Introduction to Economic Growth- I

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Lecture-14

Some more features of the quick recap before we move on to the next part of the Solow growth model is what we have seen. Remember, all those things that we were drawing are further away from an economy from the steady state. Now, this can be further down below or further up, but generally, it is down below the faster it grows or shrinks. It might shrink if it is up above the steady state. Now, this is very important and we will come back to this later once again. This does not imply that poor countries grow faster.

It implies that countries that are poor relative to their steady state they are going to grow faster. As we said, we will come back to this point once again. Because, sometimes, these questions are asked that you know if poor countries are going to ever catch up with the rich economies. Now, can we use the Solow growth model to answer such a question? Both yes and no.

So, we will look at both those perspectives later, once we have become you know more comfortable with this particular growth model. Next, what we are going to do is we are going to consider a variant of the Solow growth model. That has technological progress. The reason being we should also justify why we are going to talk about the augmented Solow growth model. The reason being so far what we have seen is by tweaking or by changing the value of s that is the saving rate and the population growth rate that is n.

The steady states can change, and what happens when s increases or n increases both as we saw from the prediction of the Solow growth model and from the empirical evidence that it affects per capita income. So, it does have what we call actually a level effect. What is level effect? We had mentioned this earlier, just GDP or per capita GDP is different from growth in GDP. Remember, earlier, we had also seen the world map, where we saw how it was, you know, diversified in terms of per capita income as well as in terms of growth rate. So, the two things are different.

So, where s that is small s and small n really make a difference is in per capita income in the long run. But if we are asking ourselves the question that you know how does an economy perpetually keep on growing. Now think about it from another angle, although small s and small n do lead to changes in per capita income in the long run. Now, can these

be very fruitful policies? So, what we mean by that is let us suppose that we are advising a government. The government wants to know that what leads to higher growth, what leads to higher per capita income, let us say in the long run.

Now, let us say we have studied the Solow growth model and with whatever knowledge we have so far. Based on that we will say that well let us target to increase the saving rate. Now, think about it logically, is it possible to keep on increasing the saving rate of an economy? Maybe it can increase up to a certain amount, how maybe by tweaking the rate of interest. But saving can, I mean theoretically it can also be 100 percent of income, but realistically speaking if you are going to save the entire income then what are we going to consume.

So, in other words saving rate, increase in saving rate cannot keep on happening forever. It is going to hit a ceiling very soon beyond which the saving rate will not go up no matter what. Also the other factor is, think about it, who saves? Typically, we save households, right? Government also saves, but the bigger chunk of it is from household saving. Now, these are saving decisions that are decisions taken by households, and there are several reasons as to why and how households actually you know they end up saving. Now, although the government might give an incentive in terms of, as we said, the rate of interest, If the rate of interest, let us say, on bank deposits increases, typically, you know, we are more inclined to save.

But as we said that this is a very much a household decision. The government as a policy maker can you know have an impact on it up to a certain level. But this is not something that the government can control entirely. So, this is also another one, can you know, think about it as we said as a consultant, If we are giving a response to the government, we would also pause for a moment and think about how realistic this is going to be, especially for how long can we keep increasing the saving rate. Similarly, you can think about the population growth rate as well.

Yes, theoretically if n comes down then we reach a higher k star in the process, we reach a higher level of you know y star that is higher per capita income in the long run. But this as a policy is even more difficult because you know changes in n cannot occur overnight, right and again, like before, up to how much can n come down right. So, these are, you know, in effect, that is why, yes, they do have an impact. There is also a policy side to it. But first they have what we call a level impact not really a growth growth impact.

And second, even for a level impact, if we are thinking of small s or small n as policy variables, both have their own limitations. We cannot keep on kind of implementing them forever. So, that brings us to the next part and the most interesting part of the Solow growth model is then is there something in the economy that helps the economy to grow perpetually does not hit a roadblock very soon? That is why we are talking about the

augmented Solow growth model. Why augmented? Because it is fairly similar to the earlier Solow growth model that we have seen. We are going to make one small change here, but that pretty much changes the story to a very large extent.

So, here the new element that we bring in; you can already see that term here. Earlier we had defined everything in terms of output per worker. Now, we have a new term here, which is output per effective worker. How is that defined? That is defined by L is for worker, so worker is L, effective worker this is E. Now, there are many ways we can think about this.

This is actually what is representing technological progress in the Solow model. In other words, what the term LE or EL stands for is known as an effective worker. So, effective worker together will be this term LE. What does it mean? So, let us just take a moment to think about it. L is worker, L is just labor the way we understand.

Now, E is what is converting it to effective worker. There are many ways of thinking about it. So, one way to think about it, it is something that increases the productivity of the worker. So, it is not just about one person, it is about how productive is this person. So, that is one way of thinking about it.

Some might say that this might also be something like you know human capital because not just in terms of education, but also in terms of skills because that is actually what makes a worker productive. So, whichever way we look at it this is how we are measuring technological progress. Now, we will talk more about how technological progress is actually represented in economics. We will do that in the last week of this course. But so far, what we understand by technological progress is anything that makes us more productive, anything that makes the system more productive.

