

Business and Sustainable Development
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Lecture - 05
Environment, Human and Economy


Hi, welcome to the session on Environment, Human, Economy, Exploring Links in Model. So, in this session, we will try to see how these models listed over here, how they are creating a link between human, environment and economy.

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And also we will see that how the sustainability how it is being presented from the economics viewpoint where we will operationalize two type of sustainability that is weak sustainability and strong sustainability.

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$I = PAT$

IPAT Equation: To estimate the impact of human lifestyles on Earth

Environmental Impact = Population x Affluence x Technology

- Population = size of population
- Affluence = Lifestyle related choices, consumption habits of an individual
- Technology = advancement in technology

Oversimplification of the problem

So, to start with let us see what the first model which is creating a link between human, environment and economy. So, this is known as IPAT. And the equation is environmental impact, which is equal to population affluence and technology. So, the impact stands for I, P stands for population, A stands for affluence, and T stands for technology.

Now, this IPAT equation is use to estimate the impact of human lifestyle on earth. Now, how do we represent these different variables? Population, this gives us the size of population. Affluence – lifestyle related choices, mostly the consumption habit of an individual which for those guided by the fact that how much the individual earns or the income.

And technology is that what is the advance and advancement in technology these are represented through this variable technology. So, there are critics over this model is that everyone finds that the impact or the problem altogether is oversimplified through this IPAT equation.

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$I = PAT1 + PAT2 + PAT3$

First World	Second World	Third World
Highly Developed nations	Transition nations	Poor nations

- First World
 - Relatively clean technologies and stable population; problem is affluence (A1)
- Second World
 - Moderate affluence but dirty technologies (T2) and, for some, population (P2)
- Third World
 - Very little affluence, some dirty technology (T3) and high population (P3)

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Now, let us see how do we; how do we operationalize this or how we understand this IPAT equation and the context of different countries. So, if you look at the entire impact is divided into three PATs that is PAT1, PAT2, and PAT3. We consider the PAT1 impact is comes from the First World that is highly developed nation. PAT2 is from the Second World that is transit transition nation. And Third World, PAT3, PAT3 is from the Third World that is from the poor nation.

Now, let us see what creates the impact in First World. So, if you look at a feature of it, it is relatively clean technology stable population but the impact comes from affluence, because that is a advancement in the technology so, they are not using the not so clean or the dirty technology. Their population is more or less stable the problem is affluence for them.

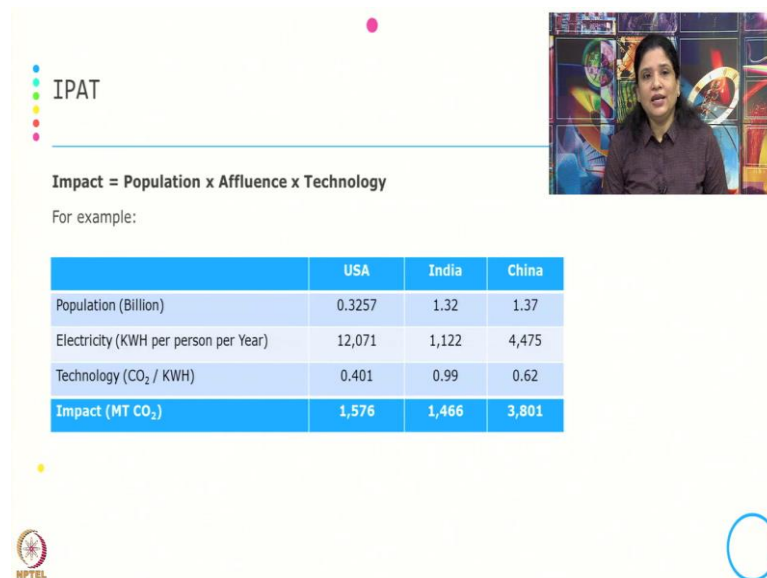
In the Second World, you will find that there is a affluence because there is a growth in the income at least for few groups, but they do not use the clean technology for them the problem comes at the impact comes from the technology and for some because of the population growth. For the Third World, affluence is not a problem. There is very little affluence.

There is some or very few dirty technology and high population. Why affluence is less? Because income is less. Why some dirty technology? Because there is no not lot of activities happening in the Third World, but the population is high. So, if you look at the

impact from all these three groups, typically for the developed nation, the impact comes from affluence; for the Third World, typically the impact comes from the population.

And from the Second World, mostly it is through the some part is from population, some part is from affluence, and the technology is the biggest driver for their impact whatever the impact they there causing through their activity.

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The slide is titled 'IPAT' and features a video inset of a presenter in the top right corner. The main content area contains the formula 'Impact = Population x Affluence x Technology' and an example table comparing environmental impact for the USA, India, and China. The table has four rows: Population (Billion), Electricity (KWH per person per Year), Technology (CO₂ / KWH), and Impact (MT CO₂). The impact values are 1,576 for USA, 1,466 for India, and 3,801 for China.

IPAT

Impact = Population x Affluence x Technology

For example:

