Energy Resources, Economics and Environment.
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Lecture-18.
Input/Output Analysis-Part 1.

We are now starting with a new topic, we are going to talk about input output analysis and its application to energy systems. We have looked at, at the level of the different projects, how to do the economic calculation to look at the environmental impacts, we now want to see what is an overall impact at a larger scale, at the societal level and for a city for a region for a country and for this, there are different ways in which we do energy economic models.

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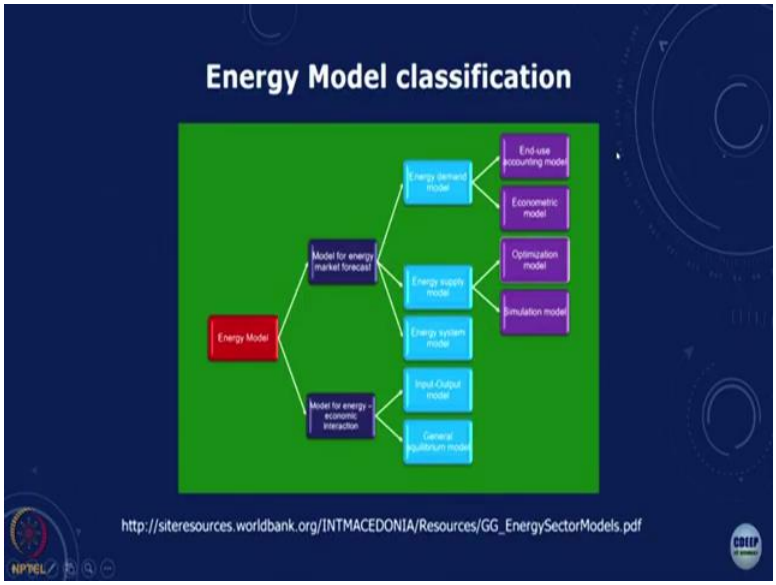

So, we have different types of energy economic models, the questions that we would like to see is that what if we replaced all our thermal power plants with renewables? What would be the impact not just on the energy sector, but overall on the economy? What would it mean in terms of the investments, what would it mean in terms of the prices, what would it mean in terms of the jobs, what would be the kind of macroeconomic methods? So, then there are different kinds of models which are available in literature.

And there could be models by which we are looking at the energy economic interactions and these typically could be classified the simplest kind of model is the input output model, which is what we will study. There are also optimization models and simulation models. There are models like Markal and there are models which are computable general equilibrium models

and then there are models for estimating the demand based on end use accounting and the econometric models.

So, there are a whole host of different models and in this course, we will have time to only look at one type of model. We will talk about the input output model, which will give us a way in which we can analyze the impacts of the energy sector on the rest of the economy.

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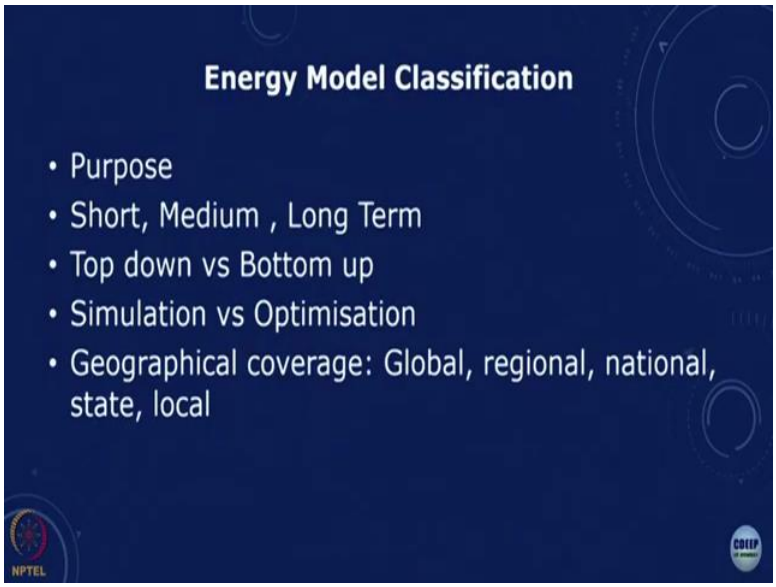

The models can be classified depending on the purpose, are we using it for one particular sector, are we using it for the overall economy do we want to see what happens if there are different growth rates. We can look at it in terms of short medium long term and obviously, in the short term, what would happen is all the coefficient to remain more or less constant, in the medium term, we can make changes in a variety of things and in the long term, many more things can be changed.

The models can be also classified as top down versus bottom up. Top down means that we look at an aggregate for the entire country as a whole or the entire world as a whole or for the state and then make an estimation, then based on that, we then work out what will be the impacts at different sections. A bottom up is where we start looking at different end users, the different sectors, look at the residential, the commercial, industrial, and for each one we have assumptions of different technologies and then build up by taking an aggregation what is the overall picture.

Then models can be also classified as simulation versus optimization. In the case of simulation, everything is specified and we would just like to know what if, what if we did it this way, look

at all the technology and the systems and then work out what would be the cost etc. and optimization is where we have some degree of freedom and there are decision variables that we can choose and then we can see what is an optimal.