There are three ways of looking at it productivity, there can be some factor that makes only labor productive like as we said may be you know someone has a college degree or a master's degree that will make the same labor more productive. Now there can be productivity that is only associated with capital stock, may be a better quality of the same product that makes the capital stock may be more productive. There can be a more general productivity which can make both labor and capital very productive. Let us say you know very liberal laws let us say in general when it comes to production. Now, that will make both labor and capital productive.

So, productivity can be of various types. The type that is considered here is the productivity associated with labor. And we are using the term productivity and technological progress interchangeably because productivity changes, in most cases they do come from technological progress, but you know we will talk more about that in a later week lecture. So, this is the big change that happens in the augmented Solow growth model. So, earlier we did not have productive labor.

Now, we have productive labor. So, the first step is to convert everything into not just Y divided by L, but this time it is Y divided by LE. Otherwise, every other notation is being kept unchanged. The second new thing that we observe here, remember earlier we had delta k is equal to s.f(k). This is what we had seen for what we call the baseline model, and then what did we see? That was the first version; in the second version, we saw when we had included population growth.

This is what we had seen. Again, a quick reminder: why did that n term come in? n represents population growth. We said that whenever population is growing, they have to be equipped with capital as well. So, that is why this new term had come in. Now, as we can already see from here, there is now an extra term. So, besides n and delta now there is a term g and this small g what it represents is growth in this effective labor.

So, the effective part is now or think of it as technological progress or technological growth that is taking place. So, this is the new thing that has been introduced here. So, this new term, so these previous two they remain the same as we have seen them before. This is the new element here, gk. What is this gk? Where we said g stands for technological progress, the rate at which technology grows, that is the interpretation of g.

So, gk is to provide capital for the new effective workers that is created by technological progress. So, think about it for a moment. It is not just labor going up now. So, it is not just in terms of head count. Earlier we had 5 workers, now we have 7 workers, but now these new 2 workers let us say who have come in or maybe for all workers in general, they are now far more productive.

Why? Because maybe everyone has learned to operate a computer. So, their human capital has gone up, one way of thinking about it. So, now it is not maybe you know enough to equip them with just computers, we have to perhaps equip them with something even more that makes them more productive. So, that might be one way of thinking about this.

So, the point here is. We earlier had just delta k, then we brought in increase or growth in population that was the population growth rate was n. So, we had a new factor there. Now, in the last part of the Solow growth model which we are calling the augmented Solow growth model. We introduce technological progress, and the kind of technological progress that we bring in here is labor augmenting, that is, it is helping labor, that is why we have LE, and what is the small g? This small g stands for technological progress.

So, two new elements that we have here. And as a result of this, what has changed? The baseline figure still pretty much looks the same, but now we have this new term here. We should also mention here that, like before, the delta, like the depreciation rate, was exogenous. This value was given. n population growth rate its value was also exogenous. We would also like to recall that the saving rate is small s, and that value was also exogenous.

Similarly, here the value of this small g which stands for technological progress. This is also exogenous to the model. So, sometimes that is why you know the Solow growth model is also known as exogenous growth theory, because of all these important parameters, small n, small s, small g. They are all exogenous to the model, we should remember that. So, otherwise, as we can see, this figure looks pretty much the same.

And where is this steady state? Just like before here, why? Because now this is our main equation at steady state $\Delta k = 0$. What does it imply? It implies $s \cdot f(k) = (\delta + n + g) \cdot k$. And all these are, you know, exogenous variables. What do you mean by exogenous variables? The values are already given to us. We are not determining the values by solving for the model.

That is what we have for this augmented Solow growth model. Otherwise, the dynamics pretty much remains the same as we have seen before. So, again if we ask ourselves a question that suppose an economy starts from here. How is it that the economy is going to move towards a steady state? All those procedures pretty much remain the same. So, this is the Solow growth model with technological progress.

Now, the thing being if we would like to distinguish it from the cases that we have seen earlier and why technological progress in the Solow growth model is important. This is one factor that can now keep on growing. For almost like forever. Remember earlier we said small s, small n they all have level effects. We will also see that more in the next slide, but with technological progress two things.

Now, technological progress is not limited by any of the conditions that we are aware of related to small s. So, it can keep on growing forever, and this is a factor that helps in growth: how you know, it is a factor that helps in growth. So, for this, I always find this table very, very, you know, you can say indicative, very insightful, and this also summarizes everything that we have learned in the Solow growth model thus far. So, we should take a minute to review this particular question, not the question I had asked. Question, let me just get back to that question again.

So, the question you recall I had asked when we first, you know, drew the Solow figure is what happens to an economy once it has reached the steady state? Does it stop growing? That was my question because it has reached a steady state. Now, let us suppose no other change is taking place in the economy. So, then is the economy going to grow or not going to grow? So, to understand that, I always find this particular table very useful, and again this table has been taken from Mankiw. So, if you are referring to the textbook, you will also find that table here. So, as we can see here, if we rather start from here, this is the Solow growth model with technological progress.