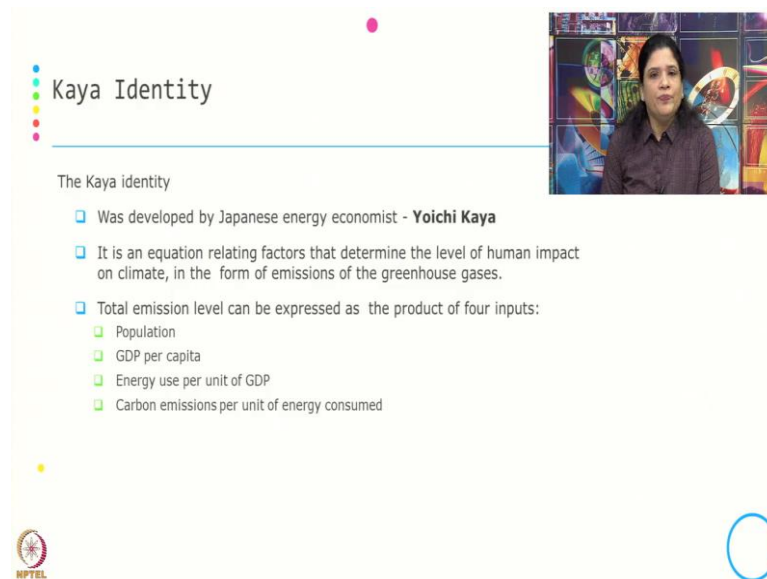
	USA	India	China
Population (Billion)	0.3257	1.32	1.37
Electricity (KWH per person per Year)	12,071	1,122	4,475
Technology (CO ₂ / KWH)	0.401	0.99	0.62
Impact (MT CO₂)	1,576	1,466	3,801

Now, let us take an example to understand this further. So, we have the data about population for all this three countries that is USA, India and China. Then we have electricity that is kilo Watt hour per person per year, and technology for proxy for technology; electricity is mostly the proxy for our affluence, and population is the proxy for population. And how do we calculate the impact? Taking the population affluence and technology.

So, if you look at the impact is very high for China, mostly for population also some amount from the consumption that is electricity consumption and also some from not using the or not using the so called clean technology.

And even if you look at the consumption is very high because of the population and because of this technology, the impact from USA is less. This is just a hypothetical example to understand that, what is the impact of population, affluence, and technology on the environmental impact.

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Kaya Identity

The Kaya identity

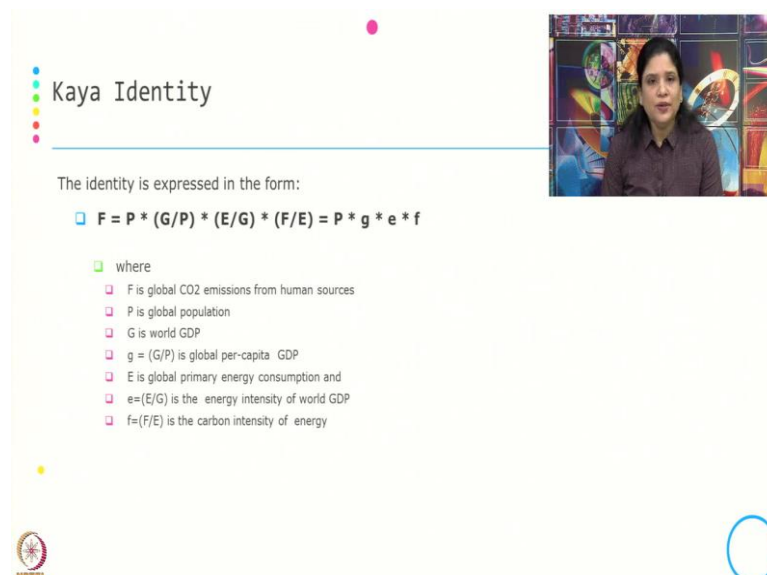
- Was developed by Japanese energy economist - **Yoichi Kaya**
- It is an equation relating factors that determine the level of human impact on climate, in the form of emissions of the greenhouse gases.
- Total emission level can be expressed as the product of four inputs:
 - Population
 - GDP per capita
 - Energy use per unit of GDP
 - Carbon emissions per unit of energy consumed

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Now, going to the next model to understand, this impact or to understand the linkage between environment, economic and human believes the Kaya identity. And it is developed by Japanese energy economist Kaya. And the equation relating factors that determine the level of human impact on climate in the form of the greenhouse gases.

And here the total emission level can be expressed as the product of four inputs – population, GDP per capita, energy use per unit of GDP, carbon emission per unit of the energy consumed.

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Kaya Identity

The identity is expressed in the form:

$$F = P * (G/P) * (E/G) * (F/E) = P * g * e * f$$

where

- F is global CO2 emissions from human sources
- P is global population
- G is world GDP
- $g = (G/P)$ is global per-capita GDP
- E is global primary energy consumption and
- $e = (E/G)$ is the energy intensity of world GDP
- $f = (F/E)$ is the carbon intensity of energy

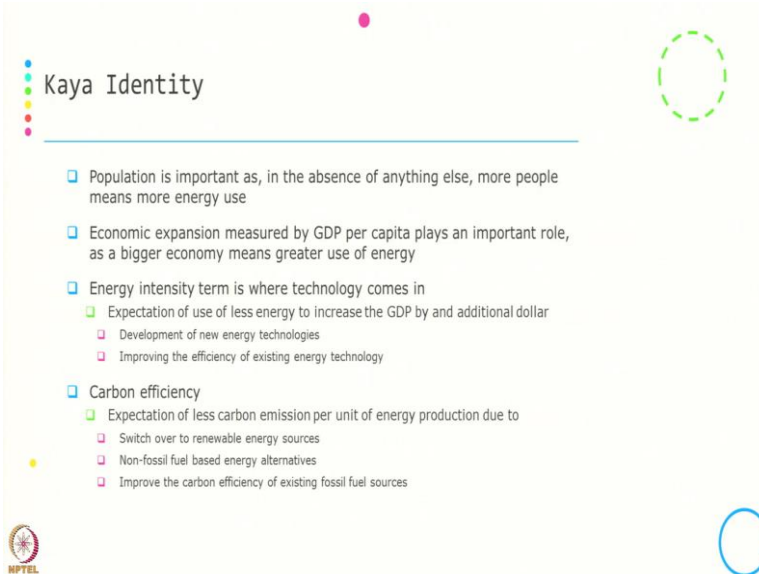
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Now, the identity is expressed in the form of F which is a function of P, P is the proxy for global population, G that is worlds GDP, and E is the global primary energy consumption, and F is the global CO₂ emission from the human sources. So, simplifying this, this should be population multiplied by our GDP by population multiplied by energy consumption by GDP multiplied by the global CO₂ emission from energy.

$$F = P * (G/P) * (E/G) * (F/E) = P * g * e * f$$

where, F is global CO₂ emissions from human sources, P is global population, G is world GDP, $g = (G/P)$ is global per-capita GDP, E is global primary energy consumption, $e = (E/G)$ is the energy intensity of world GDP, and $f = (F/E)$ is the carbon intensity of energy.

