Research and Development Implementation and Stagnation: Schumpeterian Theories of Convergence Clubs

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Ruben asked me to talk about some of the aspects of endogenous growth theory on which I have been working for the last 15 years. I will try to highlight some points related to the issue of how investments in human capital and health are related to economic growth. We know that in a long run economic growth rates depends on the rate of technical progress, and that this is a critical factor in the process. Within the framework of endogenous growth, technological progress is not given from outside the economic system, but quite to the contrary has many economic determinants.

There are two strands of endogenous growth theory. Many are familiar with what I would call the AK version of endogenous growth theory. This version of the theory says that, although it is intangible, technological knowledge is just like any other kind of capital. That is, when people accumulate capital they tend to accumulate intellectual capital along with physical and human capital. According to this version of endogenous growth theory, the process of technological progress is considered pretty much like the process of savings and investments and all we have to do is to encourage the people to save more and eventually technology will flourish and growth rates will rise.

The strand of endogenous growth theory that I've been working on uses a different approach and it has been labeled a "Schumpeterian" variety of endogenous growth theory. It makes a very important distinction between investment on physical and human capital on the one hand, and investment on technology on the other hand. There are some important differences between these types of investments. There are differences in the degree of uncertainty associated with the returns to the investments, differences in the kinds of spillovers that are involved in the process (e.g.: technologies are often easy to replicate), differences in the kinds of returns to scale that you have in these different types of investments. For instance, investments in technology can be made one time and after that that investment was done the results of these investments can be used recurrently without having to incur in new investments. However, if you want to use twice as much machinery as you already have you'll have to acquire new machinery in the same proportion. Moreover, - and this is critical point - technological progress is indeed a social process that is rife with conflict. Largely because of the phenomenon that Schumpeter called "creative destruction". Technological change brings about great benefits to vast numbers of people, but it also destroys a lot of fortunes. And it does so through the general process of obsolescence. People in fast-growing societies have to be used to a pace of rapid change and a lot of volatility. Inequality occurs as a result of these changes that lead some people to flourish and others to have their skills and occupations in industries become obsolete. As a consequence of the process of technological change individuals, sectors, and even regions can turn become winners but also losers

We know that one of the key determinants of a country's ability to undergo technological change is the willingness or the inability of those on the losing end to block the process.

And, institutions of course have to be worked out to mediate this conflict. So, that's the kind of growth theory that we're working on, (one) that looks at the micro-foundations of the innovation process with all the winners and losers and how that's different from just the process of capital accumulation. This has turned out to be just a sort of a general framework for understanding not only economic growth, but a whole set of issues that interact with growth, and because (of) this new framework we are looking at, the framework of understanding markets where competition takes place through innovation, through this competitive process with lots of winners and losers. The theory turns out to have a lot of micro-underpinnings that give lots of handles for understanding how various policies and institutions can overall affect the growth process. But it has a fairly straightforward macro-structure as well, that we can take a look at from a macro economic point of view.

Today I will not be able to share much of this theory. However, Phillip Aghion and I have written a whole book on the subject where you can read with more detail about this model. A lot of my remarks today will be drawn from this particular paper that I have recently written with David Mayer Foulkes. Nevertheless, I will attempt to offer you a very broad perspective of how this theoretical approach looks like.

When you boil it down to its microstructure, you can argue that underlying growth, in the long run, there are two kinds of processes. One is, of course, technological innovation and the other is capital accumulation. And, of course, the focus here is on technology investment as something that is distinct from just capital accumulation. But the two processes have a very close interaction. So, we can think of investment in technology as being determined jointly with the amount of capital existing in an economy. This investment occurs determined by two relationships, one being what I call a research arbitrage relationship, a relationship that determines the extent of technology investment in a country as function of the country's wealth in capital stock, how much capital it has accumulated. Also it is important to mention that this is an increasing relationship. It's increasing because of what's known as the scale effect in economic growth. That is, countries that are richer, because they have accumulated more capital offer greater payoffs to people making investments in technology. People making those investments

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expect to capture some markets and earn some profits from having some market power such as is the case of a monopoly on something that others haven't invented or haven't been able yet to copy. The bigger the market, the more the profits, and because of the fixed cost nature of investment, it costs just as much to invest for a small market as it does for a big market. The bigger the market is the more of these investments you're likely to get. And that's why you call this a positive relationship.