So, now we have instead of L, we have LE. So, this is the thing. This is how now it has changed. So, at a steady state, is capital per effective worker growing? What is the growth

rate of capital per effective worker at steady state? The growth rate is 0. Why? Because it has reached the steady state. So, capital per effective worker is not growing at a steady state.

What about output per effective worker? The output corresponding to this K. At steady state the growth rate of output per effective worker is also 0. What about output per worker at steady state, only per worker? So, that is y over L. What about its growth rate at a steady state? This is now what we were trying to drive the point home, which was output per worker at a steady state in the Solow growth model with technological progress that also keeps on growing, which was earlier not the case when we did not have technological progress. So, now, output per worker is growing at a rate of g at the steady state and what is this g? g is the rate of growth of technology.

Now, if you ask the question how do we measure the rate of growth of technology? So, we will answer that in the last week of this course. Right now, let us take it as a certain value. Let us say this g is 5 percent. And one of the reasons you know why it is assumed that this g is the same across all economies is an assumption that is made because you know technology is also diffused very fast these days. So, for all those reasons it is pretty much assumed that there is diffusion.

So, this g value might pretty much be the same across nations as well. So, this is the interesting point that only when we consider the Solow model or the Solow growth model with technological progress, even after an economy has reached a steady state, its output per worker still keeps on growing at this rate, g. This you can check and see if we go back to the model where there is no effective worker. If we just go back to the model of the regular Solow model that we have done, where we define Y as this, I am talking of this model. Go back to that model and see what is the steady state growth rate of output per worker at steady state.

It does not generate that growth. This growth is only generated in this version of the model with technological progress. And total output, you can figure it out from here at steady state. Now, total output only not per worker, that is, the absolute output, it grows at a rate of n plus g. This you can work it out and find it out. This is the most important outcome of the augmented Solow growth model.

That is why this augmented Solow growth model is so celebrated that if an economy wants to keep on growing even after reaching the steady state, then its growth will come from technological progress. That is the big takeaway from the augmented Solow growth model. In other words, this underlines the importance of technological progress. So, higher technological progress, higher will be output per worker growth in that economy after reaching the steady state. So, this is why this augmented Solow growth model is so celebrated.

This I should also mention here, is more in the context of economies that have already attained a steady state. So, if the concern is well we have attained a steady state, how are we going to grow now because we have reached the steady state, then the source of growth is going to be technological progress as long as there is technological progress per capita output is going to grow for such economies even at the steady state. The policy implications of the Solow growth model, we already, I think, kind of talked about that. Individually, when we were talking about the impact of increasing s, the impact of change in small n, but remember they all have level effects.

It is only the change in small g which is technological progress. That generates a growth effect. So, what is the big takeaway and again, remember, suppose we are a consultant to a policymaker, and if that person asks us that, based on the Solow growth model, what would you prescribe an economy should do in order to keep growing perpetually even after reaching the steady state, the answer is there has to be technological progress. So, these are the policy implications, some of the policy implications we will also come back to in the last week when we talk about convergence. So, to summarize what we have seen or learnt this week.

We had discussed the benchmark Solow growth model. So, in the second week, we had discussed a lot of data, we had seen a lot of data. In this week we have tried to kind of you know align them. So, is what we see, how can that be represented in models? And that is what we had discussed here, apart from the benchmark Solow growth model, where there is no technological progress. Later, we introduced the augmented Solow growth model where there is technological progress.

So, this is the big contribution of Robert Solow in enhancing our understanding on economic growth. So, he gave us that big answer that if economies you know they wish to grow. And they wish to grow forever even after reaching their steady state, because you know steady state is kind of like an equilibrium right that we have discussed before. Just like in every economic model you know reaching the equilibrium is the objective, but here the question is do economies grow even after reaching the steady state, the answer is yes if there is technological progress. So, next week what we are going to do is we will again come back to Solow partially because there are two implications that are very important from the Solow growth model, which we will discuss when we discuss the idea of economic convergence because you know, many times this question is asked that.

Are the poor countries ever going to catch up with the rich countries? What does the Solow model predict? So, this catching up in other words is known as convergence. So, we will look at the concepts of convergence. And because technological progress or productivity growth, these two terms are generally used interchangeably. They are so important in this literature. We will also go over two related concepts like growth accounting and development accounting.

Where we learn a little bit more about how this technological progress or productivity growth is measured in the literature. Then, we will finally you know close this particular course by introducing you know what are the new growth theories and why we eventually moved away from the Solow growth model. Remember we said it is a good starting point, but then you know there are more models and over time they have developed. And this class of models is known as new growth models. So, we will just introduce the idea of new growth models and wrap up this course.

So, thank you all of you for staying with us so far and I will see you next week once again. Thank you.