We can minimize the total sum of costs or minimize the emissions are maximize the revenue and things like that. So, this is another way in which we can classify. We can also classify based on the geographical coverage. At the highest level is the world model, we can have regional models, we can have national models, state models and local models.

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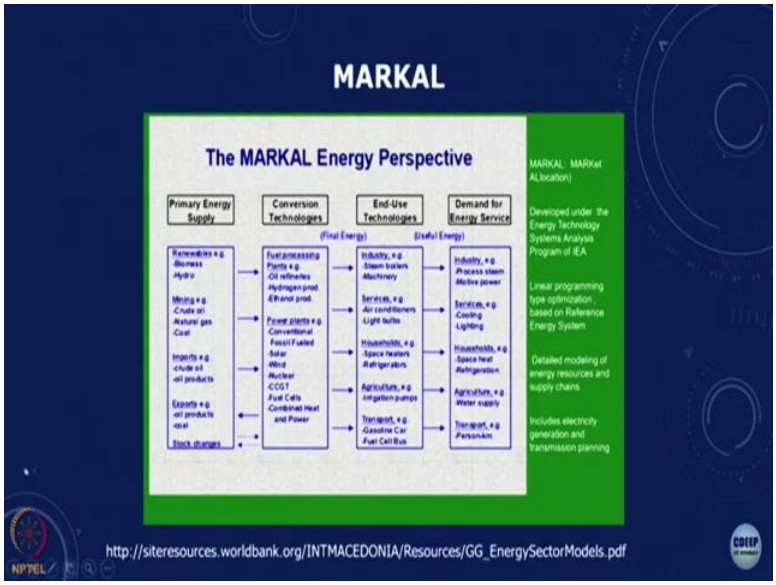

I talked to you about this model, which is there, this is called the market allocation model, which is a bottom up kind of model, starts from with a reference energy system with the primary energy, then the conversion technologies they induce and then the demand and then you can have either with some assumptions, it results in a linear programming kind of framework or it could have based on if there are nonlinearities then we can have a mixed integer kind of, if there are discrete variable.

So, there are various ways in which we can optimize and the detailed modeling can be done and you can see, there are many papers where this has been applied to India, for the world for many different countries of the world.

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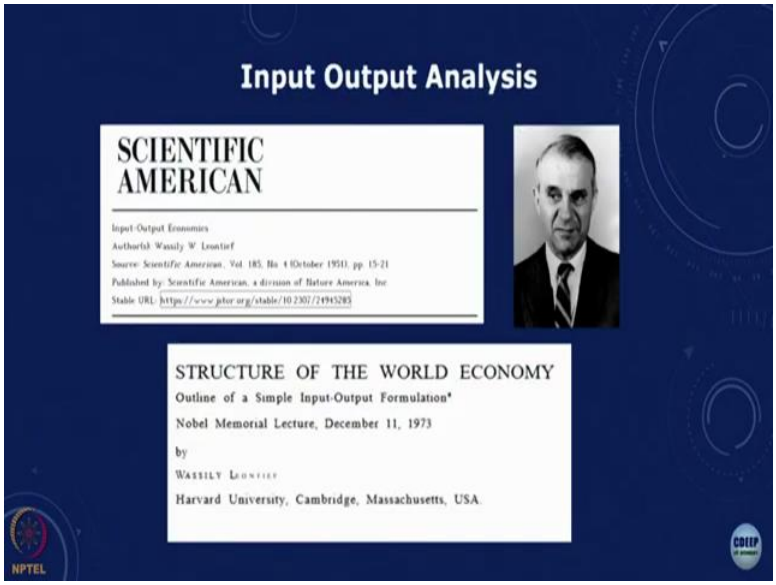

The model that we are going to talk about is the input output analysis and this was proposed by Wassily Leontief way back in the 1930s, where he initially proposed it, and then he used this methodology to extend the date to develop an input output model for the US and this was done, there is a paper in Scientific American, it is available in the public domain and you can take a look at it. This will give you an idea of exactly how the original work was done, where he talked about the entire industry flows.

And Leontief got the Nobel Prize in Economics for his work and this was given in 1970s, 1973 and you can see the Nobel lecture that he proposed, where he created a simple aggregate model of the world economy and divided it into developed countries and less developed countries, and then saw what would happen in terms of investments and pollution, and looking at the possibilities of trying to reduce pollution and the investments in industry as well as in pollution.

So, they had created a set of interesting scenarios. This is also available in the public domain and I would urge you to look at both these papers that will give you an idea of the historical development of this method. So, I am going to quickly go through some of these data and tables which were shown in these papers, which will give you that initial idea and then we will, from first principles, develop the theory of the input output analysis and show how it can be used for the energy sector.

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So, this is the sequence in which we… So, this is the paper, the Scientific American paper input output economics and he said that we are concerning a new method which can portray both an entire economy and its fine structure by plotting the production of each industry against its consumption from every other sector.

