Introduction to Economic Growth- I

Dr. Sohini Sahu

Department of Economic Sciences

Indian Institute of Technology Kanpur

Lecture-10

Hello, and welcome to yet another week on this course, Introduction to Economic Growth. Hope you have liked the lectures thus far and today we proceed with another set of lectures. Before we proceed with the Solow growth model today, let us do a quick recap of what we have covered in the last week. So from last week, the topic was measuring economic growth. As we had mentioned earlier that whenever we generally learn about economic growth, it is not just about the models which help us explain what we see around us, but it is also the data. We should also be able to understand the data and interpret the data to some extent with that objective, in the second week we had talked extensively about the data we started our discussion with GDP in the context that we require for this particular course discussion on GDP in general is a huge topic by itself and you have perhaps already come across that in a regular course in macroeconomics, so we only talked of those aspects that we will be using in this course and that is what we actually saw last week.

We did take a look at a few examples, real life data and we have also seen how economic growth can be measured using different techniques. In the same context, we had also talked about a possibility that what if GDP data is not available for some reason. We did talk about the situations where GDP data or economic activity data might not be available and what is to be done in case we do not have the data that we are looking for. In this context, we had specifically talked about the night lights data and I would again like to remind you all that night lights data is not the only proxy data for economic activities.

There can be various types of proxy variables, various kinds of variables. We talked about night light data because that is one of the most popular, you know, variables that are being used these days and also because we have lovely images. So, that helps us drive home the point. Also at the same time, we had some words of caution that whenever we are using proxy data, we should be very careful about the limitations of such proxy data. Otherwise, the conclusions that we are drawing from proxy data might be erroneous.

Lastly, we had talked about some of the things that we learned from the data. There we were trying to highlight that we have to be careful about what is the definition that is being used. Some of the variables that is being used, like is it per capita, is it per worker, are we looking at a growth variable. Or are we looking at a level variable? So, level variable is

just GDP per capita and growth will be growth of per capita GDP. Because if you recall the maps or the data underlying the maps, they can be very different based on whether we are talking of a level variable or a growth variable.

Also simultaneously we took a look at a few other variables that are correlated with per capita GDP, various types we had seen. In some case the positive correlation was obvious, in some cases the negative correlation was also quite evident and there was at least one slide I recall where the correlation was not you know very obvious there, at least from the graph itself. And we had ended on the note that whenever we are looking at figures like this, we should be very careful. In terms of the inference, that is, it is, or it does not represent causation, but it represents correlation. So, last week was all about data, various representations of data, and we had started with data because, you know, if you look around when we read newspapers when we read articles in magazines, these are some of the common things that we come across.

This week what we are going to do after covering data is we are going to delve a little deep and we are trying to see how as an economist we are going to answer some of these questions that were presented in the stylized facts. And for this we will be using a specific framework for analysis. And this was mentioned earlier as well, there are various kinds of theoretical models to explain the various observations. It is not possible to cover all the models here. The Solow growth model is one of the most popular models and like a starting point so as to say.

So, that is why this week we are going to talk about the Solow growth model. So, after doing the data, you know, part of economic growth, we are moving to the theory counterpart now. So that there is both a balance and we also see that how economists think of these questions and how have they tried to answer these questions. So, this week, we are specifically going to cover the Solow growth model. There is a benchmark Solow growth model and there is also another version of the Solow growth model that is known as the augmented Solow growth model.

And you know, while we are doing these two, it will come up in any case, but still, we would also like to single out that the Solow growth model has got several policy implications that are very, very important, and that is why the Solow growth model was very popular in the 1960s and the 1970s. So, we will also see what are the policy implications of the Solow growth model and whether these implications hold true even today. So, that is the agenda for this particular week. Now for this particular week, I generally use Greg Mankiw's textbook. There are two chapters on the Solow growth model.

So, this is the cover of the book. There is a more recent edition that can be used, but I think not much of information is lost even if we are using an older edition of this book. I would also like to mention here that instead of Mankiw you are also free to use any other standard

macroeconomics textbook that we follow in college. But here I would be using the textbook of Mankiw for this specific module. So with that, let us proceed with the introduction of the Solow growth model.

And I thought before we proceed, we should definitely take a look at the person. This is Robert Solow. We are looking at a photo of Robert Solow who had won the Nobel Prize for his contributions towards the study of economic growth. The Solow growth model is a major paradigm that was used for policy-making, and till today, we say this is like a benchmark, and we use that for fundamentally understanding how to treat growth models. It looks at the determinants of economic growth and the standard of living in the long-run.

So, that is what this particular model does. Before we go on to the elements of the Solow growth model, this is something we had also mentioned in the introductory lecture: you know, whenever economists propose a model, there has to be a background, right? I mean theories do not really exist in vacuum. There has to be a reason why a particular person thought of or thought about before he or she came up with this model. So, before we go on to the nitty gritties of the Solow growth model, I thought it is very relevant here to talk about what made Robert Solow come up with this particular model. So, these are in his own words, these are excerpts from the Nobel lecture that was delivered him, and if you are interested, it is a long one, but it is a very interesting lecture that he delivered; you can visit this particular website.

