common sources. You can assume more than three common sources, but we can start with these three common sources. What are these common sources? The first one is called the 'activity effect' which is the change in the level of activity leading to the change in energy demand.

If you look at this diagram, we are considering the same economy at two different points of time. At period T1 this is the size of the economy; however, during the period T1 the size of the economy grows, this you can also think about as the size of the GDP grows to become this much so there is an increase in GDP. Now if there is an increase in the GDP, the energy demand will also grow. This is one source of change in energy demand, which is captured in terms of activity effect.

The second one that we considered is the change in the structure of the economy. Again, if you look at this diagram, it's not only the size of the GDP that has increased but also the composition of GDP has changed. What is the change? In the initial year, the contribution of the agricultural sector which is represented by this blue part was 25%, the same was the contribution from the service sector. Each of these two sectors, agriculture as well as the service sector they are contributing 25% each respectively and 50% of GDP was coming from the industrial sector.

In the recent period there is a decrease in the proportion of the share of the agricultural sector in the economy. Although, you see that size of the agriculture sector has gone up from 100 to 150 but the contribution of the agricultural sector has come down to 21% from 25%. If you look at the industrial sector here also you can observe the same thing. The size of the industrial production that is the industrial contribution to GDP was 200 at the period T0 that has increased to 250 in the current period. The increase is from 200 to 250; however, the percentage contribution from the industrial sector has come down from 50% to 36% of GDP. The third one is the services sector, where the growth is huge. Initially, it was 100 but has gone up to 300. Not only the size of the service sector has become bigger from 100 to 300 but the contribution of the service sector has also gone up from 25% to 43% in the economy. Now, this is what is capturing the change in the structure of the economy, this is called the structural change of the economy. How the share of different sectors has changed in terms of their contribution to GDP over time.

Now, what is the implication of this structural change to the energy demand of an economy? If you think about these three sectors: agriculture, industry and service sector; the service sector is the least energy-intensive sector. To produce 1 unit of output in the service sector, you require the least amount of energy, if you compare it with the agriculture or industry sector. The industrial sector is the most energy-consuming. To produce 1 unit of output in the industrial sector you need much more energy as compared to the service sector or agricultural sector.

Therefore, if there is a structural shift in favor of the service sector, you can expect that other things remaining constant, the energy demand is going to come down. Had there been an increase in the share of industrial GDP that is had the structural shift been in favor of the industrial sector, other thing remaining constant, energy consumption of the economy would have gone up. This is the implication of structural change in energy demand. The structural effect implies the change in energy demand that is arising due to the change in the structure of the economy, that is, due to a change in the sectoral contribution to the economy.

Before we go to the third one, one important thing is that when you are doing any decomposition analysis to understand the structural change it is important to divide the economy into various parts. Some of the parts are more energy-intensive and some of the parts are less energy-intensive. And you try to understand whether it's the contribution of the more energy-intensive sector that is growing or is it the contribution of the less energy-intensive sector that is growing over time. This is the fundamental thing that you have to divide the economy into these two parts if you want to understand the structural effect.

The third part is fairly simple, this is about the energy intensity effect. If the system of production and system of consumption becomes more and more efficient over time, then to produce the same amount of thing you need less amount of energy that is the reduction in energy intensity. The third source that we are considering and trying to understand, other things remaining constant, whether there is a change in the energy intensity which is leading to the change in the energy demand. If the energy intensity increases over time then the energy demand will increase other things remaining constant. If the energy intensity declines then other things remaining constant your energy demand is also going to decline.

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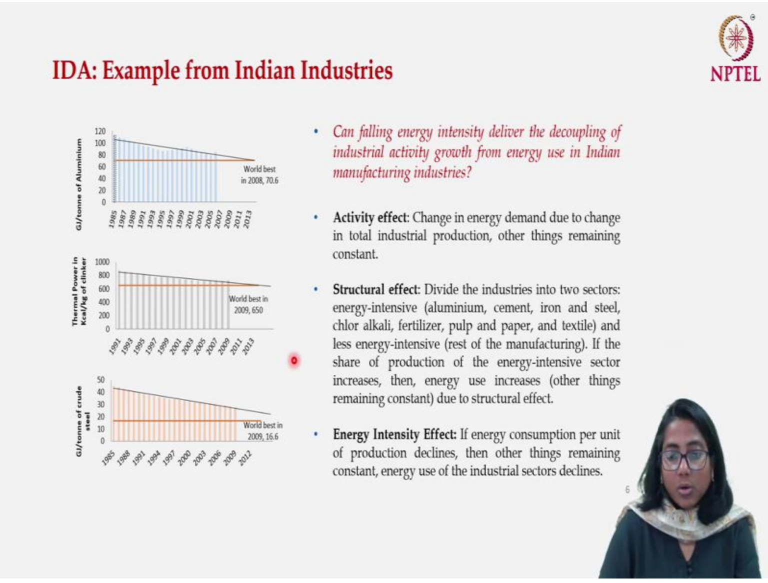

Let us start with an example and try to see what kind of questions we can answer by the use of this Index Decomposition Analysis. You are already familiar with this particular diagram, here

I have chosen only three industries. The aluminum industry, the production of clinkers for the cement industry and steel production. And what we have shown is that the energy intensity in these three industries actually had fallen quite significantly over the years but now try to match this concept with the concept of decoupling.

Now, what we have learned from this slide is that the decline that we have been showing for these three industries captures only the change in energy intensity. But, if you think about the industry as a whole there are other two effects, there are other two sources that can play a role. The question that we ask is that we understand that there is a fall in the energy intensity which will reduce the energy demand but can this falling energy intensity be able to deliver the decoupling of energy activity growth from energy use in Indian manufacturing industries. We understand that due to one source there is a decline in energy demand.

However, what is the role of the activity effect and what is the role of the structural effect? This is the question that we are trying to address here. Now, if you think about the Indian manufacturing industries what do you exactly understand by activity effect? The activity effect is the increase in energy demand or the change in industrial energy demand due to the change in the industrial output, other things remaining constant.

What about the structural effect? To understand the structural effect you have to divide the sector into two parts. One is the energy-intensive part and the other is the non-energy intensive part. In the case of manufacturing industries, we have taken a few industries like the energy-intensive industries. They are aluminum, cement, iron and steel, chloralkali, fertilizer, pulp and paper, and textile. These industries are considered to be the most energy-intensive industries because, one of the very important energy efficiency policies in India concerning the industry sector that is "Perform, Achieve and Trade" scheme also called PAT considered these industries to be the most energy-intensive industries in its first phase. These industries together constitute the energy-intensive industries while the rest of the manufacturing industries constitute less energy-intensive industries. When we talk about the structural shift, we are going to see whether the contribution of these six industries are going to go up or is it the remaining part of the manufacturing industries that are going to go up. This is what we are going to study through the structural effect.