Then we got a negative relationship, which is the sort that you might get through the standard neoclassical growth theory. More technological investment will tend to mean a

higher rate of technical progress and we know that if you measure the capital stock in terms of the capital stock for efficiency unit of labor in a neoclassical growth model, the faster the technological progress, the lower is going to be the steady state level of capital relative to the state of technology. And that's turns out to be what matters here.

So, you got these two pairs that intersect. Of course, anything that directly impinges on the incentives to invest in technology will ship this research arbitrage equation up resulting in a higher level of RND investments and technological progress, and faster growth rates for the economy. But likewise, anything that generally leads to a higher level of capital stock is going to shift this saving curb to the right and also result in the end in a higher growth rate by spurring on technological progress with a scale effect. So, you see, what we got here is a theory where an awful lot of things can affect the rate of economic growth either directly, through affecting the incentive to invest in technology, or indirectly, by making the economy richer one way or another, and thereby working through the scale effect.

Now, you might wonder what is the relevance of all this for very poor countries that typically don't do what is measured as formal RND (90% of RND measured by various peoples is conducted within the top ten richest countries in the world, very little of it has been done in middle income and poor countries). But, as Evans and many others have pointed out over the years, it doesn't matter whether you are on the leading edge of technology or whether you are simply trying to borrow technology to improve it. Various investments need to be made in order to profit from technological progress even if it is originating elsewhere. Because we know that technologies are not perfectly transportable, a lot of technological knowledge is circumstantially specific: it works in one area, but is has to be modified to work in another area. Some of the knowledge is tacit not codifydable: experimentation has to be undertaken again in order to apply (it) in a different circumstance and so on. So, we think this is very relevant. On the other hand, we do know that there is what Schumpeter called an advantage of backwardness: that countries that are behind the technology frontier can benefit to a large extent by directing the technology investments towards adapting what's been already invented elsewhere. And, this is sort of captured here. I'm just showing you two broad equations from the kind of theory that is in the book and the paper that I talked about. The one being straightforward aggregate production function, and the other being, if you like, technology for technological change. And it shows you the two rules of human capital, and how they fit into the growth process according to these theories.

Human capital is both a factor of production entering into an aggregate of production function along with physical capital, labor and the state of technology (I just indexed by A). And, that output, of course is divided between consumption, investment in physical and human capital, and investment in technology, and research. But is also a factor of production in generating technological progress and it ended therefore into this equation. This equation tells you that the rated change of technology is going to be the product of frequency of innovations and size of innovations. Think of innovations taking place in a bunch of different industries and sectors in an economy. The rate at which those innovations take places will depend upon the amount of RND spending or, in general, the

amount of generalized expenditures and investments in technology -- which is hard --, and also upon the amount of human capital in that economy. So, a lot of expenditures are not going to pay off as well in a society poorly educated or with a work force without a lot of skills.

And, both of those variables I'm dividing by this thing I'm calling A Max. You can think of A Max as being some level of technology on the leading edge in the world. Countries that are inside the leading edge are engaged typically in a race. If they want to make technology growth, they want to continue to invest. The best way to do that is to try to top into what is going on in the global frontier and make use of ideas that are developed elsewhere. Of course, more investments have to be made, but a lot of them have already been done. But, as technology advances it gets more complex, and it rises the state, it rises the requirements of how much has to be spent, how much the skill requirements are, and that's the reason why both of these things are normalized by that level. So, as technology advances in the rest of the world, if a country wants to continue to make improvements at the same rate as before, it has to have increasing expenditures and RND investments, it has to have increasing skill levels.

Then, this other factor over here measures the typical size of innovations. This is, if you like, the Schumpeter's advantage of backwardness. The further behind is your technology, (or) state of technology relative to the leading edge, the bigger will the typical investment be when you finally make a change in some particular sectors. And, what that means is that if you take a look at an economy that is tied into a global world of ideas, countries that spend a lot on R&D, will end up in a long run, growing no faster than countries that spend relatively little on RND. The difference will show up not in a difference in growth rates, but in a difference in levels. Imagine two countries that are investing at the same rate. (If) one starts to invest a lot more, it will pull ahead of the other, it will have a faster rate of technological progress in the short run, but as it gets closer and closer to the frontier, its ability to benefit from borrowing technologies developed elsewhere is going to be diminished, and that's going to slow its growth rate down, and it's going to continue to slow it down until A and A Max are growing at the same rate. So that's very important, So, whatever in a closed economy model like this will determine a country's growth rate, in a world of open ideas is going to determine the country's relative productivity level. And we are going to get a world where anything that would have otherwise changed the level of GDP in an economy independent of technology is going to have this multiplier effect that works through technological change. It's going to rise output, that's going to generate a scale effect that's going to engender more investment in technology, which is going to cause a temporary burst in growth, which will result in a country not only having more capital and more efficiency of resource allocation, but also a better technology.