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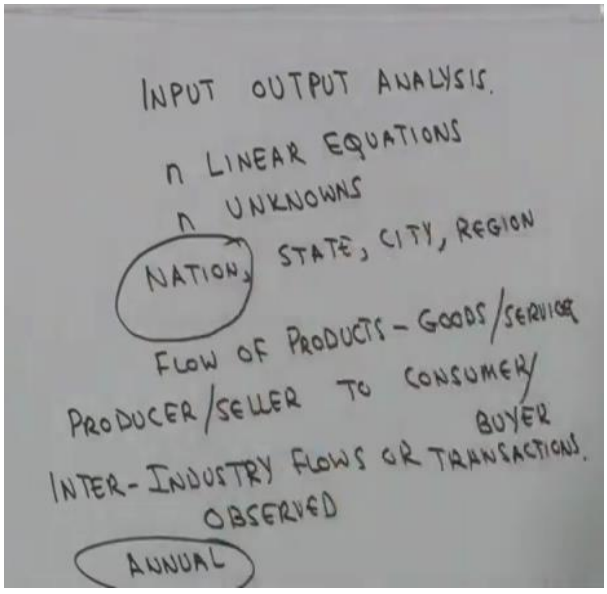

So, typically the input output method, input output analysis as proposed by Leontief, finally, results in a set of n linear equations in n unknowns. And that is, the beauty of the method is its simplicity, we can say start with what Leontief said is that there was data of the economic activity of and we can look at a region which could be a country, it could be a state, it could be

a city or it could be a region. Typically, of course, this would be have to be data, an entity for which the data is usually available.

So, usually at the country level is where the data is available. So, in any economy there will be the flow of products or goods and services, that means goods and services. So, this is, these flows are also called these will be from the producer or the seller to the consumer or the buyer and even at that time when he did this paper in the 50s and in the 1940s, the economy was being tracked.

So, what we have to do is we have to take this, this will be the inter sectoral or the inter industry flows or transactions which are actually observed and this is observed for a period. This is observed for a period and typically that period is a year, is an annual. So, this could be either the calendar year or in many cases, for instance in the Indian case we will talk about the financial year. The financial years starts from 1st April to March 31st. So, you will say 2018-19 2019-20 and so on.

And so, based on this, we will have different producers and sellers, different consumers and buyers and every good, if we talk about a particular good, for instance, if you look at steel, steel is being manufactured by the steel industry, that steel is being used by different sectors, let us say in the automobile industry.

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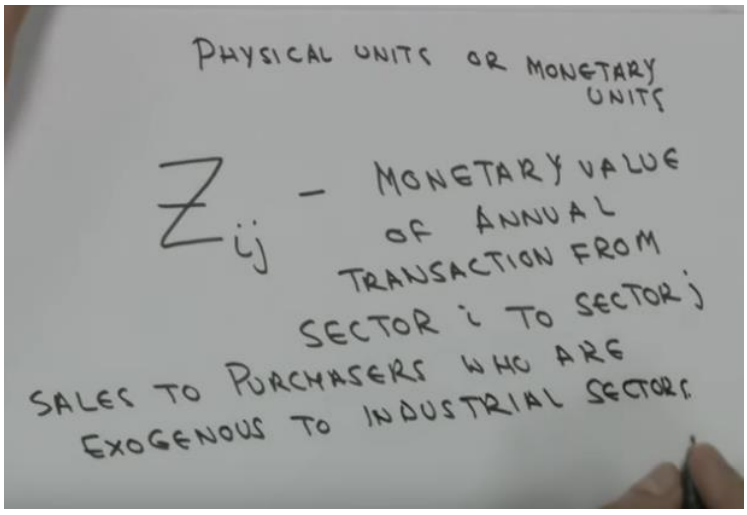

And so, we can replay we can talk about this in either physical units or monetary units and, if you think about it, if we are talking of so many tons or so many for an economy over the year, so many million tons of steel which are being produced. And then we will talk about so many million tons of cement which are being produced and so many million kilowatt hour of

electricity which is being produced and so on. But when we compare the different things and we add them all up, it is difficult to have multiple physical units.

So, one of the best ways to do that is take the physical unit, multiply it by the price or the value which is there, so you get it all in terms of monetary terms. And that is typically the way in which these transactions are put. So, essentially what we have is we can put each transaction as Z ij, which is the monetary value of the annual transaction from sector i, which is the producer, to sector j.

And so, if you look at one sector, if you are looking at steel, steel is being used for the power sector, steel is being used for the cement sector. So, there are inter industry, internally the output of one sector is being used in the other sectors. In addition to this, there is a sales to purchasers, who are exogenous, purchasers who are external to the industrial sector.

That means purchasers who are not having any production, who are exogenous to the, and that will be the final demand, exogenous to the industrial sectors. This will be the external demand and this will, who are not, they are not producers.