Now, you can notice that if the contribution of these mentioned six industries are going to go up then due to structural affect the energy use is likely to increase. Whereas, if the remaining manufacturing industries' output is going to relatively go up then energy use is going to decrease. Coming to the last part, this is an energy intensity effect. If the situation for the entire manufacturing sector is the same as what we can see in these three industries then of course, due to the energy intensity affect the energy consumption is going to come down because the production process has become more and more efficient but here we are talking about only three industries, it has to be true for all the manufacturing industries. This is how we conceptualize the activity effect, structural effect and energy intensity effect in the context of Indian manufacturing industries.

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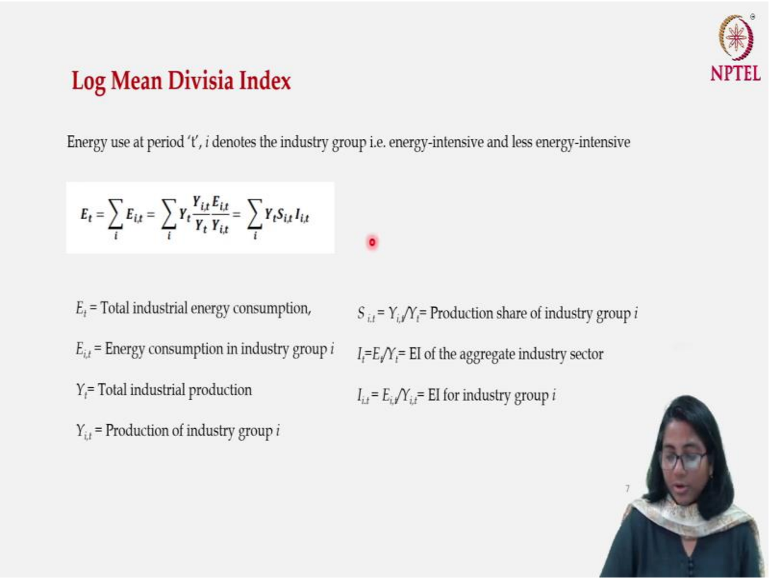

Now, let us see how we do the analysis? Coming to the theoretical formulation, this is one way of doing Index Decomposition Analysis and this is called Log Mean Divisia Index. What do we do here? We take Et where Et is the energy consumption for the Indian manufacturing sector at time point t so t denotes the time period. If I say Et this is the total energy demand of the manufacturing sector, I can write it as $\sum_i E_{it}$ where i stands for a particular industry.

This is a sum of energy consumed by the cement industry, steel industry, the fertilizer industry so on, and so forth. This is how I am breaking up the total energy consumption. Further, I write it as summation over i, Yt multiplied by Yit divided by Yt multiplied by Eit divided by it, then that again equates to summation Eit i.e.

$$E_t = \sum_i E_{it} = \sum_i Y_t \,(Y_{it}/Y_t)\,(E_{it}/Y_{it}),$$

Why? Because, if I write it in this way, these two Y_{it}'s can be cancelled, I can also cancel out these two Y_t's and therefore, simply left with E_{it}.

Now, what is the importance of writing down the total energy consumption in this manner, what does it facilitate? If you break down the energy consumption in this multiplicative form, you have Y_t which is the total amount manufactured by the Indian manufacturing industry so, this is the total output. So, one component becomes the total output.

What is Y_{it}/Y_t? This is the share of production of the i th industry or the i th group. Here we have two groups: one is energy-intensive and the other is less energy-intensive. Y_{it}/Y_t gives you the share of energy-intensive industries and the share of less energy-intensive industries.

What is E_{it}/Y_{it}? This is the energy consumption by the i th group divided by the production of i th group. You have the energy intensity of the i th group. By writing it down in this way we have three components of energy demand and in the previous slides we were discussing that there are three sources of change in energy demand.

Y_t will be able to capture the activity effect because Y_t is the output. By capturing the change in output, we will be able to capture the activity effect. Y_{it}/Y_t, we are writing it as Sit. This is giving the structure of the manufacturing sector and I_{it} is the energy intensity effect which we can capture through it. This is how we are going to write down the equation:

$$E_t = \sum_i E_{it} = \sum_i Y_t \, (Y_{it}/Y_t) \, (E_{it}/Y_{it}) = \sum_t Y_t \; S_{it} \; I_{it}$$

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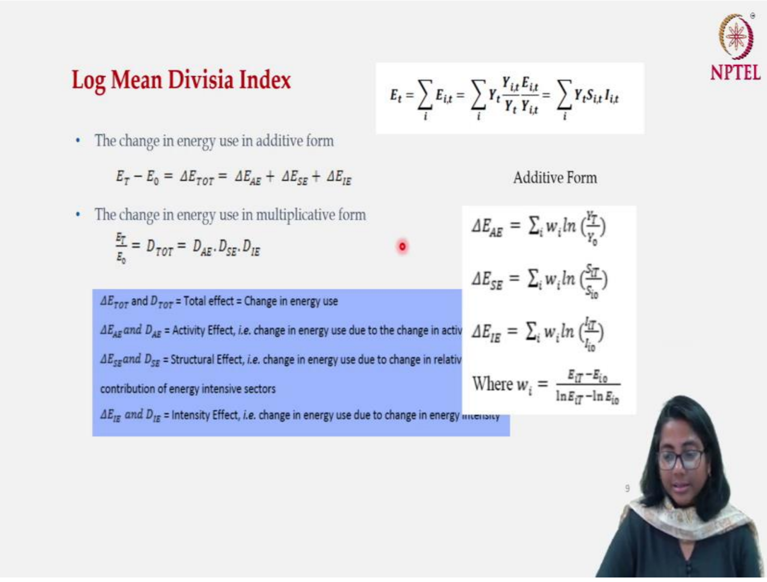

In the next step, we want to analyze the change in energy demand, we don't want only to break up the energy demand but what we essentially want is to understand the change in the energy demand. The change in the energy demand over a period of time from t_0 to t=T this is captured as $E_T - E_0$ which is equal to δE_{TOT}; TOT stands for the total. The total change in energy demand is equal to change in activity effect, change in the structure and change in energy demand due to the change in energy intensity. This is the activity effect; this is the structural effect and this is going to tell you about the energy intensity effect.

The total change in energy demand comes from these three sources. This is the additive form; you can also write it in multiplicative form. $E_T/_{E_0}$, tells us at what proportion the change is taking place. If you want to write it in that way then you have to write it in a multiplicative form. The activity effect multiplied by the structural effect multiplied by the energy intensity effect and this δE_{AE} activity effect and D_{AE} activity effect they look a little bit different. E_{AE} is the additive form and D_{AE} is the multiplicative form.

Now, what are the exact expressions for these things, activity effect, structural effect, and energy intensity effect? I am going to talk in detail about the additive form. And the interpretation for the multiplicative form is going to be quite similar and you can do that on your own. Coming to the additive form, if you want to calculate these effects under the additive form; the activity effect, the change in energy demand due to change in activity is given by

$\sum_i w_i \ ln\ (Y_t/Y_0)$.