Of course, the problem is that some countries are not going to be investing enough to take advantage of this technological change. Because, although there is this advantage of backwardness, there's the disadvantage of backwardness that comes to overhear us. Technology advances, as I said before. The investments that are needed to keep up at certain frequency of innovations keep on rising and rising. Countries that are very poor

for whatever reason, will find that as this gap rises and helps them to catch up, they are losing on this side. Size of innovations is raising, frequency is falling, countries that are too far behind originally -- and this is something that David and I worked out in our paper, in the paper that has been circulating -- will end up stagnating relative to the rest of the world. They won't be converging on parallel growth path with the rest of the world. And, we think this is a useful way for understanding why it is, for example, that we tend to see -- at least in post-war, post World War II data -- convergence among rich and middle-income countries. And, this convergence in the sense of convergence to parallel growth paths, not to identical productivity levels, but that we still see that the poorest countries of the world continue to fall further and further behind the richest countries of the world. So, we have this theory of the complex patterns of convergence and divergence. And countries that are very poor can easily fall into a low-level development trap, where they fall way behind the frontier, and therefore they can't afford the technology investments that would be necessary to bring them back out. And, you end up getting multiple equilibria and low-level traps that raise serious issues of how you can get out of them.

Now, in this sort of theory there are various channels though which health and human capital, in general, can influence growth. I got some of them listed here, and I got others that I'll talk about. First of all, there is this direct effect on the production function, obviously. People live longer, they're healthier, (and) you are going to get more output per person because they are going to be providing more effective labor service. You'll have more human capital in that dimension. There's also of course the incentive effect that you have in people that are healthier and live longer: they have longer horizons, (and) they may have an incentive to make more investments in both physical and human capital. Although, theoretically, the literature on the effects of longer lifetime on investments is somewhat ambiguous. But, still, there is directly some effect. Those are the sorts of things that you will get through the usual channel of having human capital as a factor of production. Likewise, is also true that the efficiency of the human capital accumulation function, -- I haven't put that in there, but that's part of the standard model – that is an investment function for physical capital and some human capital accumulation equation as well, it's going to depend very much upon early childhood health, upon school readiness of young children. We know that health, beginning in uterus, in the first two years of life it's really critical for the capacity to learn and so that's going to matter very much in this kind of theory, just as it would in a AK type of endogenous growth model.

Then, we also have these other things that come in particularly in the Schumpeterian models. If you talk about the efficiency of the RND function, -- one function that I put up there to show the rate of change in technology -- clearly, more health is going to provide people even with a given amount of education, people that are more vigorous, more creative, more able to cope with change and so on. And it will also show up indirectly when we take a look at more complicated models. There is a chapter in our book where we take a look at what happens and how technology investments are allocated between fundamental research and development activities. And, one of the critical parameters turns out to be the degree of adaptability of workers to new technology lines. A country

can only grow faster from having more fundamental research if people are able to cope with a rapid pace of change that this brings about. This enable them to develop new product lines, to work with new products, (and to) move from one city to another. Otherwise, you run into the sort of thing that Aghion calls the Tale-of-Two-Cities effect, where a country can dissipate a lot of the potential gains of technological change from having to pay the adjustment costs of moving from one sector to another to another to another. If you have a healthier population that has greater coping skills, you are able to do this better and avoid that.

There's another effect that works through inequality in the same model we show, and also in related works that we've done since then with John Luke De Violanti (?). We show how an increase in the adaptability of the population to new technologies can reduce the degree of inequality, of wage inequality in society. One of the reasons why we have unequal incomes within societies is that as technologies change some people are lucky enough to be able to work with them and others aren't. And, there's a big premium on luck which gets amplified the higher is the pace of technological change. And, I think that's a very important factor in many countries in recent years.