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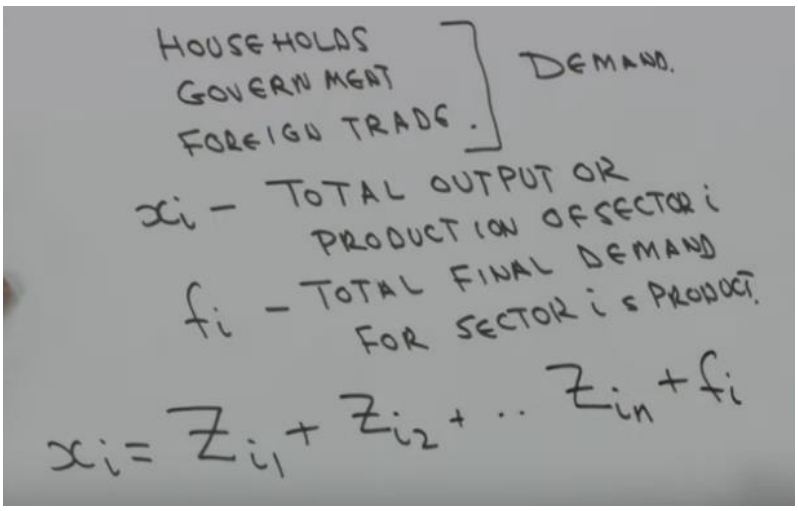

So, these would typically, these sectors would be households, government or maybe you are exporting it, foreign trade. So, these, this is the external demand. So, if we look at xi as the total output or production of sector i or production of sector i and fi is the total final demand for sector i's product, we can write a balance equation which is xi is Z i1, from i to the first sector and then there are n such sectors Zi2 + n so on Zin + fi.

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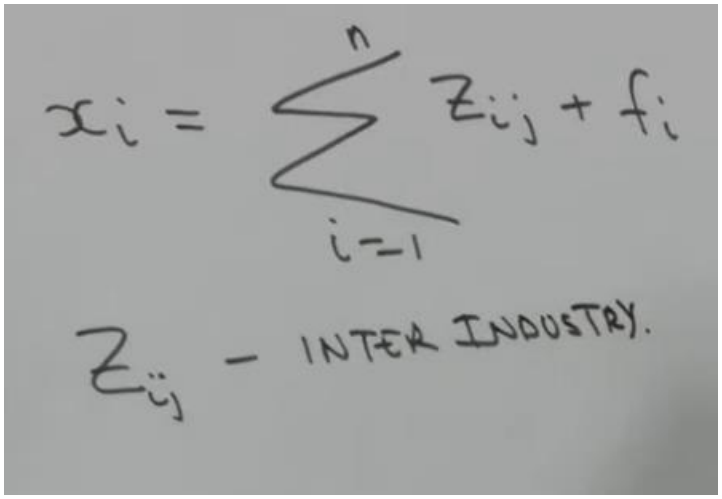

So, we can write this as xi, Z ij plus fi, where Zij are the inter industry flows, transactions in money terms. Inter industry flows or transaction.

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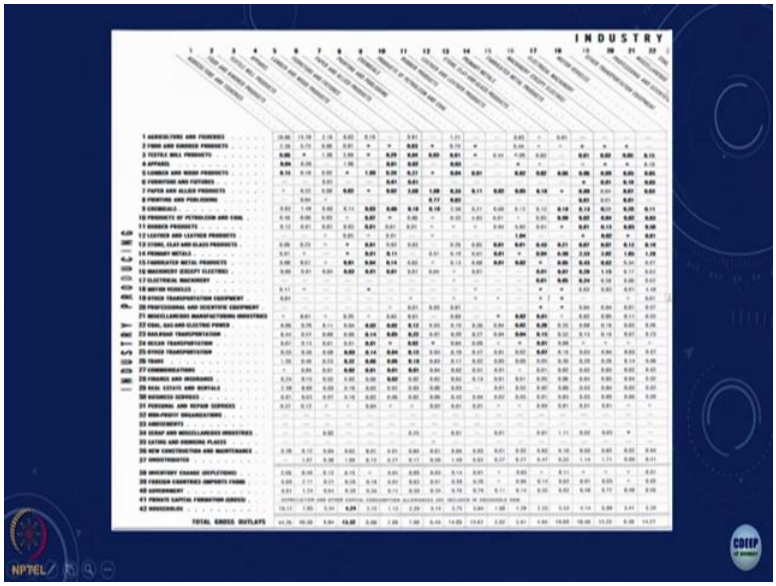

So, let us see how this was represented in the paper by Leontief in Scientific American, you can this is not very clear here, there are small items and we will explain this. You can see this in the paper, large number of sectors and in each of these from one sector to the other sectors, these are the kind of industry flows.

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So, if you look at the types of sectors, we are talking about agriculture and fisheries, food and Kindred products, textile mills, apparel and so on and each of these sectors, these are the i's which we are talking. From each sector the agricultural products are used in the other sectors and so that those transactions are represented in this matrix.