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Kaya Identity

- Population is important as, in the absence of anything else, more people means more energy use
- Economic expansion measured by GDP per capita plays an important role, as a bigger economy means greater use of energy
- Energy intensity term is where technology comes in
 - Expectation of use of less energy to increase the GDP by an additional dollar
 - Development of new energy technologies
 - Improving the efficiency of existing energy technology
- Carbon efficiency
 - Expectation of less carbon emission per unit of energy production due to
 - Switch over to renewable energy sources
 - Non-fossil fuel based energy alternatives
 - Improve the carbon efficiency of existing fossil fuel sources

HPTEL

So, once we take this identity, once we take this equation, let us understand that why have you taken these factors into the identity. As we know population is important and why it is important? Because more people use more energy, and more energy use has more impact.

Then the economic expansion is measured by GDP per capita; this plays an important role, as bigger economic is more income, more income is more consumption, and more consumption is the greater use of energy. Then the energy intensity terms typically

where we take the technology that is the expectation to use less energy to increase GDP by the additional dollar.

And why it is expected that we will use less energy? Because there would be developed development of new energy technology that is in the form of the energy efficiency and new energy sorry this is the low energy technology which will require less energy to produce the product and also there would be improvement in the efficiency of existing energy technology.

And the last term why it is important? Because the carbon efficiency. Now, what is expected over this variable? That there is an expectation that less carbon emission per unit of energy production due to switch over to the renewable energy sources, which is no carbon, non-fossil fuel-based energy alternatives, and improve the carbon efficiency of the existing fossil fuel sources.

So, mostly two things will increase the carbon efficiency that is one, increasing the carbon efficiency of the existing fossil fuel sources, and also looking at the renewable energy sources.

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The slide is titled "Kaya Identity" and features a list of bullet points. The equation for CO₂ emissions is presented as $CO_2 \text{ Emissions} = CO_2/TPES \times TPES/GDP \times GDP/population \times population$. Below this, it lists "Additional to IPAT" with two items: "GDP per capita" and "Energy intensity per GDP". It also mentions "An online tool" with the URL <http://forecast.uchicago.edu/kaya.html>. The slide includes a small logo in the bottom left corner and a vertical line on the right side.

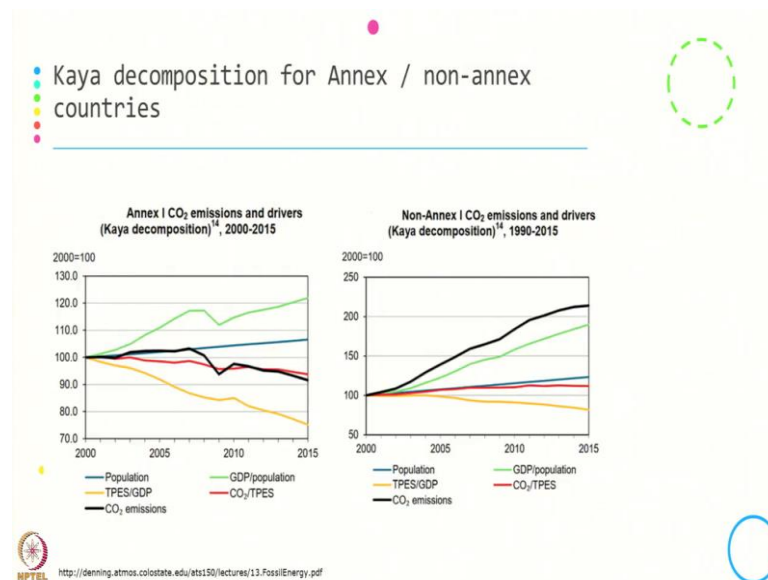
- Kaya Identity
- $CO_2 \text{ Emissions} = CO_2/TPES \times TPES/GDP \times GDP/population \times population$
- Additional to IPAT
 - GDP per capita
 - Energy intensity per GDP
- An online tool
 - <http://forecast.uchicago.edu/kaya.html>

Now, getting into the equation, CO₂ emission is again this is we have taken CO₂ or total product or total population, then GDP, and also the use of the energy consumption and also the carbon content in the energy.

$$\text{CO}_2 \text{ Emissions} = \text{CO}_2/\text{TPES} \times \text{TPES}/\text{GDP} \times \text{GDP}/\text{population} \times \text{population}$$

Now, what is additional over additional two PAT in this equation? Apart from population, affluence, and technology, we are also considering the GDP per capita and energy intensity per GDP. And there is a, online tool available which can be used to calculate the Kaya identity.

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Now, let us take a small example to understand that when we are discussing about all these four variables how they are driving the impact. So, if we look at in the left hand side, this is the annex one CO₂ emissions and drivers that is from 2000 to 2015. And see the other side is the non annex CO₂ emission and drivers. So, if you go into the first slide, the CO₂ emission is increasing.

And if you look at now what is driving the CO₂ impact, mostly the driving impact is GDP per population. And also what is possibly reducing the impact, then we can say that what is the CO₂ content per energy or we can say that is the total energy with respect to the GDP. So, mostly the energy intensity and the carbon in carbon efficiency, they will decide what would be the impact of it.