Thus, the structural effect is given by $\sum_i w_i \ ln\ (S_{it}/S_{i0})$

and intensity effect is given by $\sum_i w_i \ ln\ (I_{it}/I_{i0})$.

This changed activity effect is telling you the change in output, the change in the structure, and about the change in the energy intensity. Now, this w_i is a new term here. w_i is given as:

$$w_i = (E_{iT} - E_{i0})/(ln\ E_{iT} \ - \ lnE_{i0})$$

What does the i stand for? Actually, in the case of this example you are going to get the value of two i's. So, maybe one is a weight for the energy-intensive sector and you can calculate the weight for the less energy-intensive sector.

And, then plug the values of these weights and calculate what is the energy intensity effect, what is the structural effect and what is the activity effect? Now, the good thing about this kind of Log Mean Divisia Index is that, if you add these three terms you will get $E_T - E_0$, no remainder is staying with us. This is a kind of additive form; it leaves nothing which is not interpreted. Any change in energy demand comes from either of these three sources.

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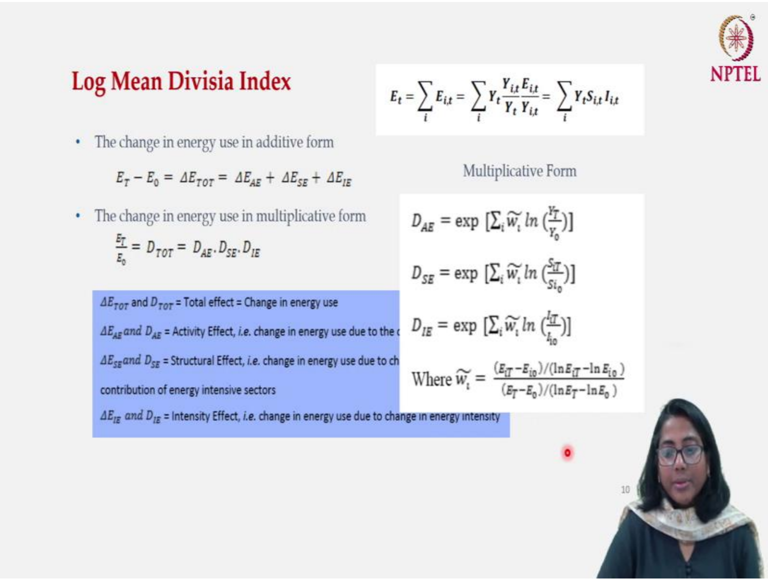

If you want to go by the multiplicative form then it looks like this. The expression has changed a little bit. Now, you have the exponential of this term. And the weights have also changed for multiplicative form. Things will become clearer if we go for an example.

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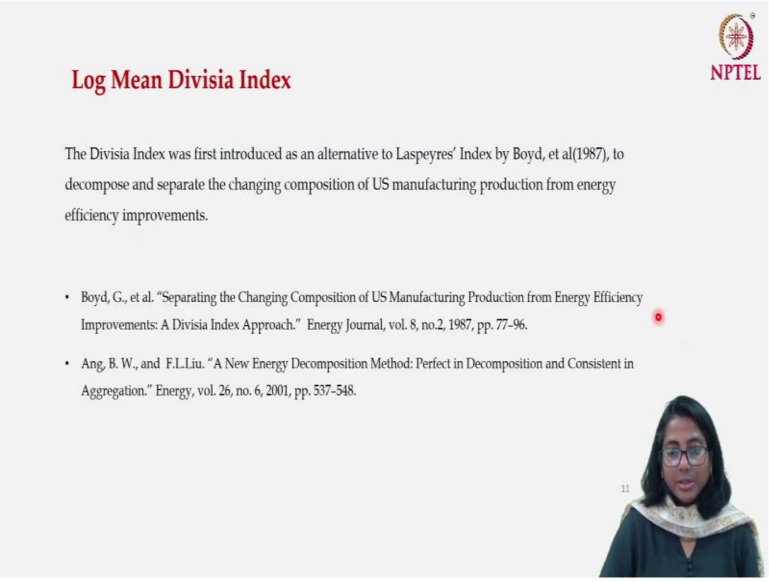

Before we move on to an example let me just give you a brief background of the Log Mean Divisia Index. This is an index number and before this index number was used to understand the decomposition of energy demand, there was Laspeyres' index, which was in use but in 1987 Boyd and his colleagues wrote a paper on, "Separating the changing composition of US manufacturing production from energy efficiency improvements" and there they used this kind of Divisia index method. After that, there was regular use of this particular method and this decomposition of energy demand came from various attributes. Another important article that can be referred to is by Ang and Liu.

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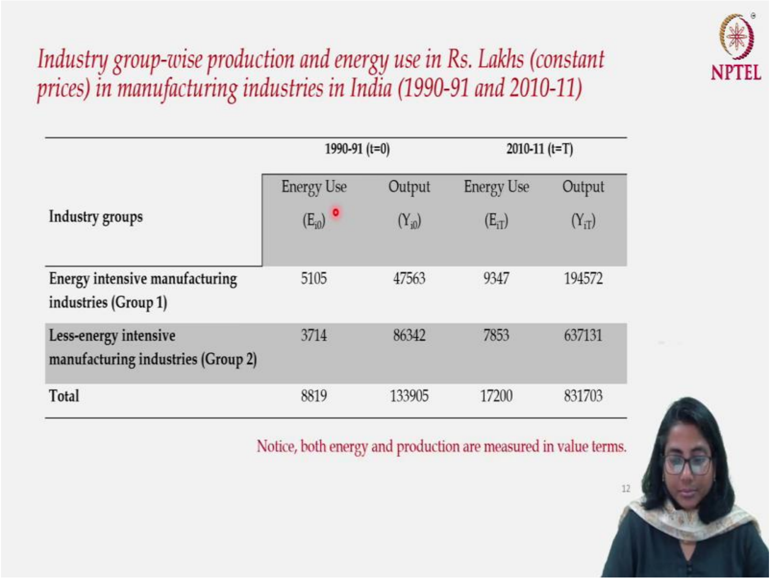

Industry groups	1990-91 (t=0) Energy Use (E_{i0})	Output (Y_{i0})	2010-11 (t=T) Energy Use (E_{iT})	Output (Y_{iT})
Energy intensive manufacturing industries (Group 1)	5105	47563	9347	194572
Less-energy intensive manufacturing industries (Group 2)	3714	86342	7853	637131
Total	8819	133905	17200	831703

Notice, both energy and production are measured in value terms.

We come back to the example where we are going to talk about the decomposition of energy demand in the manufacturing sector in India. And, the first thing that we need to understand, how do we define the structure of the manufacturing sector? There are two rows called group 1 and group 2. Group 1 is energy-intensive manufacturing industries, where we have 6 manufacturing industries that we have already talked about. And in the second group, we have the rest of the manufacturing industries who were called less energy-intensive manufacturing industries.