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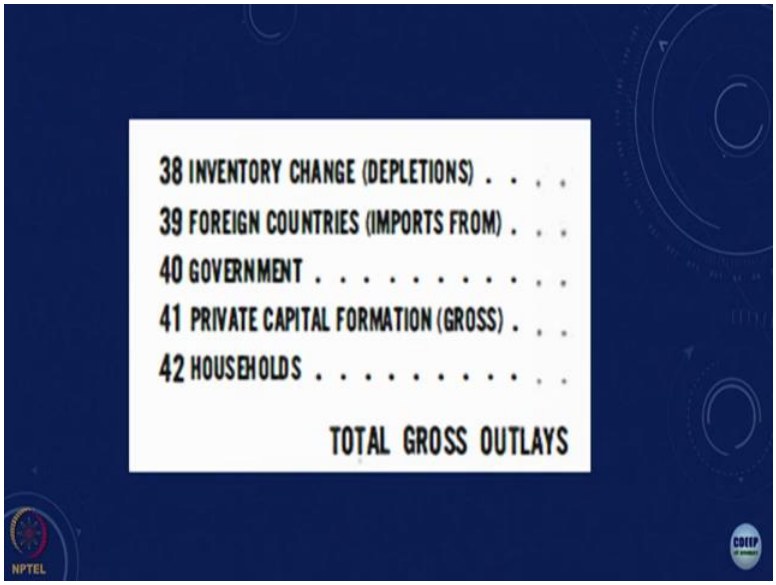

And then, we also talked about the final demand and the final demand if you see foreign countries, government, households and the private capital formation.

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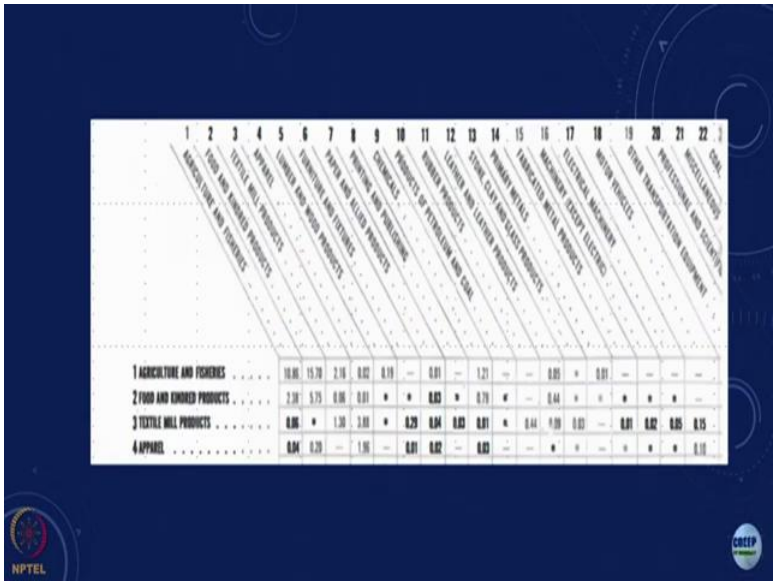

And this is a sort of in more detail, you can see each of these sectors and from the sector to the other sector, this is the transaction matrix. From agriculture to agriculture and fisheries, some of the products are used internally. For instance, if we look at electricity sector and we look at the electricity which is used within the electricity sector that would be like the auxiliary consumption of the power plants.

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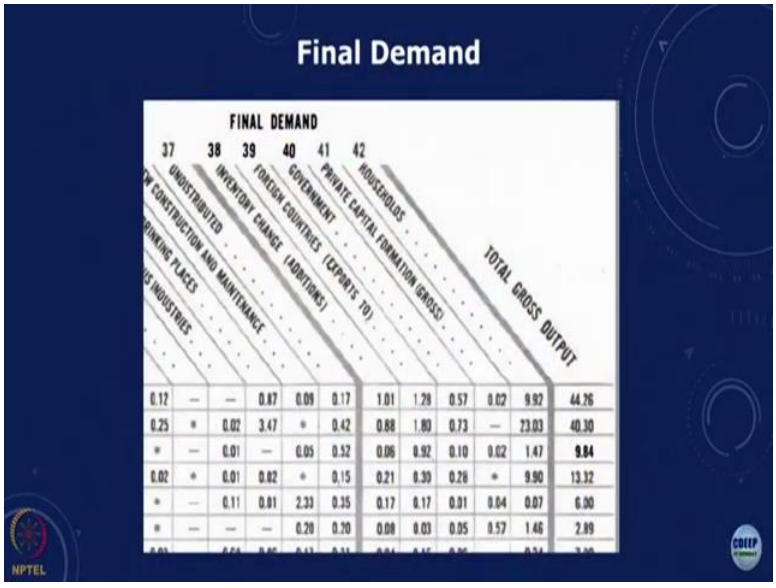

And so, this is the way in which these transactions and then we talked about the final demand. And when we sum this all up, this will be equal to the total gross output or the xi that we had. And this is the final demand, these are the internal demands.

