[SQUEAKING]

[RUSTLING]

[CLICKING]

**RICARDO CABALLERO:** OK, so today we're going to start talking about the long run. I've been talking about the business cycles, and today we're going to start talking about things that happen over decades.

But before I do that, before we finish with the short run, medium run, I don't want to give you the impression that once you understand the IS-LM-PC you can start managing monetary policy immediately. There is a lot of noise of all sorts of complexity in the real world, of course, that can make policies very hard to manage in practice. Macroeconomic policies.

And one fundamental principle, I would say, is that policymakers understand that speed can kill, and that's very obvious during financial crisis. There we all understand that the response needs to be large. It has to be a response with overwhelming force.

Essentially, because things are happening so fast that very few corporations, even healthy corporations that can adjust quickly enough to the pace at which things are changing, prices become non-informative, fire sales take place, and obviously it's very difficult to make economic decisions in that context.

And so that's the reason they are-- the speed on the policy direction goes very clearly in one direction. Do it quickly and very large.

Now, on the other hand, when you're going through a period in which you're hiking interest rates, for example, like we're going through now, the tendency is towards gradualism, to do it very slowly, because something can break along the path. And it's often the case that for sufficiently large adjustments, something breaks.

And so here you have an example of major episode of hiking in the US and things that have happened among those major episodes. This one actually, I have a personal attachment to that one, because I was studying in Chile around then. Everything was going wonderfully. Massive capital flows through Chile. Emerging markets were very popular. We all felt very wealthy, rich, and so on.

And right after I finished college, I was not planning to come to the US. Why? Things were going very well in Chile. But the US decided to hike interest rates very aggressively. All of a sudden, capital flows to emerging markets disappeared. We went into an enormous financial crisis. I lost-- I had no opportunity cost, and I had to come to study to the US.

So I know that aggressive hikes can matter, can make differences to people. And there is a decade that followed that episode that is called the lost decade of Latin America, essentially. So things did break.

And one of the main reasons they did break is because at the time, most of the capital flows-- that's not what happens today-- were really being managed by global banks. And banks can get very distressed when interest rates rise very quickly.

And so that was essentially a problem with the US banks, the major global banks, but the US banks in particular that triggered an emerging market crisis.

This one also had huge consequences, actually. And it's interesting because this episode is similar to what is going on right now or what may happen soon. So this episode of hikes that ended what is called the savings and loan crisis. And those, the best parallel to today, are the small regional banks, if you will.

And they weren't able to withstand this sharp rise in interest rate, which is very much what is going on right now in the US.

This one actually ended up with also another problem, which is the bubble burst in Japan. Episode of hiking in the US. And there we had a major crisis in Japan. The price of real estate collapsed, and essentially they, since then, they have never been able to grow as they used to before that episode.

That's called sometimes the tequila crisis. This is a Mexican bond crisis, and it was, again, the result of a hiking episode in the US. Conditions tightened to emerging markets. Their bond market essentially exploded.

This is a global financial crisis, the Great Recession. It was again preceded by episode of aggressive hikes, which eventually let to turn around as house prices were rising steadily throughout the episode and a lot of financial assets were created around that housing wealth that was being created. That hike in interest rate eventually put a stop, an end to that appreciation of house prices. In fact, they turned around, and it led to a very significant financial crisis.

And this is where we're at right now. And so we are already seeing some tremors and so on.

So the point is when sometimes people say, well, why isn't the fed more aggressive if we have high inflation and go very quickly at it? Well, it's because things can go wrong. And it typically happens that things do go wrong. You don't know exactly what will blow up, but something may blow up.

And typically it's associated to some financial market that is very hot, and the market and the banks are always involved in that because the banks are very lever. They have little capital relative to the assets they have, and that means a small variation in the price of assets can lead to very large changes in the value of their capital.

Anyways. So just a warning. So if you get a job at the fed, please be careful.

OK, now let me switch gears. We're going to talk about something a little different from what we have been discussing up to now. So this is growth projections for different regions in the world. This is something that is published by the IMF. It's called the World Economic Outlook. I think I mentioned it before.