And you can read the entire lecture there. I am just, you know, culling out parts from that particular lecture that are relevant for our particular case. So, I read out growth theory did not begin with my articles of 1956 and 1957 and it certainly did not end there. Maybe it began with the wealth of nations and probably even Adam Smith had predecessors. More to the point, in the 1950s I was following a trail that has been marked out by Harrod Domer and also by Arthur Lewis in a slightly different context.

Actually, I was trying to track down and relieve a certain discomfort that I felt with their work. I shall try to explain what I mean in a few words. Discomfort arose because they worked this out on the assumption that all three of the key ingredients, the saving rate, the rate of growth of the labour force, and the capital-output ratio, were given constant facts of nature. The saving rate was a fact about preferences, the growth rate of labor supply was a demographic, sociological fact, and the capital-output ratio was a technological fact. That was the spirit in which I began tinkering with the theory of economic growth, trying to improve on the Harrod-Domer model.

I cannot tell you why I thought first about replacing the constant capital-output and labor-output ratio with a richer and more realistic representation of the technology. So this is, like, you know, it kind of sets the tone or sets the stage for our discussion today because, as we said that before we discuss a model, it makes sense to go back to the background in

that sense like what gave rise to that model. Now, going back to this first quote here that we are looking at, he mentions a few people here and you might have come across the Lewis model and the Harrod-Domer model while doing development economics. So, we would also like to recall as we had mentioned during the introductory lecture that these are all post the second world war. So, the world had witnessed the great depression, the two world wars and then it was like the entire world was restructuring.

And that is the time when all these different kinds of questions were being asked about the various nations. So, this serves as a background. What he also goes on to mention was that there were existing works, but they had certain limitations in terms of assumptions. So, we already know that economic models, how models work, they are based on assumptions. That is how we build the models.

So, he mentions here that he was not comfortable with few assumptions regarding a few variables and that was the spirit as he mentions that he started tinkering with the existing models of Harrod-Domer. We are not going to discuss the Harrod-Domer model here per se. But as we said, in development economics, this is generally covered, and the kind of answer, you know, or the kind of rather the question that Solow is looking at the Harrod-Domer model was in a somewhat similar spirit. Now, we are familiar with the background to some extent and before we actually dive into the model. So, we are going to present the model shortly, but before that, I thought that let us spend some time training our thought process.

What do you mean by training our thought process? Every individual, the way we think, especially when we are thinking of our subject, we think in a very specific manner. For instance, as an economist, if I am talking about an economy, so maybe I would write it down here. When we talk about the economy as economists, I will mention the economy here. It is very common that we get questions like, what do you think about how the economy is performing? Now, these questions can be very overwhelming because, you know, we might not always know where we should begin because an economy is a very big entity. So when we are trying to answer questions what we typically do as especially macroeconomists, we divide our tasks into smaller modules.

How is that so? For instance, when we are thinking about the economy, we think about the supply side of the economy and the demand side of the economy. Now, what would be the supply side of the economy, and what would be the demand side of the economy? Now, let us think of it like this. Now, we have all learnt about GDP either in basic macro or at least in week 2 of this particular course, we did talk about GDP to some extent. This is the output of an economy. So, we are talking about the output of an economy.

When we talk about the output of the economy, we can think about it from two different perspectives. They are like two sides of the same coin. One is the supply side and the other

is the demand side. This is typically how macroeconomists think. What is on the supply side? Supply-side, when we are considering the GDP, we are asking ourselves a question: how is output produced? This is the question that we are asking ourselves here, and on the demand side, we are asking ourselves the question: where does the output that has been produced go? So, that is the question we are asking ourselves on the supply side and on the demand side.

So, if we are asking ourselves the question that how is output produced in an economy, then as a macroeconomist we are going to look at the production function. We are familiar with the concept of production function. It is generally first covered in microeconomics. That concept comes back here as well, and we are going to talk about it in the Solow growth model. So, we are going to take a look at the production function.

It is with the help of the production function that output is produced in an economy. So, that is the supply side of the economy. What about this question that where does this output that has been produced that goes? To answer that question again this is something that we are familiar with, we have done in basic macro. So, we look at it from the expenditure side which would be there is consumption. and a part of the output that is produced is consumed, a part of the output that is produced goes into investment.

A part of the output that has been produced goes towards government expenditure, and then we have imports because not all output that is consumed within an economy is domestically produced, and some are exported together. We have net exports. So, this is a very simplistic way of understanding an economy. So, what we said is that when we begin with a model, we have a question in mind. And to answer that question it is best that we break it down into modules, otherwise it becomes very overwhelming, we might not know where to start from.