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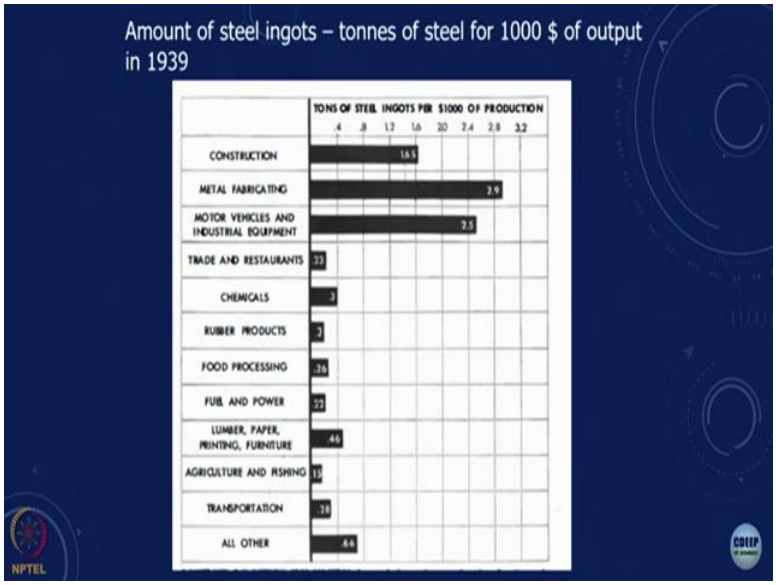

And similarly, we had this kind of curve. With this, what the paper showed is that for some of the sectors, it illustrates, what it can do, and this was done, this is a 1950 paper using the data for 1939. It is the tons of steel for a certain amount of output, which is there and you can see tons of steel ingot per thousand dollars of production of each of these sectors. So, if you look at the construction sector, in the metal fabrication, the motor vehicles and sector, these are the three main sectors and relatively less for the others.

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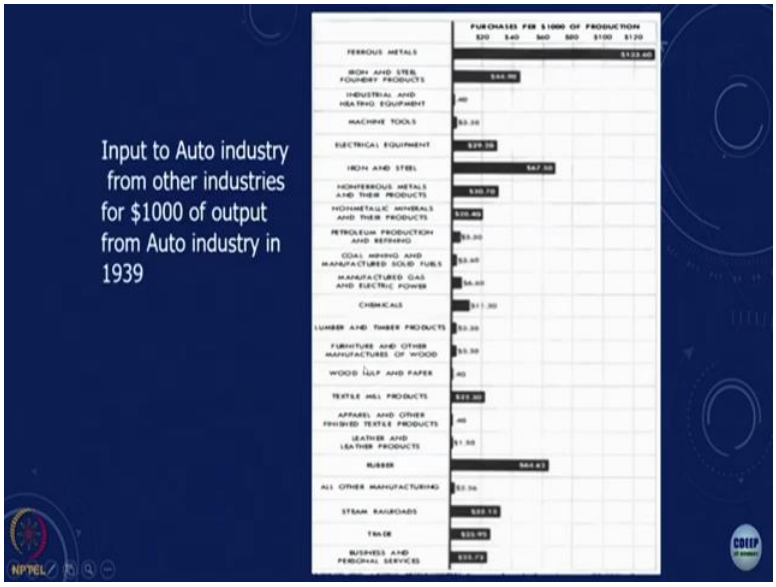

We can also look at, for the automobile industry, what are the per thousand dollars of output of the auto industry, how much is the input and you can see the ferrous metals is the main input and then you have all of these. So, these are some of the illustration of the kind of things.

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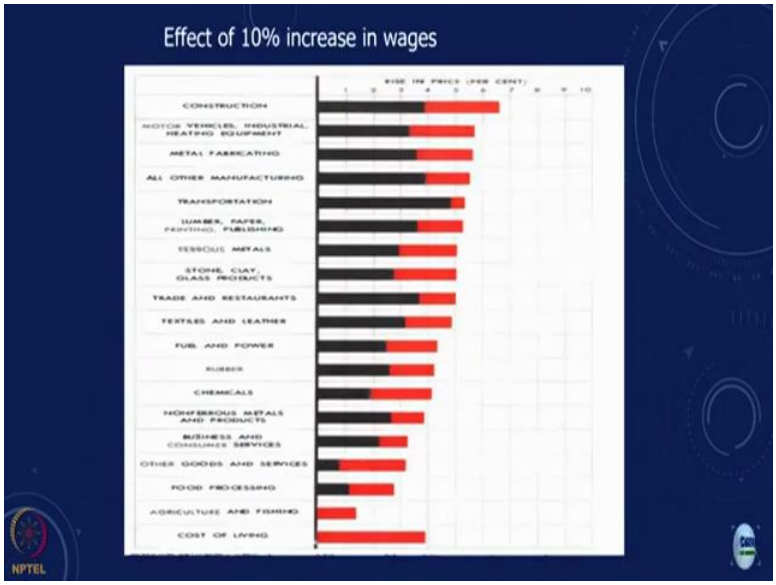

And then Leontief used this for static economy wide, US wide mapping of all the inter industry transactions and then he wanted to illustrate that what happens if we have a 10 percent increase in the salaries or the wages and how would that affect the overall economy and then showed the impact on different sectors.