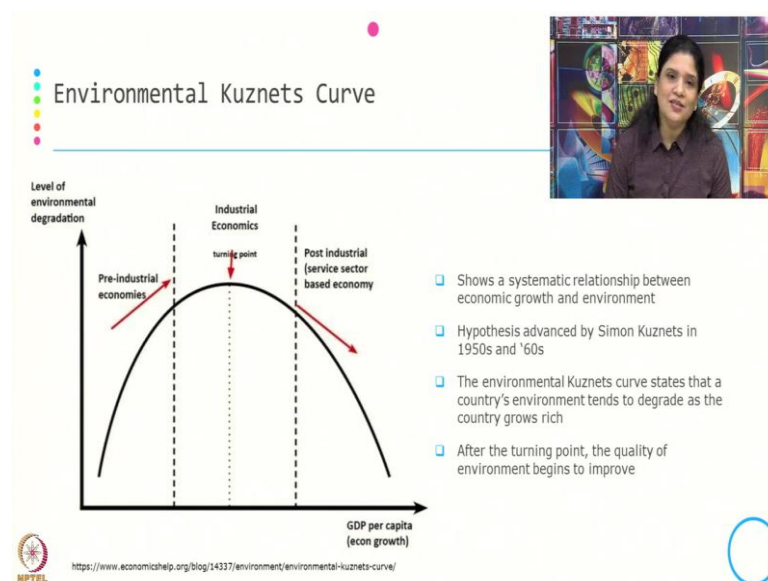
And in this case the affluence component or let us say the consumption component that is GDP population there, they are typically deciding more about the impact that is created by the country. Now, if you are coming to the non a non-annex CO₂ emissions

and driver, so here if you look at the population is increasing, there is an increasing trend from 2000 to 2015, the CO₂ emission is also showing a increasing trend.

And, but possibly what why it is increasing? The major factory is again GDP per population. But also, we can see that there is the more prominent over here is that we are not using in case of non-annex country we are not using more energy efficiency kind of technology, and also the types of fuel we are using that is more of the carbon.

So, this Kaya decomposition it can be done country specific, it can be done in the different scale, sometimes it is done in case of sector, and also sometimes it can be done in the case of the industry. It can be done in all this scale.

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Now, going to the third model, what we are going to discuss today is the environmental Kuznets curve. This is from a, this is typically consider as the most important model to understand the relationship between the environment and economy. Now, what it shows? It shows a systematic relationship between economic growth and environment. And this hypothesis was developed by Simon Kuznets in 1950 and 60.

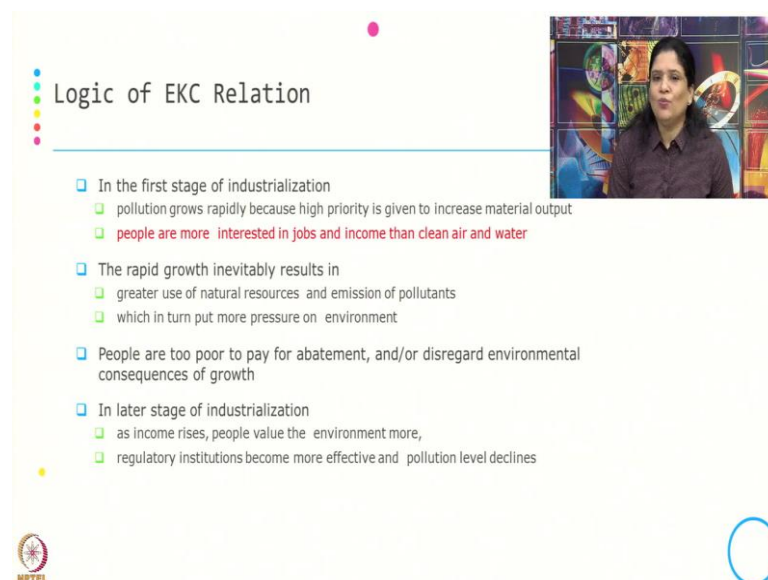
So, initially this environmental Kuznets curve, this Kuznets curve was mostly to study the relationship the study about the income inequality; at the later point, this hypothesis added the environment over this and this is known as the environment Kuznets curve. It

states that country's environmental trend, country's environment tend to degrade as the country grows rich.

And after the turning point, the quality of the environment begins to improve. So, if the country is going through the growth phase, typically you will find that the growth phase has been characterized as initially there is a pre industrial economies, then the industrial economy. And finally when the sectoral shift happen or the structure of the economy change from the industry to service, then the entire growth is based on the service sector.

So, initially growth is based mostly on the agriculture, and partly it is industry, then it is based on the industrial activity, and then it is based on the service sector activity. So, according to this environmental Kuznets curve, initially when the growth happens typically with this the environmental degradation also happens. Once it reach the turning point, beyond this, whatever the growth happens that leads to decrease in the environmental degradation or we can say that environmental quality increases.

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Logic of EKC Relation

- In the first stage of industrialization
 - pollution grows rapidly because high priority is given to increase material output
 - people are more interested in jobs and income than clean air and water
- The rapid growth inevitably results in
 - greater use of natural resources and emission of pollutants
 - which in turn put more pressure on environment
- People are too poor to pay for abatement, and/or disregard environmental consequences of growth
- In later stage of industrialization
 - as income rises, people value the environment more,
 - regulatory institutions become more effective and pollution level declines