Now, if you increase the health of the population, then technological change isn't going to have as much of an impact in inequality and there are lots of channels through which having less inequality is actually going to raise the economic growth. Oded Galor has worked a lot of these things, the simple fact that if you have credit market restrictions. The more equal the distribution, the larger fraction of the population will be able to afford to get educated and make technology investments and other kinds of investments that are critical to growth. There is the PearsonTabalini (?) effect that works through the political process, and other mechanisms that work through the political process, and you get very unequal distributions. You may have a lot of people below the average income that have an interest in trying to block technological progress for one reason or another, but simply are going to be benefiting the wealthy, and you also have an effect that a number of people interested in public health has talked about, and I'm going to talk about it later.

There is some evidence to the extent that more unequal societies tend to be less healthy societies. This evidence is somewhat in dispute, I know, but there is a lot of evidence that some of my former colleagues of the Canadian Institute for Advance Research have shown that, if you look across states in the US or even look across municipalities in the US, those with the most unequal income distribution tend to be those with the highest mortality rates age-adjusted and so forth. And this is also a critical factor.

Let me turn to what I think is really interesting, (and) comes out of this and I've been thinking about lately: The particular channels through which health matters in a Schumpeterian growth model, where growth brings about all this change, and conflict and inequality, and stress, in general, have a lot to do with people's coping skills, people's ability to put up with the stress of constant change, of technological unemployment, the resource reallocation, winners and losers and so on. And we know that a lot of this depends upon early childhood development. There have been tremendous advances in neuro-science in the last ten or fifteen years. By the way, a lot of this has

been written up in this very interesting study by McKennan Mostar (?) called the Early Year Study done for the Ontario government, which made use of a couple of the different research programs of the Canadian Institute for Advance Research and you can download a copy at this address, if you want. Very interesting.

We now know there's a tremendous amount of brain development that takes place in the first three years of life, starting with conception, and that a lot of this really determines to a large extent the course of a person's health. Some of it involves these windows of opportunities. And, we know (that) these windows of opportunities are there because, for example, children that are born with cataracts (and) have them removed don't develop vision. Whereas, if they have cataracts a little bit later in life and then they are removed, their eyes recover. We know through evidence like this that there are critical periods of development for particular neural functions, and if you miss those periods, it becomes very difficult to compensate for it later in life. This is true, (as) you know, in learning languages, and so forth. It's truer for some things than other, and we've learned a lot in neuro science about which areas of the brain retain their plasticity over the years, and which of them lose it very rapidly.

Apparently, one of the areas that lose its plasticity very early is the midbrain, the section where the control of arousal is developed. And that turns out to be very important for coping with stress. We know that the basic mechanisms, the basic endocrine processes, that we have for coping with stress involves this sort of fighter-flight response in a new stressful situation that's created, and the brain produces all sort of hormones, particularly cortisol, which brings a heightened awareness (and) increases memory, but also tends to shut down various other things such as the immune system. So, there's a reallocation of recourses that takes place automatically within us.

Healthy people, people that cope well with stress have a very quick reaction of these systems. They fire up very quickly and you can measure them. Now, that measurement has been done with great precision with rats, monkeys, cats and so on. It's also been done with the British civil servants, and there's a long study called the White Hall study on British civil servants with amazing results that I don't really have time to tell you all about. Having a lot of cortisol in the body in a chronic state is a very bad thing for your health. People with that tend to die early, independently of all the framing factors and so on and early heart attacks. People with healthy systems will react very quickly to a situation, they have these various mechanisms (that) higher up quickly, and as soon as the stress goes away, people back to a normal state. People that are unhealthy constantly have these systems operating at a low level, and the immune system tends to deteriorate, and also other functions of the body. This is one of those areas that are critically determined in the early years. It seems to me that the general lesson that I get out of thinking of all this in contact with Schumpeterian growth theory sort of persuades me more than ever that focusing not just (in) health, but also in general nurturing and education resources on the very early years, particularly the first three years of childhood, is even more critical than we thought. This is, I think, particularly true in a world where computer technology is changing the world so rapidly and so much creating as much stress and as much inequality as we've seen around the world. In order to take advantage of the prospects of

economic growth and to top into global technologies, poor countries are going to have to expose themselves to these kinds of stresses. And I think (that) the better their coping skills are the better they'll be able to do it.

I'd like to say more, but I've already taken more than my time, so I'll stop.