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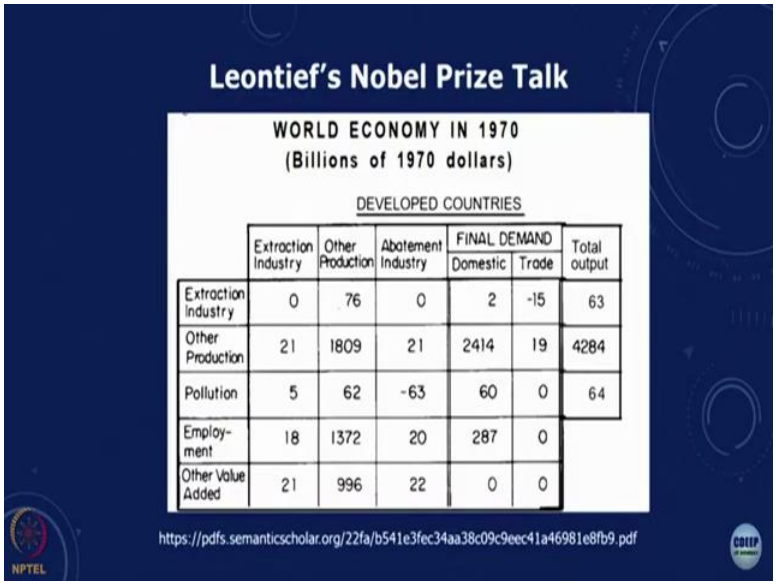

	Extraction Industry	Other Production	Abatement Industry	FINAL DEMAND		Total output
				Domestic	Trade	
Extraction Industry	0	76	0	2	-15	63
Other Production	21	1809	21	2414	19	4284
Pollution	5	62	-63	60	0	64
Employ-ment	18	1372	20	287	0	
Other Value Added	21	996	22	0	0	

Leontief's other paper, which was part of the Nobel Economics Prize Talk, he talked about in this case, this was a talk given in 1973, he estimated and built up input output framework for the world as a whole. For the world, he divided it into developed and developing countries. And in this he aggregated it in terms of extraction industry, other production, and then pollution

and then the employment and value add and then looked at the transactions in billions of dollars from each of these sectors.

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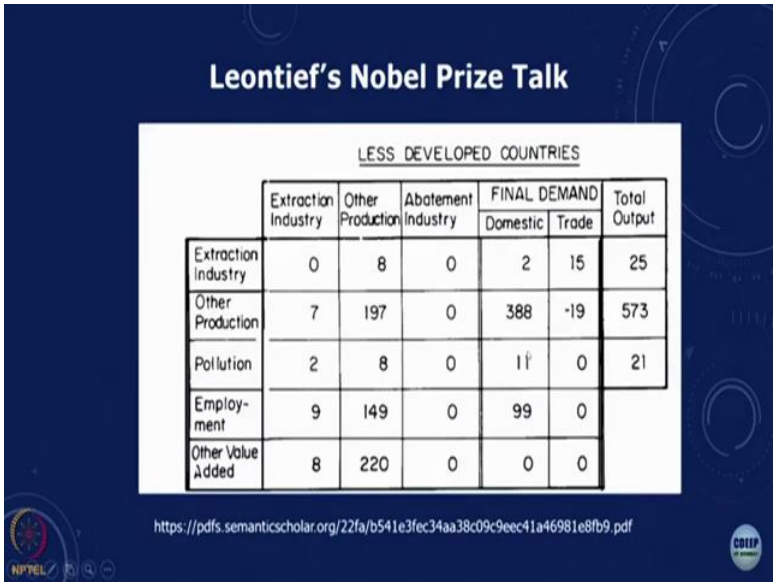
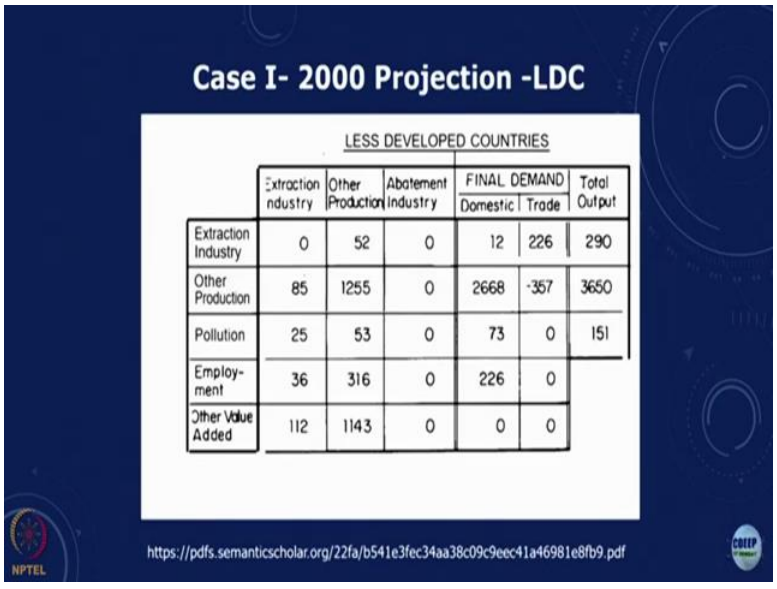