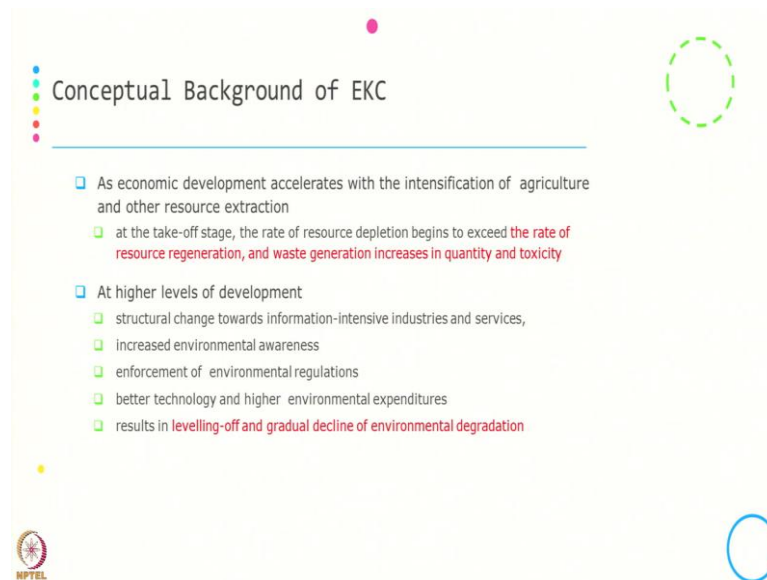
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Now, what is the logic of this EKC relationship? So, in the first stage of industrialization, pollution grows rapidly because high priority is given to the material inputs. The typical example is that at that point or the focus of the economy at that point is then, how to create more employment opportunity, how to create more economic opportunity rather than looking at the activity which is give us clean air or clean water.

So, obviously, whenever the growth happens at the initial phase, you will find that there is more importance to income, but also it is creating more degradation. This rapid growth typically results in greater use of natural resources. One is your using resources also the emission of pollutant will happen because we are not giving more emphasis to the cleaner technology or the better resources, which intense puts more pressure on the environment.

But you cannot expect much over here also that people are poor to pay for the abatement or possibly they will just disregard the consequences of the environmental the so-called environmental consequence of growth. But at the later stage of time when the industrialization happens as the income rises, people value environment more. Regulatory institution become more effective, pollution level declines.

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A presentation slide titled "Conceptual Background of EKC" with a yellow background. The title is in black text, preceded by a vertical bar of colored dots. Below the title, there are two main bullet points, each with a blue square icon. The first bullet point describes the initial stage of economic development, where resource depletion exceeds regeneration and waste generation increases. The second bullet point describes the later stage of development, where structural changes, increased awareness, and regulations lead to a decline in environmental degradation. The slide also features a green dashed circle in the top right, a blue solid circle in the bottom right, and a small HPTEL logo in the bottom left.

Conceptual Background of EKC

- As economic development accelerates with the intensification of agriculture and other resource extraction
 - at the take-off stage, the rate of resource depletion begins to exceed the rate of resource regeneration, and waste generation increases in quantity and toxicity
- At higher levels of development
 - structural change towards information-intensive industries and services,
 - increased environmental awareness
 - enforcement of environmental regulations
 - better technology and higher environmental expenditures
 - results in levelling-off and gradual decline of environmental degradation

Let me just give a small example from the individual perspective. When we earn more or when our income increases, we try to consume more then we see that whether this is environmental friendly or not. So, in this case, we see that initially with the increase in the income, increase in the growth, we try to consume more rather than try to consume more environmental friendly product.

But when our income increases further, we can when we can afford to go for environmental friendly products, then only we buy the environmentally friendly

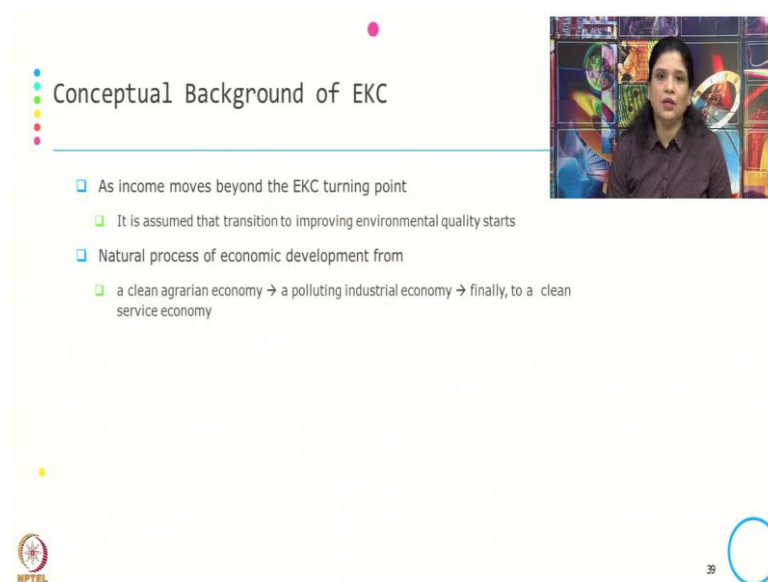
products. So, at the initial stage, as an individual we are also ignoring the in the consequence the environmental consequence associated with our consumption.

Now, as the economic development accelerate with the intensification of agriculture and other resource extraction at the take off stage, the rate of resource depletion begin exceed the rate of resource regeneration, and waste generation increases the quantity and toxicity. So, at the higher level of development, these are the things happen.

Structural changes towards information intensive industry and services that is more towards leaning towards the service-based economy, increase the environmental awareness, enforcement of the environmental regulation, better technology and higher environmental expenditure, and all these results in a leveling off and gradual degrade decline of the environmental degradation.

And that is the reason we find that our environmental Kuznets curve decreases or let us say environmental degradation decreases or environmental quality increases.