And here you have some forecasts. Well, this is actually what happened. So growth in the global economy was about 3.4% 2022. Advanced economies grew at 2.7%, emerging markets and developing economies at 3.9%. And then you see forecasts. And the further out you go is less related to the current cycle. It's more related to what is structural. The structural growth of the different parts of the world.

And you see that for 2024, the global economy is projected, expected to grow at around 3.1%. These forecasts were made before financial mess that were going on right now, so probably the next World Economic Outlook will have, at least for 2023, will downgrade the growth. Probably not for 2024, but yes, for 2023

Anyways, advanced economies expected to grow at 1.4%, emerging markets at 4.2%. So these forecasts are based on a combination of cyclical factors, fluctuations of the short run, medium run, the kind of things we have been discussing up to now. Some economists will have to go through recessions. Some economists are going through booms. That probably dominates the forecast on 2023.

But as I said before, the further out you go, the less relevant is the current business cycle and the more relevant is the structural trend of the different regions of the world. So I would conjecture that in this, when they formulated this forecast, this is very much based on more longer-run growth model, the kind of models we are going to discuss now. While this is probably totally dominated by the kind of things we discuss up to now.

There are several things that are interesting here, aside from the fluctuations in year to year. One thing you can see, for example, is that regardless of year, on average, emerging markets tend to grow faster than developed economies, advanced economies. So one of the things we want to understand is why is that the case.

But it's very clear here. The first model we're going to look at, which probably will happen on Wednesday, will try to explain essentially that-- why is it that these guys tend to grow faster than the advanced economies?

So growth is important. Understanding economic growth is hugely important for the world, for understanding the health of an economy. Here you see-- this comes from the textbook-- the US GDP in 2012 dollars from 1890 to 2017, I think is this one, the end year.

The important thing to notice here is how large is the change in GDP in during this period. GDP here, measured in the same prices, so 2012 prices, is 50 times that in 1890. That's a big thing. When we talk about business cycle fluctuations, we're talking about, in an economy like the US, 2%, 2.5%, 3% up and down. This is 50 times.

So over longer periods of time, you can almost ignore the business cycle, and it's all about that long-run trend.

Here, what is this episode? So here, if you look at this picture, especially the further out you are on the room, what dominates here is clearly the trend. The only action you see, really significant action different from the trend, is around here. What happened there?

It's the Great Depression. So even the Great Depression doesn't look that big relative to what the trend can do. So of course, it's very difficult to affect the trend of a country, but the trend makes a huge difference for the welfare, for the economic well-being of a country. Good.

Now, a lot of that is because also the US population grew up and grew a lot during this episode. So often when you look at long-run trends, rather than looking at the level of GDP, you tend to look at the level of GDP per person, per capita, or something like that. And that picture is exactly the same picture as the previous one but divided by population at each point in time.

OK. And that's an important-- over long periods-- at the business cycle frequency, you can almost ignore changes in population-- no, changes in population you can not ignore completely unless you are in a war. You worry about other things-- labor force participation and stuff like that. But population is irrelevant to the business cycle. Growth is relevant to the business cycle frequency, but not over long periods of time.

In this period here, population in the US increased from 63 million to 320 million. So that's a lot more workers in principle that you have for that economy. So a lot of that trend is explained by population growth, and that's one of the reasons-- sorry.

A lot of the strength in this picture here is explained by population growth. That's one of the reasons we're in a tricky time in the global economy, because there are many important regions of the world where population is no longer growing.

So we got used to a period in which population growth was very steady and high, and now, many parts of the world, important parts of the world, have negative population growth-- Japan, Korea, China, most of continental Europe, even places in Latin America, and so on. So this is a big change for the world.

But anyways, during that period there was a lot of population growth. And the US in particular, again, as I said before, from 63 to 320 million. So if you really want to measure welfare of the economy, the well-being of individuals in the US, the previous picture is misleading because you have to-- yeah, the final pie is 50 times larger than the first, than the beginning pie, but you have 320 million people to split it among as opposed to 63 million.

