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Redefining Growth in terms of human capital and deliberate technical progress

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1. Introduction

We saw in the Solow model that growth is driven by technical progress. We need to ask here, "how is technical progress attained?" Technical progress does not occur by itself. It is attained by conscious efforts of human beings in a society and in rare cases some breakthrough may be achieved by luck.

Objectives

1. Understand the effect of technology, physical capital and human capital on development.
2. Understand how savings are invested in physical and human capital to enhance development.
3. Figure out if developing countries can reach the level of development of rich countries merely by improving their savings and technological parameters.
4. Apprehend the concept of deliberate technical progress
5. Understand the externalities of technical progress and knowledge.

Understanding role of labour, skilled labour and technology in development:

If labour and capital along with technical progress define growth as we have observed in some models presented earlier then poor countries with large amount of labour must grow very well and surpass rich countries easily. This is because of 2 basic reasons:

(1) Technical progress increases the productivity of labour; and,

(2) When use of capital and technology increases in the labour scarce and capital rich countries, the marginal productivity of capital falls.

But, in reality it is difficult for poor countries to compete with the capital rich countries. This is so because, when technical progress takes place, countries need labour which can operate sophisticated machines, which can create new ideas, and introduce new methods in production. In a way, technical progress by itself becomes possible because of human capital. Hence, there is a difference between labour and skilled labour; or there is a difference between merely having large number of human beings and having human capital.

Countries that have invested more in human capital have been able to create new technology as well as reap better growth from technology rather than countries which have large supplies of unskilled labour and borrow technology more than they create technology.

In some models which we studied earlier, we saw a growth process where savings were invested in physical capital. Let us now see if savings are invested not just in physical capital but also in human capital.

In the theory which we study in this chapter, human capital is deliberately accumulated and is not just the outcome of population growth or exogenously specified technical progress.

Relationship between Investment in Physical Capital and that in Human Capital:

Let us suppose that,

$$y = k^{\alpha} h^{1-\alpha} \qquad (1)$$

Where, h stands for human capital.

(Human capital is used in this equation instead of labour as labour consisted of skilled as well as unskilled labour).

y is the per capita output (income).

k is the per capita capital.

h is the human capital per person (per capita).

For simplifying the model, it is assumed that population is constant and depreciation is ignored.

Now, Total output Y = Consumption + Savings.

And, savings are translated into physical capital and human capital.

Therefore, let us suppose that 'ς' is that fraction of per capita income which is saved to create physical capital and 'q' is that proportion of the per capita income which is saved to augment human capital.

Therefore,

$k_{(t+1)} - k_{(t)} + \varsigma y_{(t)}$ is the increase in physical capital between two time periods (2)

and,

$h_{(t+1)} - h_{(t)} + qy_{(t)}$ is the increase in human capital between two time periods. (3)

The economy grows at some common rate which will be determined by *ς,* q and the ratio of human to physical capital $h_{(t)}/k_{(t)}$.

Let us understand how this growth takes place.

Since ς is the proportion of per capita output 'y' which is saved to create physical capital, we can explain the growth of per capita capital 'k' as,

$$\frac{k_{(t+1)}}{k_{(t)}} = \varsigma \frac{y_{(t)}}{k_{(t)}} + 1 \qquad \text{(from equation 2)} \qquad (4)$$

Which is equal to,

$$\varsigma \frac{k_{(t)}^{\alpha} h_{(t)}^{1-\alpha}}{k_{(t)}} + 1$$

From equation (1)

we know that $y = k^{\alpha}h^{1-\alpha}$

and therefore, $y_{(t)} = k_{(t)}^{\alpha}h_{(t)}^{1-\alpha}$

This can be rewritten as,

$\varsigma\, k_{(t)}^{-1}\, k_{(t)}^{\alpha}h_{(t)}^{1-\alpha} + 1$

Thus we get,

$\varsigma\, k_{(t)}^{-1+\alpha}\, h_{(t)}^{1-\alpha} + 1$

Which becomes,

$\varsigma\, \frac{h^{1-\alpha}}{k^{1-\alpha}} + 1$

Now, let 'r' be the ratio of human capital to physical capital in the long run. Hence, we rewrite the equation here as,

$\varsigma r_{(t)}^{1-\alpha} + 1$ (5)

And, we can similarly derive

$\frac{h_{(t+1)}}{h_{(t)}} = q\, \frac{y_{(t)}}{h_{(t)}} + 1$ (6)

$= qr_{(t)}^{-\alpha} + 1$ (7)