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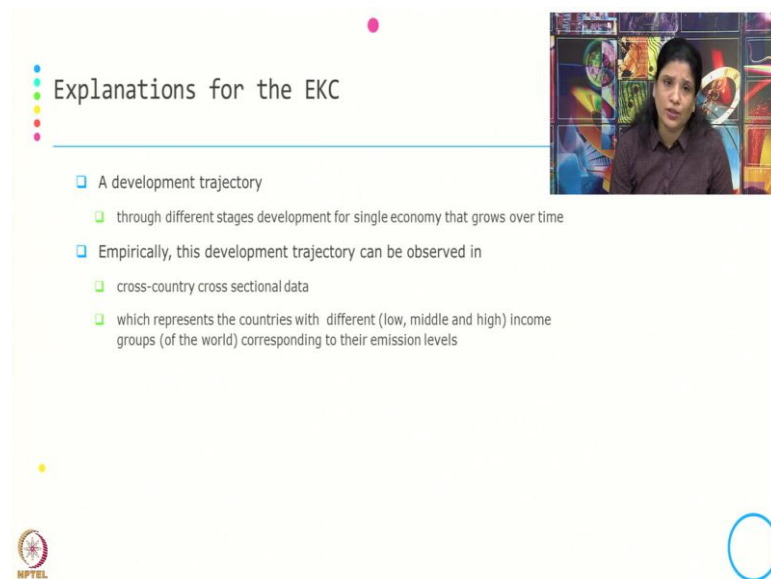
Conceptual Background of EKC

- As income moves beyond the EKC turning point
 - It is assumed that transition to improving environmental quality starts
- Natural process of economic development from
 - a clean agrarian economy → a polluting industrial economy → finally, to a clean service economy

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So, as income moves beyond the EKC turning point, it is assumed that transition to improve the environmental quality starts. So, what is a natural process of the economic development? From a clean agrarian economy to a polluting industrial economy and finally, to a clean service economy.

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Explanations for the EKC

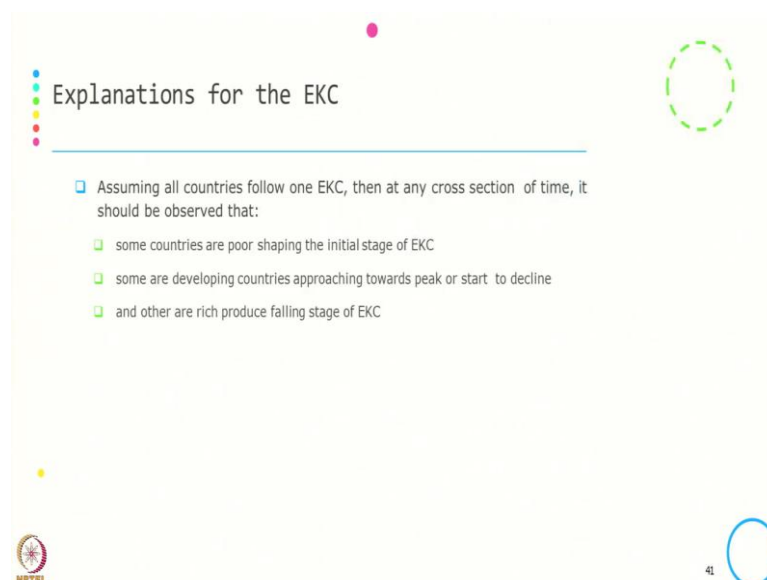
- A development trajectory
 - through different stages development for single economy that grows over time
- Empirically, this development trajectory can be observed in
 - cross-country cross sectional data
 - which represents the countries with different (low, middle and high) income groups (of the world) corresponding to their emission levels

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So, let us explain this little bit more with respect to the different stage of development. So, typically, this is a developmental trajectory for a single economy, but when we take all the economy together mostly the transition will not the same for all the economy. So, typically, this is a development trajectory for the single economy that grows over a time for a, from the agrarian economy to the industrial economy and finally, to the service economy.

This is this can be also tested empirically through the cross-country cross-sectional data, which represents the country with different low, middle, high-income groups and also corresponding to their emission level.

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Explanations for the EKC

- Assuming all countries follow one EKC, then at any cross section of time, it should be observed that:
 - some countries are poor shaping the initial stage of EKC
 - some are developing countries approaching towards peak or start to decline
 - and other are rich produce falling stage of EKC

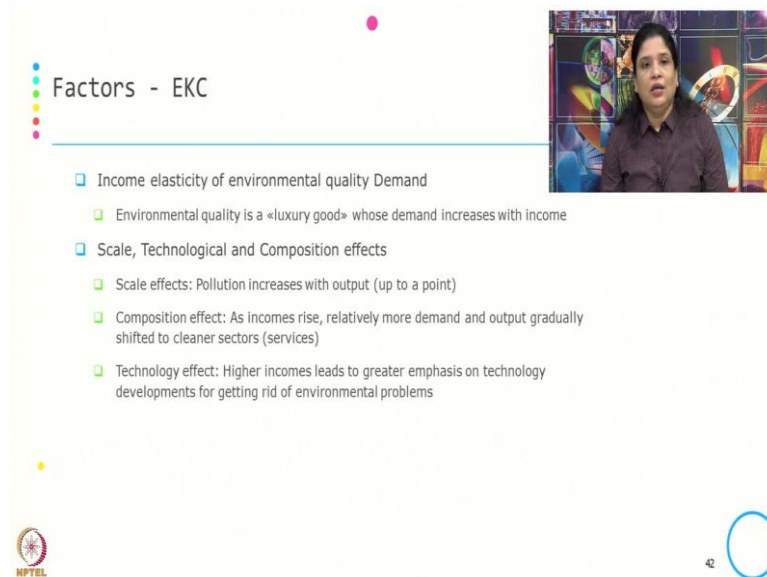
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And assuming all countries follow one EKC, then in any cross section of time it should be observed that few of the country they are responsible for the increasing part of the Kuznets curve that is some countries are poorly shaping the initial stage of EKC. Some of the developing country they will be responsible for the peak that is approaching towards the peak or start to decline, and the other rich produce at the falling stage of EKC.

But this is just an assuming that which country will fall under which group. Initially possibly since the developing countries is the poorer country they are not using more of the resources; they will not contribute more. But for the transiting nation for the developing countries when they produce more use more of resources they will contribute to the degradation part, but when their income increases growth increases, they will also contribute to the decreasing part of the EKC.