So this picture captures that. A statistic that is often described when you talk about long-run growth is GDP per person. And you still see that what dominates this picture is a trend, but the difference between this GDP per person in the US at the end of the sample versus the beginning of the sample, it's 10 to 1, not 50 to 1, so it makes a difference, population. It's still big. It's still what dominates this picture is that.

Of course the Great Recession looks bigger now because you're comparing it with a number that grows by a factor of 10, not by a factor of 50, so it looks bigger naturally. The same 30% decline in output is a lot bigger when you're comparing it with a factor of 10 than when you compare it with a factor of 50.

But still, it looks bigger. But the picture is dominated by the trend. So all this to say that what we're going to study now is very important. It's not what dominates the day to day news because it happens slowly and over time, but it is very important.

So how do we measure these things? When you're looking within a country, you do reasonably well, not perfect, but reasonably well, and perhaps not over periods as long as the one I showed you, by looking at GDP per capita. That's fine. You measure it real GDP per capita, that's about fine.

But when you compare across different regions of the world and so on, those comparisons is very misleading. So to say that the US has-- I don't know. What is the US GDP per capita today in the US? Somebody should check it. But it's about maybe $70,000, something like that. I don't know.

And then you see another country that has, say, Italy, $50,000 per capita. That comparison is not that meaningful. It's indicative of something, but it's not completely meaningful. And I'm going to show you an example which is much more extreme than that. But the reason it's not very meaningful is essentially because the prices are not the same across different parts of the world.

So we have a method to do that, to be able to compare across countries. And again, even for a given country over long periods of time, we make a correction to the GDP numbers we have and we correct them by what is called PPP, Purchasing Power Parity. And I'll explain what that is.

So whenever you see comparisons of GDP per capita across countries, when somebody is doing a growth analysis, it's going to be PPP adjusted.

Now let me explain the logic of PPP. And again, I said, within the same country or periods, perhaps not 300 years, but over periods of 40 years, it's reasonable to use just real GDP. But when you start comparing Botswana versus the US, it gets a lot trickier because there is a lot of goods that are a lot cheaper in poorer countries, in particular food. OK. And so you have to be careful with those comparisons.

So I'm going to give you this example, which is somewhat hypothetical, but the numbers are not crazy. So suppose you have two economies, the US and Russia-- well, anyways. And suppose that in both economies, households and firms consume cars and food.

And suppose that the average consumer in the US buys one car a year for $10,000 and a bundle of food for $10,000 as well, so the total expenditure in consumption for this household on average is about $20,000 a year. That's what a US household consumes. These numbers are fantasy numbers, but the big picture is not that fantasy.

Russia, the average consumer buys 0.07 cars a year for 40,000 rubles and the same bundle of food that in the US. Same, assume that. Same bundle of food good for 80,000 rubles. So the total expenditure of this average household in Russia is 120,000 rubles.

Suppose that the exchange rate is 60 rubles per dollar. This thing has moved a lot in recent times, but suppose that's the number of rubles per dollar. So you divide $120,000, and you want to convert them into dollars, you divide the 120,000 rubles by 60,000 rubles per dollar, and then you get how much a Russian household on average spends on consumption in a year, and it's $2,000 a year.

So here you have 120,000 divided by 60. it's 2,000. That's the number of dollars that an average household in Russia consumes.

So the question is, you have a US household spends $20,000 a year, a Russian household spends $2,000 a year. And the question is then, is Russia 10 times poorer than the US? OK. If you were to compare real GDP, that would be answer. Yeah.

And it's true. If you look at, again, in this example, if you look at the real GDP numbers on the same year converted all into dollars, that answer is correct. But it doesn't represent-- the point is that it doesn't represent really the well-being of the average household in Russia for this reason, at least.

Why not? But you ultimately matter is how much real goods the household consumes. That's what really matters. If you live in a country where the price of everything is zero, your consumption expenditure consumption will be zero. But that doesn't mean that you are as unhappy as somebody that consumes zero. You're consuming whatever it is. It happens that the prices tend to be very low.

And that's essentially the story here. As I said before, it tends to be the case that in poorer countries, a lot of things are cheaper. There is certain very high-tech things that are not even consumed in poorer countries, so you have to adjust for that as well. But a lot of the regular things, the bulk of the purchases tend to be a lot cheaper ir poorer countries.