Combining equations (4), (5), (6) and (7) we get,

$\frac{r_{(t+1)}}{r_{(t)}} = \frac{qr_{(t)}^{-\alpha} + 1}{\varsigma r_{(t)}^{1-\alpha} + 1}$ (8)

If we juggle this equation a little we derive,

$r_{(t+1)} = \frac{q}{\varsigma} \times \frac{1+(\frac{r_{(t)}^{\alpha}}{q})}{1+(\frac{r_{(t)}^{\alpha-1}}{\varsigma})} = r_{(t)} \times \frac{\frac{q}{r_{(t)}} + r_{(t)}^{\alpha-1}}{\varsigma + r_{(t)}^{\alpha-1}}$ (9)

From these equations (8) and (9), we can draw two conclusions:

(1) If at any date *t,* we have $r_{(t)} > q/\varsigma$, then

$r_{(t)} > r_{(t+1)} > q/\varsigma$

(2) If at any date *t,* we have $r_{(t)} < q/\varsigma$, then

$r_{(t)} < r_{(t+1)} < q/\varsigma$

(3) when, $r_{(t)} = q/\varsigma$, there is convergence.

(4) Now since we saw that, $\frac{k_{(t+1)}-k_{(t)}}{k_{(t)}} = \varsigma r^{1-\alpha}$ and, $\frac{h_{(t+1)}-h_{(t)}}{h_{(t)}}$ $= qr^{-\alpha}$, in the long run the two rates become equal, that is, $\varsigma r^{1-\alpha}=qr^{-\alpha}$

or

$r = q/\varsigma$.

This means that the larger the rate of savings in human capital relative to that of physical capital, the larger will be the ratio of human capital to physical capital in the long run.

(5) Thus, we can say that the rate of savings, the investment in physical capital and the investment in human capital have growth rate effects. Thus, unlike Solow mode, this theory of human capital becomes endogenous.

(6) If countries have similar savings and technological parameters in a new time period, they still cannot come together on same level as the initial differences will be maintained.

(7) The Solow model predicted that the productivity of capital will gradually rise in the poor countries because they use less capital and it will fall in the rich countries because they use more capital since, capital is subject to diminishing returns. But, this model explains the reality. Rich countries have relatively higher productivity of capital than poor countries as the rich countries invest more in human capital.

2. Deliberate Technical Progress

Debraj Ray explains a model of technical progress along the lines of Romer's model.

Suppose that 'H' is the available stock of human capital which can be used to produce output or may be used to conduct research which produces knowledge.

Research helps to advance the knowledge in rightward direction such that we can express that machines produced with advanced research are considered as advanced machines.

At any given time period 't', machines of several knowledge stages may exist. So, machines ranging from knowledge stage 0 to knowledge state $E_{(t)}$ may exist in time period 't'.

Research must then push the knowledge or the state of machinery to an advanced stage as, $E_{(t+1)}$, $E_{(t+2)}$, and so on.

The state of technical knowledge in time period 't' is given by the joint productivity of all the machines with different embodied state of knowledge.

The production function can then be given as,

$Y_{(t)} = E_{(t)}^{\gamma} \; k_{(t)}^{\alpha} \; [uH]^{1-\alpha}$

Where,

$E_{(t)}$ is the amount of technical know-how at date 't'

$K_{(t)}$ is the amount of capital stock at date 't'

u is the fraction of human capital which is devoted to the production of final goods.

The rate of growth for knowledge is then,

$$\frac{E_{(t+1)}-E_t}{E_t} = \alpha(1-u)H$$

- 1-u is the fraction of human capital devoted to research to produce new knowledge.
- H is human capital.
- α is some positive constant.

Thus, knowledge grows with increased allocation of human capital to research and, capital grows with the rate at which income is saved and thus,

$K_{(t+1)} - K_{(t)} = \varsigma Y(t)$

ς is the rate of savings.

3. Externalities, technical progress and growth

Capital accumulation or R and D (Research and Development) have externalities. The negative effect of an externality may be on the individual or the firm who invents new knowledge as the knowledge may transmit fast or may be copied and thus may wipe out the power of patent and the inventing individual or firm may incur losses. However, there can be positive externalities for the entire society.

Let us suppose that there are several firms in an economy and each firm has a production function as,

$$Y_{(t)} = E_{(t)} k_{(t)}^{\alpha} P_{(t)}^{1-\alpha}$$

Where,

- $E_{(t)}$ is macroeconomic parameter common to all firms and it indicates a measure of overall productivity.
- $K_{(t)}$ is the capital stock and $P_{(t)}$ is the labour employed.