We have the information on energy use and on the output produced, for both the years 1990-91 and 2010-11. We need information on change in output, change in structure and energy intensity. Now, if you have information on energy input, energy use, and output, you can derive the other two. To understand the structure of the manufacturing sector we simply have to divide the output of group 1 by total output so, that gives you the structure of the economy.

If you want to understand what is the energy intensity, for group 1 you simply have to divide 5105 by 47563. If you are given information on energy use and output, you can derive the structure of the manufacturing sector and you can also derive the energy intensity of manufacturing sectors.

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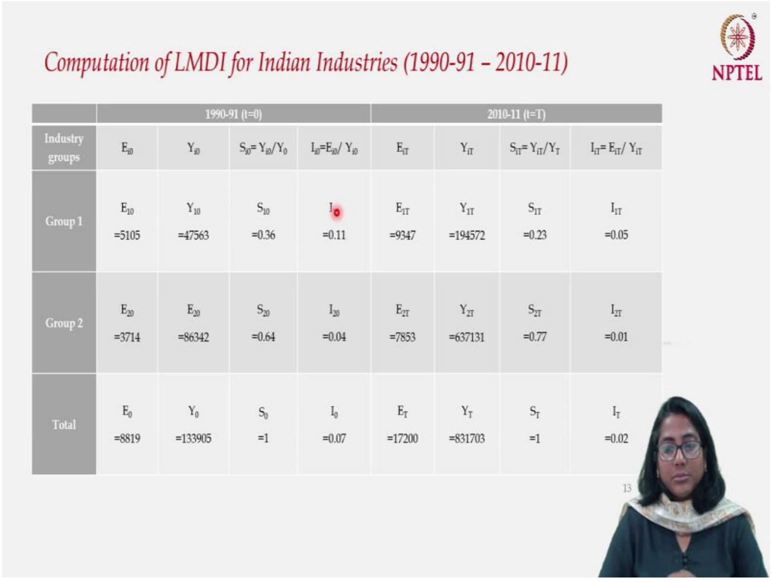

We come to this particular table, after doing all the calculations.

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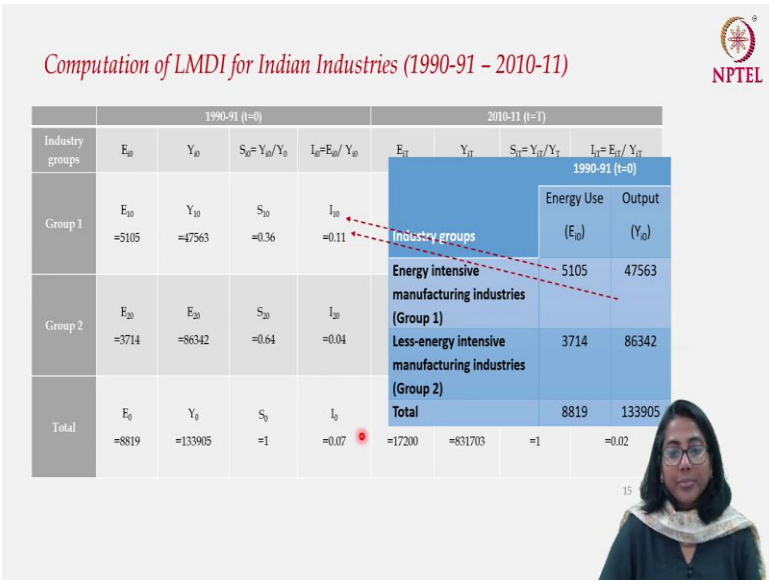

For the time period 1990-91 you have one column, this is telling you what is the total energy consumption of group 1, group 2 and total, what is the output of group 1, group 2 and total, what is the structure and what is the energy intensity? How do we make the calculation? Look at this number, this is telling you 36% of manufacturing production is coming from the energy-intensive industries and we have derived this by dividing this value by this value. This is the total manufacturing output from the energy-intensive industries.

This is telling us 36% is being produced by the energy-intensive industries. As a result, you can see 64% is being produced by the non-energy intensive industries in the year 1990-91. Next, if you come to the structure this value is derived from here. Third, if you come to the energy intensity for group 1, energy intensity is calculated based on these two values. 0.11 is $5105/_{47563}$. If you look at the energy intensity of the second sector, this will be $3714/_{86342}$ and this is the total energy intensity of the entire manufacturing sector. This is how you calculate the structure as well as the energy intensity.

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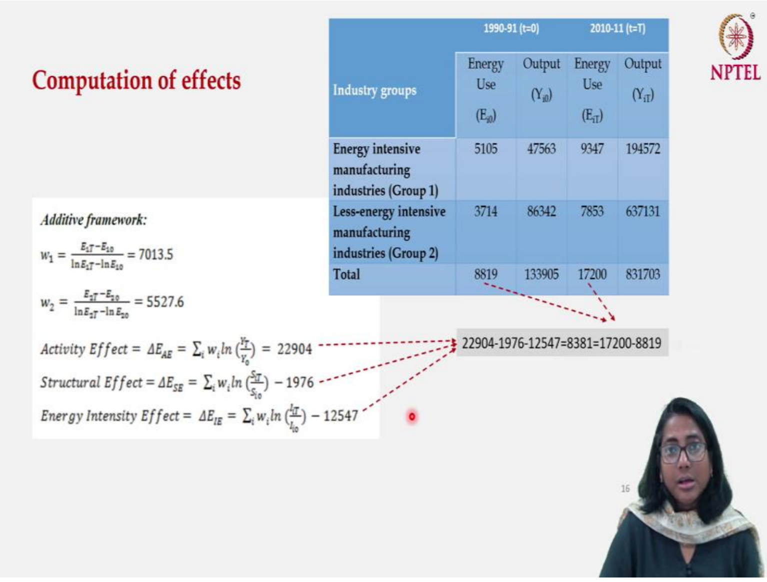

If you have that information, you have to calculate two weights. $w_1 = (E_{1T} - E_{10})$. Here you have E_{1T} in this box and this is your E_{10}. Here you see $(E_{iT} - E_{i0})/(ln\ E_{iT}\ - lnE_{i0})$. This is becoming the weight that you are going to use for your decomposition. Similarly, for the second group, the less energy-intensive industries, this is going to be the weight. Once you know the weight, you can easily calculate the activity effect, structural effect and energy intensity effect.

You are going to multiply this weight with $log\ (Y_T/_{Y_0})$ which again you are going to get from here. Here you have Y_T and here you have Y_0. This is going to tell you the value of activity effect, structural effect and energy intensity effect. This Y_T and Y_0 you are getting from here and here, for S_{iT} and S_{i0} you probably have to go back to the previous table and energy intensity also, you have the figures.

What do you need to observe? If you look at the activity effect it comes with a plus sign. This means that due to an increase in manufacturing production, other things remaining constant, the energy demand has gone up. That is why it has a plus sign. The structural effect has a minus sign, this means that due to structural effect, the energy use has gone down. It means that there is a shift from energy-intensive industries to less energy-intensive industries, structure-wise so that structure of the manufacturing sector has changed in favor of less/ low energy-intensive industries.