And developed country although it is assumed that they will always contribute to the decreasing part of environmental quality, but there is also evidence that they are the one also who comes contribute to the peak part of it. And interestingly empirical investigation will show the different turning point of each of the country and how they are contributing to the environmental Kuznets curve.

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The slide is titled "Factors - EKC" and lists the following factors:

- Income elasticity of environmental quality Demand
 - Environmental quality is a «luxury good» whose demand increases with income
- Scale, Technological and Composition effects
 - Scale effects: Pollution increases with output (up to a point)
 - Composition effect: As incomes rise, relatively more demand and output gradually shifted to cleaner sectors (services)
 - Technology effect: Higher incomes leads to greater emphasis on technology developments for getting rid of environmental problems

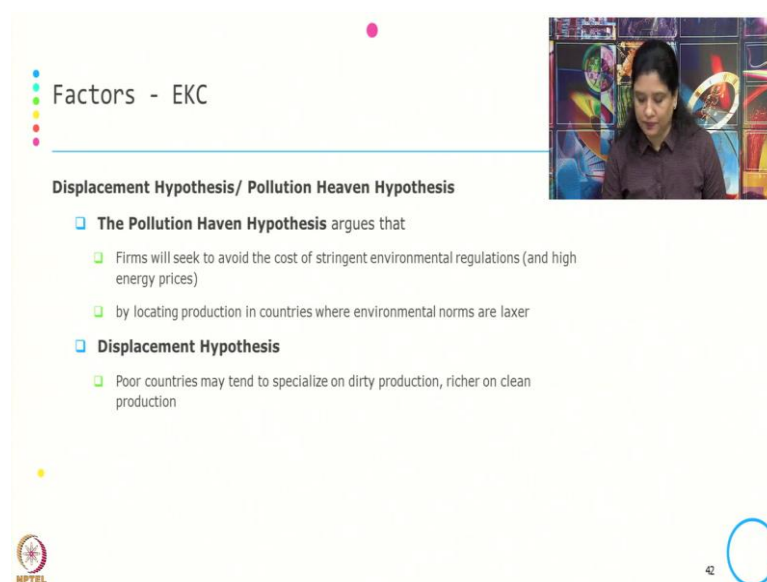
The slide also features a small inset video of a presenter in the top right corner, the NPTEL logo in the bottom left, and a blue circle with the number 42 in the bottom right.

Now, what are the factors responsible for EKC? There is an income elasticity of environmental quality or demand. Like typically consider environmental quality is a luxury good and whose demand increases with the income. So, let us say when our income increases, we buy a house right. But when we buy a house with clean air, clean water that becomes a luxury goods that we can afford only to go for the when where income increases further. So, in most of the cases, environmental quality is considered as the luxury goods.

Then there are three effects responsible for this EKC. Scale effect – pollution increases with the change in the scale of the output. Composition effect – as income increases relatively more demand and output gradually shifted to the cleaner sector. The composition means we are moving from agriculture industry mix to the industry service mix where the service sector contribution is high.

Technology effect – with the high income, we can give more emphasis on technology and we can use better technology to get rid of the environmental problem.

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Factors - EKC

Displacement Hypothesis/ Pollution Haven Hypothesis

- ❑ **The Pollution Haven Hypothesis** argues that
 - ❑ Firms will seek to avoid the cost of stringent environmental regulations (and high energy prices)
 - ❑ by locating production in countries where environmental norms are laxer
- ❑ **Displacement Hypothesis**
 - ❑ Poor countries may tend to specialize on dirty production, richer on clean production




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Then apart from this, there are other two hypothesis who are responsible for this EKC. One is the pollution hypothesis; second one is the displacement hypothesis. What is pollution haven hypothesis? It argues that firm seeks to avoid the cost of stringent environmental regulation and high energy price, and that is the reason they locate their production into the country when environmental norms are the laxer.

And what is the net outcome? The net outcome is that even if there are not much capability with the developing country while the environmental norms are little relax, you will find that more impact is coming from there. And displacement hypothesis says that over a period of time you will find that the poorer country and the developing country they are specializing more on the rather than specializing more on the production of goods and services which are creating more impact because these are been given to the developing country, and the reach on the cleaner production.

And while developing country even if they know that this is dirty technology, it is creating more impact till they do it because for the poorer country the focus is more on creation of employment opportunity and income.

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Factors - EKC

Regulation

- Formal regulation:
 - Pollution will grow unless environmental regulation is strengthened
- Informal regulation:
 - May substitute for formal regulation in many situations
- Property rights:
 - Improved property rights may strengthen environmental and natural resource management in higher-income societies

Then there is a role of the regulation, formal regulation, informal regulation, and also the property rights. So, if you remember at some point of time, we are discussing about the common resources. And if there is common resources, there is more environmental degradation. So, in that case, the property right may strengthen the environmental and the natural resource management in high-income society.

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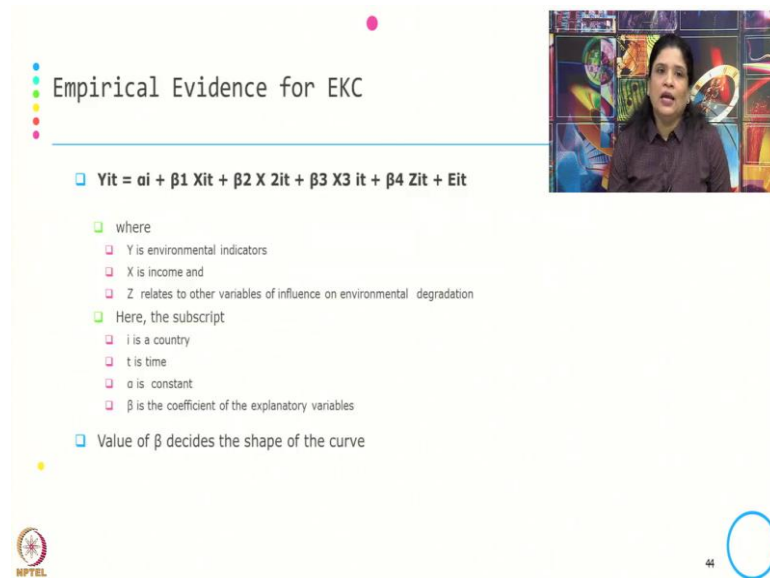
Factors - EKC