	Extraction Industry	Other Production	Abatement Industry	FINAL DEMAND		Total Output
				Domestic	Trade	
Extraction Industry	0	8	0	2	15	25
Other Production	7	197	0	388	-19	573
Pollution	2	8	0	11	0	21
Employ-ment	9	149	0	99	0	
Other Value Added	8	220	0	0	0	



	Extraction ndustry	Other Production	Abatement Industry	FINAL DEMAND		Total Output
				Domestic	Trade	
Extraction Industry	0	52	0	12	226	290
Other Production	85	1255	0	2668	-357	3650
Pollution	25	53	0	73	0	151
Employ-ment	36	316	0	226	0	
Other Value Added	112	1143	0	0	0	

And similar kind of thing was done for the less developed countries and then based on this, he created different scenarios. And there was one scenario for the less developed countries where you had not that much production.

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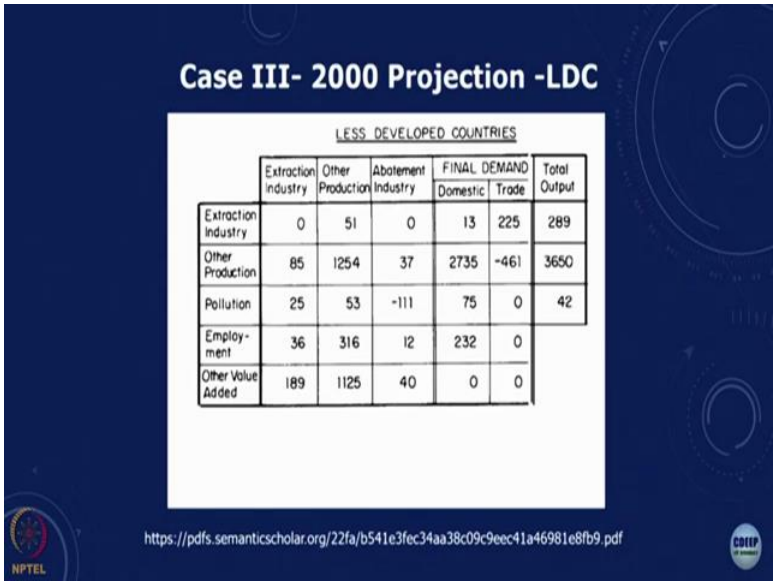

	Extraction Industry	Other Production	Abatement Industry	FINAL DEMAND		Total Output
				Domestic	Trade	
Extraction Industry	0	51	0	13	225	289
Other Production	85	1254	37	2735	-461	3650
Pollution	25	53	-111	75	0	42
Employ-ment	36	316	12	232	0	
Other Value Added	189	1125	40	0	0	

The other one was where you had a large amount of pollution control in the less developed countries and with these scenarios used, showed the power of the method. And I would suggest you look at the details of this paper and that would give you an idea of how this methodology can be used.

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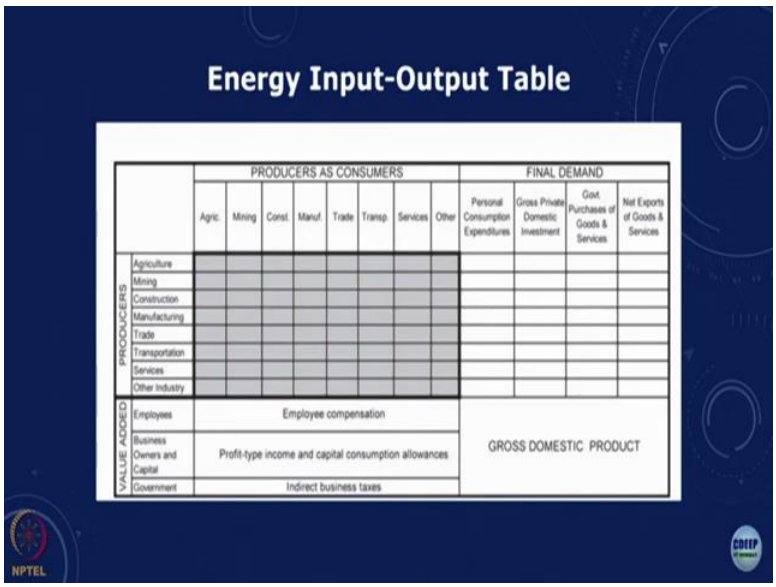

In general finally, when we look at the input output table that is there, this is from the book by Blair and Miller, you can look at the book on input output analysis, the second edition, we will see different kinds of producers and then the final demand. And in addition to this, so we look at this it typically agriculture, mining, construction, manufacturing, all of this will have, you have a matrix where it goes agriculture to agriculture, agriculture to mining and so on.

In addition to this is the salaries that we pay, the taxes that we pay to the government and anything in terms of the profits, etc. So, all of this together, if you look at the entire transactions we can get, if you look at overall, this will give us any indication of an estimation of the gross domestic product.