The third is the energy intensity effect, it comes with the minus signs and this is a big value. This means that over time Indian industries have achieved a lot of gains as they have reduced their energy intensity over time. These are the three effects. Now, if you add them up, if you add 22904 minus 1976 minus 12547, the value that you get is 8381. What is this value 8381? This is nothing but the difference between the energy consumption at two different points of time. You have decomposed the change in energy demand from 17200 to 8819 that is, 8381. 8381 is the change in energy demand and you have decomposed the change in energy demand into three parts. The change in energy demand due to change in activity, change in energy demand due to change in structure and the change in energy demand due to change in energy intensity. This is how you can carry out a decomposition analysis based on this Log Mean Divisia Index to understand the sources of change for the energy demand of a country or of any sector of the country for example, as done for the manufacturing sector.

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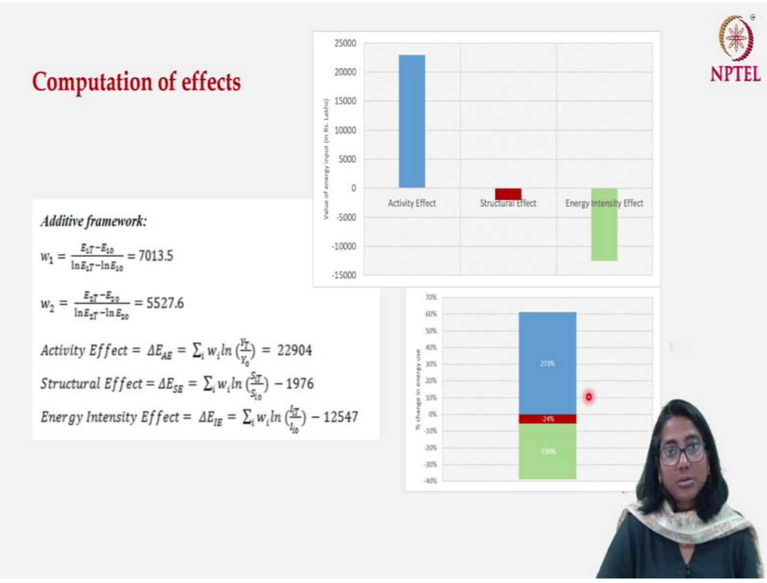

Before we go to the multiplicative format this is how you represent your result. As you add them up you are going to get the figure that we have discussed. This value, 8381 is divided between three bars. This is the increase in energy demand due to activity effect, this is 22904. 1976 is the reduction in energy demand due to structural effect; however, this is quite small. Although there is a shift in favor of less energy-intensive industries, the shift is not much and the third one is energy intensity effect. You can see there is a lot of decline in energy demand because of the reduction in energy intensity in these industries.

There is another interesting way in which you can represent your result which is through a stacked diagram. What does stacked diagram say? It says that had there been no change in structure as well as in energy intensity, energy demand would have grown by 273 percent of what it is now, considering the current change to be 100 percent, it would have been more than double the current change.

What is this structural effect and the energy intensity effect doing? They are trying to pull your energy demand down while the activity effect is trying to push your energy demand up. Now, what is the relative effect of these three sources is finally going to determine what is happening to your final energy demand. Here you see as a pull factor, the structural effect is contributing but it's not contributing greatly, it's a small amount of contribution.

However, energy intensity gain is contributing a lot. If you deduct this 24 and 150 from this 273 or you can say 274. This will be 100 percent. Had there been no structural effect and no energy intensity effect, the energy demand would have been double than what it is now. This is another way how you can represent this.

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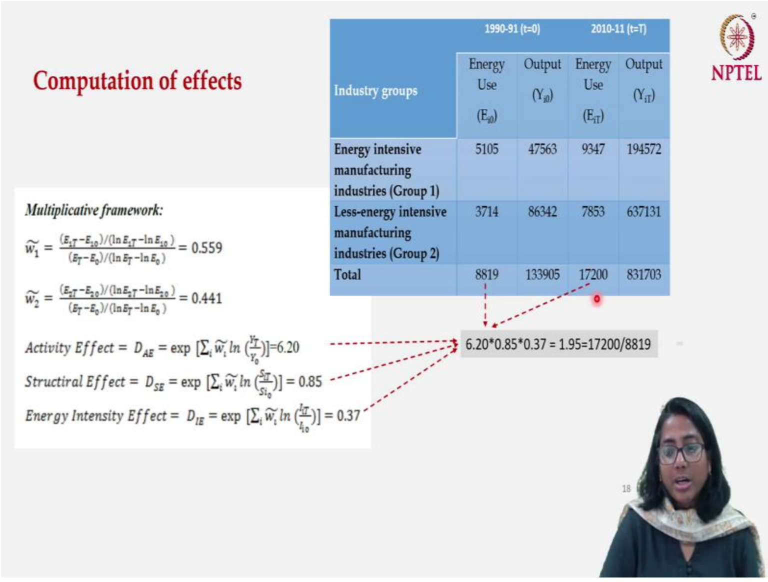

Let us have a quick look at the multiplicative framework and how we represent that. Here in the multiplicative form, you can see that the activity effect is captured by 6.20, the structural effect is 0.85 and the energy intensity effect is 0.37. Unlike the positive or negative sign, here we look at whether the value is more than 1 or less than 1. If the value is more than 1 that indicates the increase in energy use due to this particular effect. There is a 6-fold increase in energy use due to increase in activity. However, there is a reduction in energy demand due to structural change and energy intensity effect.

This corroborates the result that you get from your additive framework. And, we can cross-check? What do these figures mean? If you multiply these three values 6.2, 0.85 and 0.37, you get 1.95. This 1.95 is 17200 divided by 8819. So, 1.95 is the proportional increase in energy consumption over the years. You see the energy consumption has almost doubled. This 17200 is almost double the value of 8819 or specifically, it’s 1.95. This 1.95 is the proportional increase in energy demand which you should get once you multiply these three effects.