And that's exactly what is behind the reason why in this example, the answer is no. It's not true that the Russians are 10 times-- the Russian household in this example is 10 times poorer than the US. Let's check it.

So that's our example. And I said, not so fast. Let's use-- so assume that the goods are the same, so the cars that the Russians buy is the same as the cars that the US households buy. That was truer a few months ago than now, but assume that's the case. It's just that the Russians change their cars less frequently. In this example, the US household is changing the car once a year, while the Russians are changing the car no less than once every 10 years, one every 15 years or so.

Let's assume also that the bundle of food is exactly the same in both places. So since the car is the same and the bundle of food is the same, I can use US prices to measure ration consumption. And that's comparable to what US consumption is because I'm trying to convert the goods they're consuming into something that's comparable to what the US consumes.

Since the goods themselves are the same, if I value them at the same price, either of the two prices, but at the same prices, then I'm going to be able to make the comparison that I really want. That's what PPP adjustment means.

So look at our particular example. Here, the Russian household would be consuming 0.07 cars times $10,000, which is the price of a car, plus 1 unit of a bundle of food. And the US price is $10,000 for that. So the total consumption of the household, PPP adjusted, the Russian household is $10,700. OK.

That's not 1/10. It's 53% of US consumption. So true, Russian household is poorer than an average US household, but it's not 10 times poorer. It's 53% as rich as the US household.

And so this is big. And all the numbers I'm going to show you next, especially when we compare across countries that are very different in terms of level of development and so on, have these kind of corrections built in.

If you need the data for these kind of things for whatever reason, you find them in what is called the Penn Tables. The Penn Tables is essentially collects all the national accounts of all places and makes these corrections. The problem is they don't update them very frequently. But if you look in, [? Fred, ?] for example, which is using one of the P sets, there will be numbers for a few countries that have this PPP adjustment.

OK, so that's going to remain in the background now, but I just wanted to tell you how you construct numbers when you want to talk about long-run and comparison across countries.

First set of numbers here. These are obviously all, today, at least, developed economies. Look at the growth between 1950, 2017. Obviously, the war created a big mess there, but before that, so let's start from 1950. And what you see here is France, on average during this period, France grew-- 2013 I think is the last-- yes, it's the last year. I think they were recently updated, but at least when the book was published, that was the last year they had Penn Tables for.

But France grew, on average, 2.6% per year on average. They also had a business cycle and so on, but on average, 2.6% per year. Japan during this period grew by 4.1%. UK, 2.1%. The US, 2%. So the developed world essentially grew around 2.7% on average during this period.

Look at the effect that this has on the level of GDP per person. And all these PPP are adjusted. For the case of France, 5.6 times. So they started with $7,000, and they were close to $40,000 in 2017, so the ratio is raised 5.6.

Look at the US. The US is 2%, and that ratio is-- it's still richer than France per person in 2017, but the ratio of that to that is smaller than that. So over a long period of time, that's what the trend in the picture capture. A small difference in the rate of growth, if they are sustained for a long period of time, can make quite a bit of difference for the change in GDP.

And so what is the first-- what is the pattern-- let's find the pattern here. There's a very clear pattern in that picture, in that table. What is it? Can you spot it?

I hadn't actually realized it when I was looking at my notes and then realized that it's very clear in this table. That's the reason I added this line, I updated the slide this morning. Do you see a pattern? Yes.

**AUDIENCE:** The higher growth rate have a higher multiple.

**RICARDO CABALLERO:** Yeah, Yes, but that's math. OK. So it's a true statement, but that's just math. There's an economic thing that I want to-- so you're right, but I want-- I should have clarified. There's an economic pattern there.

Let me simplify. Just look at these two columns, because a higher number here simply-- sorry. A higher number here simply means that you have a higher rate of growth. That's your math facts. So ignore this column. What I suggest is that you just look at these two columns.

Do you see a pattern? Just look at these two columns. This one, in a sense, just repeats information that is here for the reason you described. But just look at these two columns. Is there a pattern there?