Market Mechanism

- Relative prices of natural resources tend to fall in higher-income countries; takes away emphasis on this type of production
- Market pressure through environmentally conscious behavior of producers and consumers

And then the market mechanism mostly through the price of the natural resources, and the environmental conscious behavior of the producer and consumer through market pressure also create a also has a influencing factor on the shape of the EKC.

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Empirical Evidence for EKC

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \beta_2 X^2_{it} + \beta_3 X^3_{it} + \beta_4 Z_{it} + E_{it}$$

where

- Y is environmental indicators
- X is income and
- Z relates to other variables of influence on environmental degradation

Here, the subscript

- i is a country
- t is time
- α is constant
- β is the coefficient of the explanatory variables

Value of β decides the shape of the curve

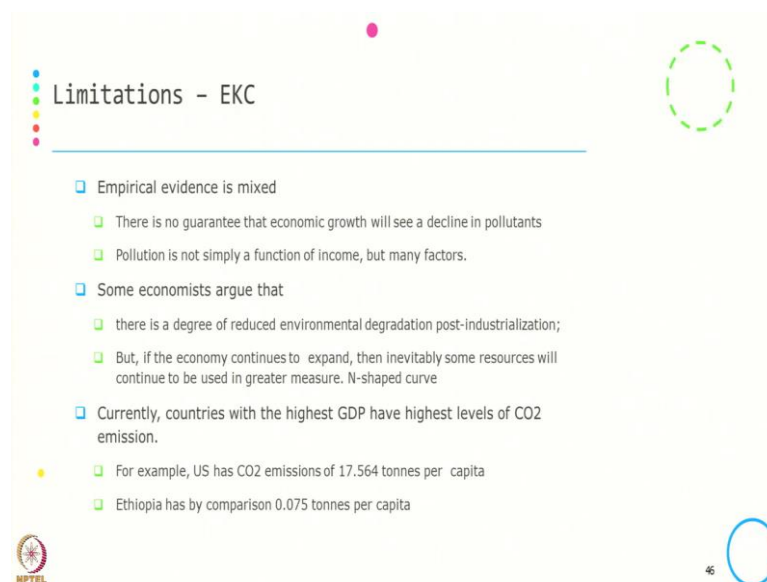
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Now, this is how we can create a empirical evidence of EKC through this equation

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \beta_2 X^2_{it} + \beta_3 X^3_{it} + \beta_4 Z_{it} + E_{it}$$

where Y is the environmental income indicators, X is the income, Z is related to other variable influence of environmental degradation. And typically, the value of beta different beta that decide the shape of the environmental Kuznets curve.

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Limitations - EKC

- ❑ Empirical evidence is mixed
 - ❑ There is no guarantee that economic growth will see a decline in pollutants
 - ❑ Pollution is not simply a function of income, but many factors.
- ❑ Some economists argue that
 - ❑ there is a degree of reduced environmental degradation post-industrialization;
 - ❑ But, if the economy continues to expand, then inevitably some resources will continue to be used in greater measure. N-shaped curve
- ❑ Currently, countries with the highest GDP have highest levels of CO₂ emission.
 - ❑ For example, US has CO₂ emissions of 17.564 tonnes per capita
 - ❑ Ethiopia has by comparison 0.075 tonnes per capita

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This EKC has been criticized that although it talks about a clear relationship between the environment and economy. There are also some limitations or there is some criticism that the empirical evidence is mixed. There is no guarantee that economic growth will always see the decline in pollutant.

What I was trying to also refer when I was discussing the case of the developed country. So, even if the developed country their GDP is high, the economic growth is high, it does not mean that will help in declining the pollutant if they are not putting effort on the clean technology or if they are not getting into the alternative resources.

Similarly, pollution is not simply function of income, there are many other factors which has not being consider in the equation of the environmental Kuznets curve. Some economist argue that there is a degree of reduce environmental degradation post industrialization.

But if the economy is continue to expand at least they will be going on using some resources, they cannot expand without any resources they will go on using some of the resources and possibly rather than the inverted U-shape although it will decrease to the lowest at a point. But beyond a point, again it is going to increase further the degradation is going to increase further.

Because even if the economy is expanding, it is not going to stop the consumption of the resources; and if they are not going to stop the consumption of the resources, that degradation is going to happen. So, most of the also you will find most of the empirical evidence, it suggest a N-shape curve rather than an inverted U-shape curve.

Currently country with highest GDP have highest level of CO₂ emission, so that way we cannot justify that the falling part of Kuznets curve is mostly because of the developed country. Although theoretically we assume that since their growth is more they can spend more on technology they can or possibly they will not expand further their contribution would be less, or they will also invest on the better environmental quality or better technology.

But if you look at the fact the USA CO₂ emission of this per capita, and US is considered to be the most developed nation across the globe. But that contrasting result over here is that the Ethiopia's per capita and per capita CO₂ is just 0.075. So, if you look at this fact, possibly we cannot accept the theoretical framework or cannot accept what we get in the conceptual framework that the poorer are responsible for the increasing part of EKC, and the richer are responsible for the decreasing part of EKC.

So, in the next session, we will try to understand how do we operationalize sustainability through the weak and strong sustainability. And in this session, we have tried to summarize these three models IPAT, Kaya identity, and EKC, how they create a link between human, environment, and economy.

Thank you.