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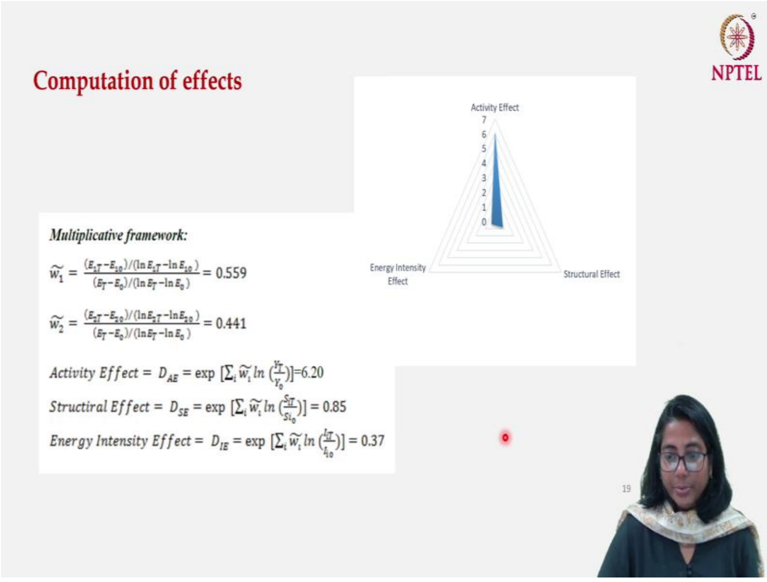

How do you represent that? It’s usually represented by this kind of a radar diagram, where you see, due to the structural effect it is declining, due to the energy intensity effect again it's declining and due to the activity effect, this is increasing. But they essentially tell you the same story. Meaning, if you carry out the additive framework there is no need to repeat it for the multiplicative framework. It’s the same story that is being told.

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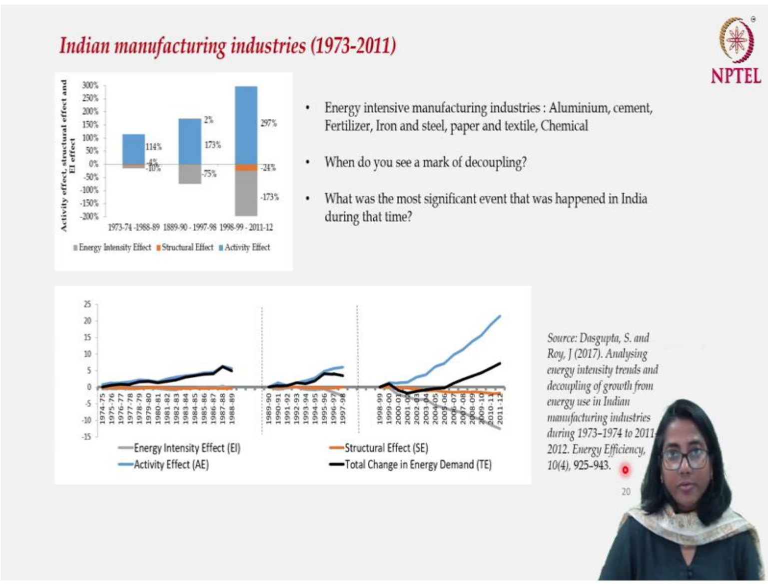

With the help of this kind of analysis, I will just brief you about one of the studies and in this study, we have taken the same industry group as the energy-intensive industries. And the rest of the manufacturing industries were considered as the less energy-intensive manufacturing industries and we have plotted the result of decomposition analysis in this manner. The periods are 1973-74 to 1988-89, 1989-90 to 1997-98 and 1998-99 to 2011-12 and what we see here is that the size of the bar is increasing. The energy demand is growing and that is obvious, but the interesting fact is that during 1973-74 to 1988-89, that is the early years represent the increase in energy demand due to an increase in industrial production. The push factor was quite important; whereas you see there is hardly any pull factor in terms of the gain in energy efficiency or in terms of structural change.

If you go to the next period 1989-90 to 1997-98, although structural change hardly plays any role, actually you see a little bit of orange strip here which says that there is a slight increase in energy use due to the structural change. However, the role of energy intensity effect increases. There is a lot of energy efficiency gain which is reducing the energy intensity of the manufacturing sector. And, as a result, the pull factor becomes more important. In this period the activity effect has gone up. However, a lot of the activity effect has been neutralized by a significant gain in energy efficiency.

Energy intensity has declined a lot in 1998-99 to 2011-12. Now, if this is the case let us again come back to the question of decoupling. What does decoupling mean? The decoupling means that there will be an increase in energy use because there is an activity growth; however, this increase in energy use should be nullified by some pull factors. If there is a lot of gain in terms of structural shift and there is a lot of gain in terms of energy intensity gain or energy efficiency, that will be in a position to nullify the increase in energy demand that is arising due to activity effect, that is the whole story.

We also try to understand the sign of decoupling. In the first phase, hardly anything is being neutralized whereas, in the second phase a part of energy demand is neutralized, in the third phase a bigger portion of energy demand is being neutralized. Now, the question comes from when do you start seeing the sign of decoupling? For that, we have plotted the data over the whole period of time.

Instead of plotting it for a period of time, we are doing the year-wise plotting of the activity effect, structural effect and the energy intensity effect and there is something interesting that you can see. This black line is giving the growth in energy demand, total energy demand without any implication for any effect. This black line is the increase in energy demand. What is the blue line? Blue line captures the growth in energy demand due to an increase in activity. If you look at the period 1973-74 to 1988-89, blue line and the black line are going hand in hand.

The entire growth in energy demand was due to the increase in activity. There was no decoupling of energy demand from the activity growth. If you look at this period up to point 1995-96, the blue line and black line are going hand in hand. Again, up to this point there is no decoupling. However, post-1995-96 the blackline has started coming down whereas, this blue line has started rising. This trend becomes even more prominent if you come to the recent period, the blue line is rising like anything whereas, the black line is much below the blue line. Why is it that? Because this is the total demand, this is the increase in energy demand due to activity.

However, out of this, a huge portion has been neutralized because of the gain in energy efficiency. If somebody asks that do you see a sign of decoupling? That answer is pretty much 'yes', we see a sign of decoupling in this period and this is one of the very important eras in Indian economic history, this is just the post-liberalization period. After this point of time, a lot of technology was brought into the manufacturing sector, where these technologies were able to bring a lot of energy efficiency. And that can be a cause of the decoupling of energy demand from the activity growth.

The last thing to observe, the structural effect does not play much role in the case of the Indian manufacturing sector. There was not a huge shift either in favor of energy-intensive sector or in favor of less energy-intensive sectors. You can go back to this particular reference if you want to know more about this decoupling story and the use of energy intensity.

This is where we are going to stop with the decomposition analysis and finally, we are going to devote some amount of time to the parametric approaches briefly. Here we will not go into much of the details of the theory but we will just see how results can be interpreted when you use certain parametric approaches to understand the energy demand.