Exactly. Very important. Richer countries tend to grow slower. The richest country here is the US. Had the lowest rate of growth on average. The poorest was Japan there, and they had the highest rate of growth. OK. So that's a very important correlation. And again, the first model we're going to see of economic growth is going to explain that correlation. Why is it that we see that?

Those were for five economies. You could say it's an axiom. But look at this. This is rich countries in general since 1950s. And you look at here in this axis, you have the annual rate of growth, the average rate of growth, and here, the GDP per person in 1950. So at the beginning of the sample, 1950, these countries have this level of GDP per capita. And then here is the rate of growth on average from 1950 to 1987.

And it's very clear there that there's a downward sloping pattern, no? So that's the same fact now for many more countries, this it's a downward-sloping relationship. The richest countries tend to grow much slower than the countries that were poorer at the beginning of the sample.

There are some interesting outliers, like Mexico, and it's interesting in itself. I'm not going to say a lot about why that's the case, but let me for now stick to the pattern, the dominant pattern, which is a downward-sloping relationship.

That's another way of seeing it. And this is for just a bigger variety of countries. I have Botswana, China, Thailand, and so on. And you see here, GDP at the beginning of the 1950 and GDP by 2018. And the pattern here, which is essentially a repetition of the pattern that I showed you before, is that there is much more compression here than here.

How can you have more compassion here than here? Well, because there is some sort of convergence. There is a sense of convergence. It's that those that were poorer tend to grow a little faster than those that were richer, and therefore they tend to converge to each other. So that's the point I'm highlighting here.

A lot of this pressure, 1950, much less dispersion in 2018. That means that on average, the poorer countries are growing faster than the richer countries. And again, all this is per capita, PPP adjusted, and all that.

This picture, again, sort of makes the point, but now it takes many more countries. The point of this picture-- it's in the book-- is to highlight that-- it's a little messy, the picture, but to highlight that if you look in different regions, OECD is the major economies, tend to-- the pattern I showed you holds. If you only isolate only the blue squares, you tend to see that negative relationship.

If you look at within Asia, it's a little bit noisier, but you also tend to see a negative relationship. If you look at Africa, that relationship is lost completely. OK. So when you look at the world as a whole, the picture is not as neat as the one I showed you because there are certain pockets of the world that are not behaving according to the kind of models I want to discuss in the next few lectures.

And the reason they're not behaving, is entirely-- it's almost outside economics. It's political conflicts, wars, and things of that nature which continuously disrupt the economic forces that I'm going to highlight in the next few lectures. OK.

So that's a different issue. All the models I'll show you next are about the blue and the green squares and triangles there. Not about the red ones.

So I show you what happens across countries over a certain period of time, which is long but not that long. Here you see what happens in longer history. There are two patterns that I like to highlight here, is that first, for a while you didn't see much, but you tend to see a big acceleration, in the Western world especially, around the 1950s or so.

So clearly the Western world was growing faster than the rest of the world. The Western hemisphere. This is a more [INAUDIBLE] type and grouping. And you see that there's a very fast acceleration in growth in this episode here.

Western Europe was also flattish and then picked up very strongly there. And you see the different regions of the world. And again, you see the sub-Saharan Africa region that sort of hasn't really picked up. OK.

Much longer history. Well, that's the way it looks for the world as a whole. OK. Exponential pictures tend to look like that, but this is more dramatic than exponential. And again, what happened here is going to be very different from the kind of models I'll describe next.

This period here is mostly dominated by what's called the Malthusian era, which is essentially people live, population grew, and so on, depending on how good was the harvest that year and so on. So you had this model in which this population grew faster. There was a main driver of growth.

Well, but, you know, there wasn't enough food to sustain a higher population, and then you stay. So there was a fight between food and people and not much space for-- most people were in agriculture, and there wasn't much to build on.

Nowadays there are pockets in the world, and we had the severe situations during COVID, but food is not really a constraint for growth for the world as a whole. OK.

So, in other words, had you taken this course in year 1,000 or in the Renaissance, nobody would have talked about growth. It's not something that happened, really. It's a very modern thing to think about these pictures with these long trends and so on. OK. You would have talked about a lot more interesting things than this, but not about growth, that's for sure.