So, generally, what we do is the prototype economy that we are talking about; we divide an economy into the supply side and into the demand side. In the supply side for the Solow growth model, we are asking ourselves the question that where is GDP coming from because remember the solo growth model as the term is already embedded there it is a growth model, and it is going to talk about it is going to take us deeper into how output is produced and the questions regarding the GDP that we have posed thus far. So, this is all about GDP and in doing that what we are doing here is we are looking at the supply side of the economy. We are represented by the production function, and we are also looking at the demand side because to complete the entire picture, we are also asking ourselves the question of whatever output has been produced: where is it going, right? And we said that well it is a part of it is consumption demand, a part of it is investment demand, part of it is government expenditure and part of it is net exports, okay? So, two sides of the economy that we are going to define like this and then finally because they belong to the same

economy. So, how is it that we bring them together? So, that is the last step that we will be doing.

We will bring the supply side and the demand side together here. So, that we know that we are talking about the same economy. So, we bring them together, and we, you know, in our parlance, we call it some kind of equilibrium. We have heard about the term equilibrium several times and you know micro markets when we were talking about it, we have also heard about the term equilibrium when we were doing the ISLM model etcetera. Essentially, what does it indicate? It indicates bringing together the demand and the supply side together.

Similarly, here also we will bring the demand and the supply side together. Otherwise, how would we know that it belongs to the same entity? We will see how we bring them together and once we bring them together. We will not be using the term equilibrium, the term equilibrium is generally not used in the context of economic growth rather we use a term here known as steady state. We will also see why it is called a steady state, but this is how the format of this model is going to be like. So, this is what I meant by how we first need to train our thought process.

So, whenever we come up with any problem in macroeconomics, you can now go back and think about the IS-LM model, and you can think about the ADAS model; they pretty much follow the same template. So, for an economy, we have a demand side and we have a supply side. Depending upon the question we are asking, we determine how is the supply side determined, how is the demand side determined, and finally, the last step not to be forgotten: we have to bring them together. Remember the ADAS model, so there was like a cross, so we were bringing them together. Similarly, here also we will bring the supply and the demand side together and we will arrive at something known as the steady state.

So, if we can do all these steps sequentially, we have built a small prototype of an economy, something that represents the economy as per the Solow growth model. And once we have done this, we should be able to answer some of the questions that we have posed in this particular course. So, we begin with the production function. So, why do we begin with the production function? As we said we are beginning or we are starting with the supply side of the economy. I hope it is clear up to this point because when we study from the textbook generally just begins with the production function, but I thought that we should first have the road map clear.

So, that we know why is it that we are talking about the production function. So, we are talking about the production function because it represents the supply side of the economy. So, we are asking ourselves a question: where does output come from? This is where the output comes from. Now it begins with an aggregate production function which we have seen before while studying microeconomic;

$$Y = F(K,L)$$

These are in aggregate terms. How do we know they are in aggregate terms? They are all in capital letters. So, Y is output, K is physical capital and L is labour force. The first thing that we generally do while talking about the Solow growth model is convert these aggregate terms into per-worker terms or per-capita terms, right? So, here, because L is representing labor or workers, everything is being converted into per-worker terms. So, how does it look like? So,

$$y = Y/L$$

So, this is pretty much like per capita income. Instead of per capita, this is per worker. Similarly,

$$k = K/L$$

k is capital per worker. Now, for the Solow growth model, we require a production function that has constant returns to scale CRS. Now,

$$y = F(k, 1)$$

It is a very general production function that has been mentioned here.

You see, I have not given a specific example. Can this be the Cobb-Douglas production function? Yes, it can be the Cobb-Douglas production function, but right now we are just keeping things very general here and this is a production function that follows CRS. And the next thing that is done is, you know, as it demonstrates here, that because we are dividing throughout by L, finally, we can represent the production function;

$$y = f(k)$$

So, that is what the last line that we see here on this particular slide represents. How does this look like? This is very important. Most of the analysis that we are going to do about the Solow growth model here will be graphical analysis.

So, let us take a moment to understand the graph here. So, on the x-axis, we have a small k. Now, maybe every time I am not going to say small k, I will just say k, but since we have converted everything into per-worker terms, k will always denote capital per worker. I hope we should be clear about that. And whenever I say output, it will always denote output per worker because we have already done that conversion. Are we good to go? Well, then, on the x-axis, what we are measuring is K, which is capital per worker.

On the y-axis what we are measuring is output per worker or y. And the production function that we had seen earlier is a general production function. It just obeys CRS. This

is how it looks like. Now we are also familiar from our knowledge in microeconomics that the slope of this production function, this is the marginal productivity of capital.

And because of the shape of this particular production function, what do we see? We see that the marginal productivity of capital is positive. How do we know it is positive? Because the slope is positive. Wherever you draw a tangent to this particular curve, it is going to be positive. So, it is positively sloped.

So, the marginal productivity of capital is positive. But another observation is that the slope is positive. But the rate at which the slope is growing that slows down later on. So, this production function exhibits diminishing marginal productivity of capital. I hope all this rings a bell because all these things are generally covered in basic micro-courses. We are just transporting it from there and we are planting it here in order to represent the supply side of the economy.