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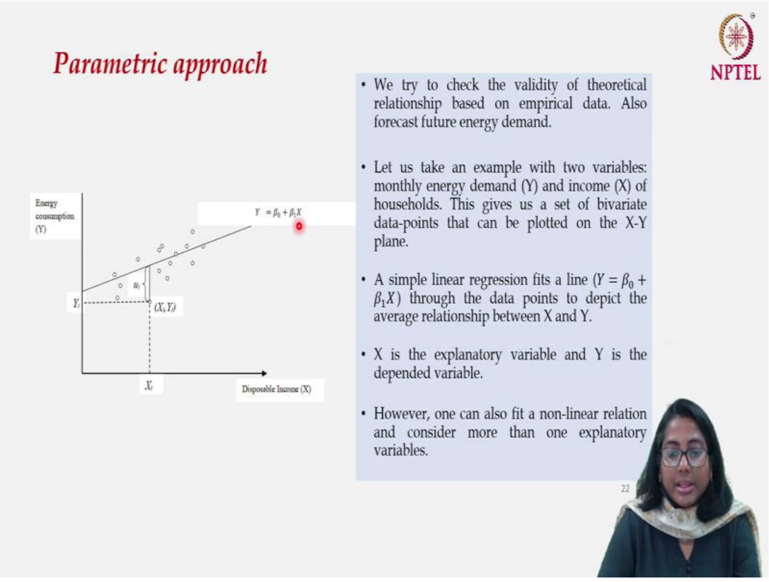

What is the parametric approach? We try to check the validity of the theoretical relationship based on the empirical data, also this framework can be used to do the forecast of future energy demand. For example, on the y-axis, we are plotting energy consumption and, on the x-axis, we are plotting disposable income. We have already discussed when we were talking about income elasticity, we tried to understand what is the responsiveness of energy demand to income?

We saw that in case of certain fuel you can expect a positive response that is as the income goes up, the consumption of that particular energy also goes up. You can think about it as LPG or electricity. What is this data telling you? Each of these points represent one particular household and they tell what is the disposable income of this particular household? If you take this point here $X_i Y_i$, this is telling you, the disposable income of this particular household is X_i and the energy consumption of this household is Y_i.

The same information is here for the rest of the households, each represented by one dot. Now, what do we want to do through parametric regression? We want to fit one line which captures the average relationship between energy consumption and disposable income. But, how do we fit the line? How do we come up with this particular line?

We come to this particular line by fitting a linear regression equation and in this framework, we call energy consumption as the dependent variable and X that is the disposable income as the explanatory variable. If I plot, if I fit a line the equation of the line can be represented as $Y = \beta_0 + \beta_1 X$.

Now, what is β_0 and $\beta_1 X$? We will just look into the next slide.

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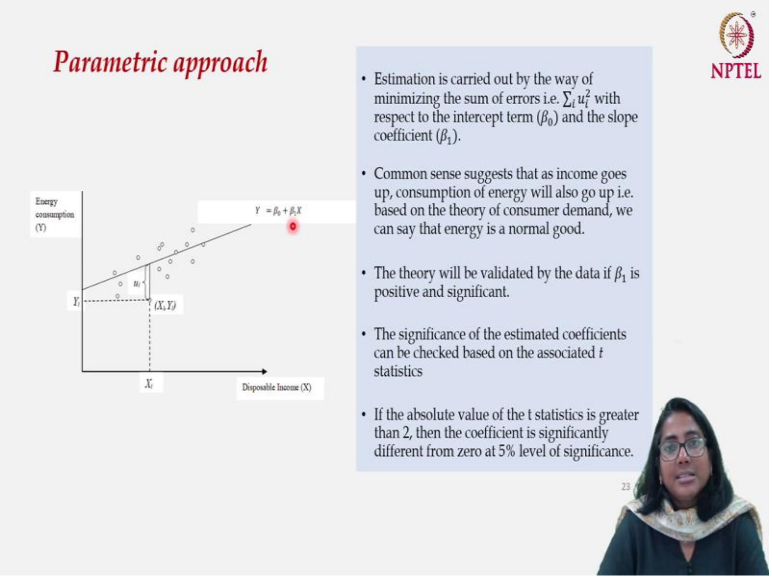

β_0 is the intercept term of this line and β_1 is giving the slope of the line. If I think about β_1 that is telling you what is the change in energy consumption if there is a change in disposable income. The slope of the line tells you the responsiveness of energy consumption to disposable income.

Coming to the question, how do we fit this line? If I think about this point (Xi, Yi) this is the original point that I have, this is the original disposable income and energy consumption of the household. However, when I am fitting the regression line which is depicting the average relationship, the line looks like this. If the disposable income is Xi than that particular household will consume Yi amount of energy. But if I try to depict it by the average relationship it shows that energy consumption is a bit higher.

And this difference between the average relation and the actual thing is called an error, which has been captured as ui. When we are fitting this line, we are trying to minimize the sum of squares of the errors. By minimizing $\sum ui^2$ with respect to β_0 and β_1, we are obtaining this particular line. As we have already discussed that for many of the energy sources, the common sense suggests that as income goes up the energy consumption of energy resources will also go up and this is what theory tells us. Now we are going to test it with the empirical data.

The empirical data will validate the theory, if I find that β_1 is positive and significant. This is the thing that I have to check for. Since this fitted line is positively sloped, I know that β_1 is positive but now I have to check whether this is significant or not. How do we understand whether this is significant or not? This β_1 under the null hypothesis, we test whether β_1 is equal to 0 for the population or not, that follows a t distribution. We try to obtain the t-statistic or the t-value for both the parameters, for both the statistic β_0 and β_1.

And if I find that the t-statistic for β_1 is the modulus value, the absolute value of the t-statistic is greater than 2; that means that beta is significant.

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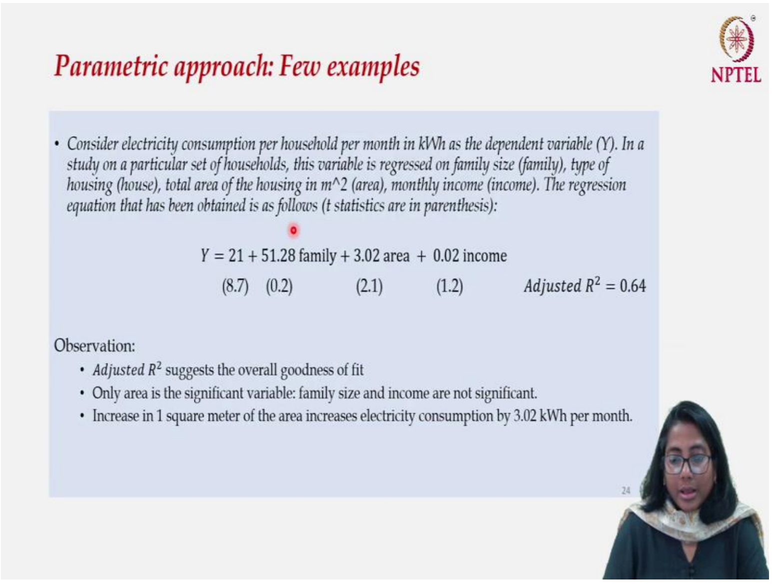

Let us now look at couple of examples. This is most important if you get the result of a particular exercise, how do you interpret that exercise within the parametric framework? This is a study carried out in some parts of the world and the results are a little modified here, they had a lot more variables. We are considering the electricity consumption per household per month in kilo Watt hour as the dependent variable. Y is the electricity consumption that is household electricity consumption. What are the explanatory variables? The explanatory variables are family size (so how many people are there in the family), the area of the house, and the income. Now, electricity consumption per month is regressed on family size, area, and income and this is the result that is obtained. What do we understand from the result? First, we look at the adjusted R square. The value of the adjusted R square is 0.64. This implies that 64 percent variation in Y, that is 64 percent variation in electricity consumption is explained by the variation of family size, area, and income. The overall goodness of fit is quite well.