And growth, the last point I think I want to make about this is it makes a big difference. I don't know if you can read that. I can't. But what I have here is GDP per capita in 1950 versus GDP per capita in 2016.

And you have these isochrons here. As you move up-- so this line here is what happens to countries. It's a 45-degree line, so if you are on the 45-degree line, means that you haven't grown at all during this period. No, because that means that your GDP per capita in 1950 is the same as your GDP per capita in 2016. That means on average, you didn't grow.

But as I keep moving these lines up, it means you grew faster and faster and faster. And if you move along this line here, that means you have negative growth on average during that period. So each of these lines represents multiples. For example, this top line here is 30 times richer. These are guys that grew very fast. I cannot read either, but I sort of know who is in each place.

This is an example here. This is Taiwan. This is Taiwan, and this is Singapore. They have a name. How do we call those countries? No, well-- the Asian Tigers. They grew very strong for a long time since the '60s or so.

But there you see. You can compare. If you could see, you would see that Taiwan and the Democratic Republic of Congo had the same GDP in 1950. Now the Democratic Republic of Congo has less GDP than it had in 1950. It had $1,700 here and $800 today, while Taiwan has 30 times what it used to have.

And so today, Taiwan is one of the richest economies in the world. It's close to $50,000 per capita, while the Republic of Congo has $700-- $800 per capita. So growth makes a big difference. And these are not that many years. This is just 70 years.

And I can assure you that these people, they have other concerns, but their standard of living is a lot higher than these people. And at some point, they were the same. The big difference is some countries grew and some countries got stuck.

Where is Argentina here? I don't know. Somewhere here, probably. It's Argentina. I don't know. I cannot see. I'll have a better chance here. I cannot see. OK, good.

So growth does make a difference. And it has made a huge-- the world we see today and the countries we think as rich or poor were not the same countries that you thought in those terms in 1950. Asia is one of the most prominent differences. They have massive growth through the '60s starting with Japan, but then the rest. And again, were the famous Tigers-- Hong Kong, Taiwan, Singapore, and Korea. South Korea.

Good. So let's start building some models of what we have just seen. Remember, when we look at the short run, we really didn't care about the supply side of the economy. Remember, it was all about demand. They said, well, demand, look what consumers, investment firms, and governments do with demand. That determines output.

And how output happens? Well, it happens. We didn't really care too much about it. Then when we talked about the medium term, we say, OK, no, no, we have to care because to produce, you need workers, and workers are not going to work for any wage, and so we have to begin to talk about the supply side of the economy.

But we made it very simple. We just looked at the problem of wage bargaining and price setting. But the production function itself wasn't that interesting. It was output equal to labor. And I told you it's very unrealistic, but it was convenient for that part of the course because capital doesn't grow that fast.

So typical production function will have both capital and labor, but at the business cycle frequency, investment, the change in capital can be large, but the stock of capital doesn't move that much and so you can ignore it for business cycle type fluctuations. But if we want to look at the long run, capital plays a huge role, capital accumulation. And so we have to be explicit about the role of capital in the production function.

And now we're going to forget about aggregate demand. We're going to say, look, we're going to focus about aggregate supply, and demand will do whatever it needs to do. So we get what the supply side says. So output now will be an increasing function of both capital and labor. [INAUDIBLE].

Now this function will have a bunch of properties, many of which are-- no, at a broad level, they are empirically validated, but they are also very convenient from the modern point of view. The first and most important property is constant returns to scale. We're going to use a lot of properties, so please get that concept.

Constant returns to scale means simply that if you scale the factors of production, you also scale the output. OK. So say if x is 1.1, that means if you increase capital and labor by 10%, you get 10% more output. OK. So that's constant returns to scale. If I scale all the factors of production by the same amount, the same proportion, then output grows by the same proportion. It's scalable. That's what it means, constant returns to scale.

Very important property what comes next-- decreasing returns to capital. That is, as you increase capital for a fixed amount of labor-- so constant returns to scale is a property of a scaling everything up. The property I'm describing here is what happens if we increase only k. What happens to output if we increase only k but fixing n?

In other words. set this to one, and it start moving this up. You're not going to get x here. You're going to get something different from x. What this tells you is that, yes, you're going to get more output, but less and less the more capital you have.

So this says, for example, suppose that you start with 100 workers and 100 units of capital, and it happens that this produces 100 units of goods. If you add now 10 units of capital, say you're going to get seven units of output. Not 10, seven, because you didn't increase labor. Had I increased labor also by 10, I would have gotten 10 of output, but I've been increasing only capital by 10, then I'm keeping output fixed-- then labor fixed, then output will increase by less than 10.

But what this decreasing returns to capital says is that now if you increase again from 110 to 120 units of capital, you're going to get less than seven units of output more. You're going to get five. And if you increase again from 120 to 130, you're going to get less than five. You're going to get three. And so on and so forth. That's decreasing returns to scale-- decreasing returns to capital.

And the reason for that economically is that more and more capital is working with a fixed number of workers, so labor becomes very scarce for capital. And that's the reason. So you have very little of-- these are factors of production which are complementary. They need each other, labor and capital. You fix one, and it starts increasing only one, then it's harder and harder for each extra new unit of this one to work with fewer and fewer of the other factor of production.

So the same principle applies to labor. If you fix capital and you only increase labor, then initially you're going to get a big jump in output, but it's going to be smaller and smaller and smaller the more you keep adding labor.

So one x that we're going to use throughout is we want to make x-- one of our favorite x will be 1 over n. You see what I'm trying to do. When we set x equal to 1 over n, so that x equal to 1 over n, what I get here is output per person. No? That's what I get. y over n.

So if I set x equal to 1 over n, I can use some constant returns to scale. I know that this is equal to y over n, k over n, n over n, so that is one, so this guy doesn't move. And I have now that output per person is increasing in capital per worker. Worker and population, this part of the course are the same. Forget unemployment. Any population is employment. Labor force is everything. This is not a place to worry about unemployment.

OK, so remember that all the plots I showed you, the different figures, were about this variable-- how it change over time, how it was different across different countries, how it grew at a different rate in different countries. But from this very simple model, you see that in order to explain the change in this growth in y over n and why one country grows more than the other, you have with the simple model only two options.

So if I tell you country A grew more over this period than-- grew more per person than this other country over this period of time, there are only two options here. The first one is in that country, there was more capital accumulation per worker, so k over n went up. If k over n goes up more in one country than the other one, y over n will go up more in that country than in the other one.

And the other option is that this function itself shifted up. So for any given amount of k over n, now you can produce more y over n. And that's what we call technological progress. That's the second thing.

So is the difference in growth of output per person is due to an increase in k over n, well, we call that a capital accumulation mechanism. If it is because the function f shifts up, that's technological progress. And what we're going to do is in the next lecture, we're going to talk about this channel, the capital accumulation channel. And in the lecture after the spring break, we're going to talk about shifts in the function f.

So in figures-- so fixing the technology, that this is the function f is fixed and you just move k over n, this is the picture you have. Now that's a production. I'm plotting this function here as a function of k over n for a fixed function f. And that's what you get.

So output-- I have here capital per worker and output per worker. And you see that obviously it's in an increasing function. The more capital per worker you have, the more output per worker you produce. But it's also concave. Why is it concave?

That's decreasing returns to capital. When you have very little capital per worker, a change in capital per worker gives you a big jump in output per worker because there was very little capital. That was a problem with that economy. When the economy has more and more capital, the same change in capital leads to a much smaller change in output.

Here at this level, when capital per worker was very low, the economy was very poor. Then this change led to this change in output per capita. At this level of wealth you get as capital, economists would hire capital richer, capital per worker, the same change. This change is of the same size as that. Leads to a much smaller change in output. And that's a result of decreasing returns to capital.

And that's the other option. Again, that's what we're going to talk about in the next lecture. This one. And two lectures from now, we're going to talk about growth that comes from shifts in the production function, this technological progress. OK. Very good. See you on Wednesday.