The second observation, that we can make by looking at these values. These values in parenthesis, they are telling the t-statistics. Only for the explanatory variable area, the t-statistic is greater than 2 which implies area is the only significant variable explaining the household electricity consumption and neither family size nor income is significant. What is the next interpretation that we have? By looking at this value, 3.02, it says that if the area increases by 1 square meter, then the increase in energy consumption on an average will be 3.02 kilo Watt hour per month. This is the interpretation. This is how you can use simple regression equations to understand different aspects of energy demand.

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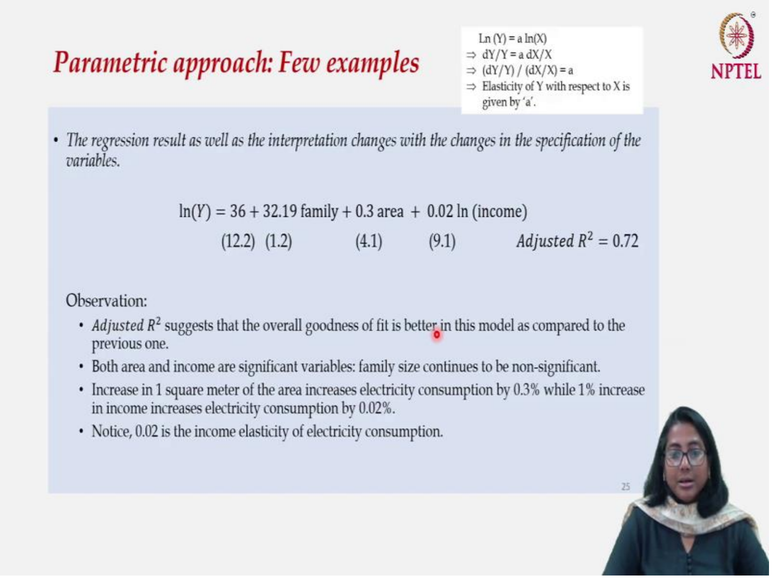

In the second example, the same kind explanatory and the dependent variables are used however the functional forms are tweaked a bit. Instead of using energy consumption as a Y variable, we are using the log of energy consumption. And we have a family size, area as we had in the last example and instead of using income, we are using a log of income. Here now what you see is that other than area, log of income also becomes significant.

Income and area - both these variables are now significant determinants of energy consumption. Here we can say that if the area increases by 1 square meter than per month energy consumption is going to go up by 0.3 percent. Notice here I am not saying that it's going to go up by 0.3 unit but I am going to say it's going to go up by 0.3 percent because I am using the log value here. If we come to the log of income, the coefficient of the log of income is 0.02 and the interpretation therefore is, if the income goes up by 1 percent then the electricity consumption will also go by 0.02 percent. Both things are expressed in terms of percent. Why am I doing so? Because, if you have a relationship like $log\ Y = a\ logX$ then, $dY/_Y = a\, dX/_X$. So,

$$\frac{dY/_Y}{dX/_X} = a$$

This if you can remember is the elasticity, percentage change in Y divided by percentage change in X. If you have a formulation where your dependent variable, as well as the explanatory variable both, are in terms of the log then this particular coefficient will give you the elasticity value. 0.02 is the income elasticity of energy consumption for households in this model.

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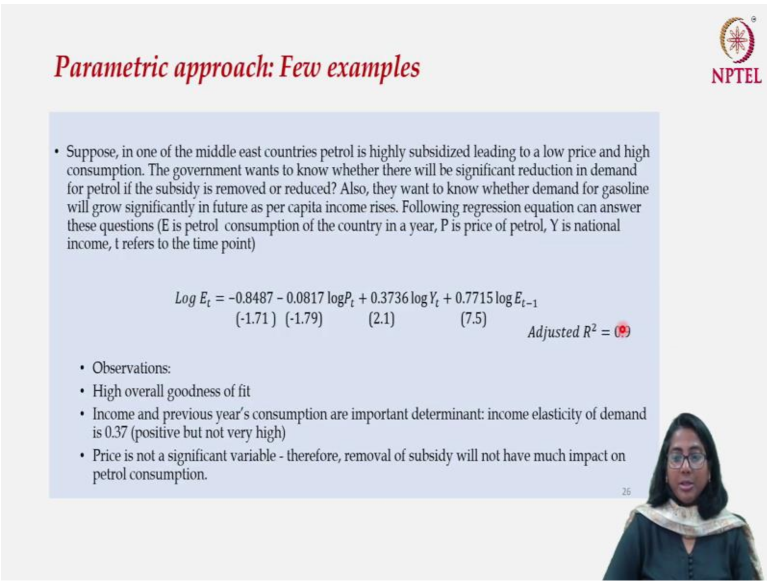

Coming to the next and the final example, this is the result of one of the middle east countries, and this example we have also used in some previous slides where gasoline is highly subsidized. The price of petrol is very low because petrol has been subsidized and therefore the energy consumption has gone up like anything. Now, the government wants to know whether there will be a significant reduction in demand for petrol if the subsidy is removed or reduced.

Also, they want to know whether the gasoline demand will grow significantly in the future as per capita income rises. The following regression equation can answer this question. What is the regression equation? Here, log Et is the energy demand of this country at a particular point of time t. This is being regressed on log of Pt, Pt is the price of gasoline or the price of petrol at the same point of time. Then you have a log of Yt which is the income here, don't confuse it with the previous Yt where Yt stood for electricity consumption, here Yt is the income.

We are taking a log of Yt. This is the previous year's demand; this is the lagged regression model that we are estimating. If the coefficient for the price is not significant and -0.0817 is the own-price elasticity of gasoline in this country which is not very high. Not only it's not very high, the other thing is that it's not significant at all.

So, even if there is a change in the subsidy policy, even if you remove the subsidy and the price is increased, it's unlikely to have a great impact on demand. If you want to reduce the demand for gasoline in this particular country removal of subsidy or changing the price is not going to give you the result. What will give you the result? As income increases, energy consumption also increases. Energy is a normal good here and significantly increases with an increase in income.

And 0.3736 is the income elasticity of energy demand. As the income grows, they will anyway buy more and more gasoline irrespective of what intervention you do in the price sphere, whether you remove the subsidy or not and this is again a significant variable. Obviously, the lagged value of energy consumption is going to impact today's energy consumption.

This way it gives you a very important policy implication that price is not the channel for intervention if you want to get results in terms of reduced energy demand. You have to do it in some other way because as income increases, the consumption of petrol will increase in this particular country.

We are going to stop here. In the next week, we are going to come back with some more topics under energy demand and we will discuss some of the policies that are useful and implemented in the context of energy demand.

Thank you.