Here, $E_{(t)}$ is neither exogenously determined nor endogenously determined by deliberate R and D decisions of firms, but it is the positive externality generated by the joint capital accumulation of all firms in the economy.

Thus, when individual firms accumulate capital for their own selfish interest, there also is an improvement in the macroeconomic productivity because of positive externalities.

If there is one owner of many firms, and the average capital of all of her firms is K^*, the owner internalizes the externalities of all capital investment by any of her firm as all firms belong to her.

In this case, let $E_{(t)} = \alpha K_{(t)}^{*\beta}$

Replacing this in the equation,

$Y_{(t)} = E_{(t)} k_{(t)}^{\alpha} P_{(t)}^{1-\alpha}$

We obtain the equation,

$Y_{(t)} = \alpha K_{(t)}^{*\beta} k_{(t)}^{\alpha} P_{(t)}^{1-\alpha}$

Now,

- When all firms belong to different owners, firms tend to under-invest as capital investment may give lower individual benefits and greater social benefits owing to externalities. Firms do not invest in expensive R and D owing to this reason only. And, this builds up a strong case for patent protection of novel research.
- While the production function of individual firms may show constant returns to scale as we observe in the initial equation in this section; the macroeconomic production function shows increasing returns to scale. Hence, capital investments by firms have increasing social benefits.

If $K_{(t)}$ of the individual production function is equal to $K^*_{(t)}$ which is the average capital stock by all firms in the economy then we can rewrite the equation

$Y_{(t)} = \alpha K^{*}_{(t)}{}^{\beta} k^{\alpha}_{(t)} P^{1-\alpha}_{(t)}$

As,

$Y_{(t)} = \alpha K^{\alpha+\beta}_{(t)} P^{1-\alpha}_{(t)}$

This demonstrates increasing returns.

4. Complementarities in externality

An individual firm makes capital investment considering the future productivity of this investment. Now the future productivity of firm A's investment will depend upon how much investment is made by other firms.

For example, the productivity of a wholesaler's card swiping machine will depend upon the use of payment cards by her clients and the availability of internet facilities in that area.

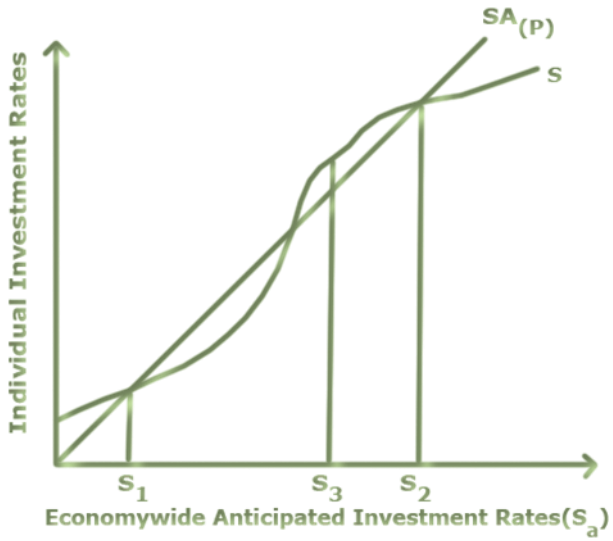
When firms accept that an increase in the average stock of capital held by all firms will increase their future profit, they will sacrifice current consumption and save more to invest in capital. When complementarities are known to increase future profits, an investment by one firm will incentivize other firms to raise their investments in capital.

Hence, complementarities will play a big role in making India's push for digitalization a success.

Let us now assume that 's' is the saving rate for individual firms and 's_A' is the average saving rate of all firms. In Solow's model 's' was exogenous, but if we use 's_A' in his model then savings rate becomes endogenous as it is determined by the beliefs of

various firms regarding investments by others and the resulting complementarities.

The average rate of savings (and investment) will be higher in the economy if all firms believe that investments will be made by all firms. If they believe that investments will not be made by all then the average rate of savings will be lower.



In this figure s_A is the projected average rate of savings by all firms. 's' is the savings rate by individual firms. The equilibrium is attained at a lower level of savings s_1 when all firms believe that others will not invest. And, the equilibrium is attained at a higher level of savings s_2 when all firms believe that others will make higher investments. Hence, this equilibrium is a result of *beliefs* more than actions.

5. Total Factor Productivity

If Marginal productivity of capital is MPK and that of labour is MPL then total productivity of capital will be MPK multiplied by

the amount of capital employed and the total productivity of labour will be MPL multiplied by the amount of labour employed. The change in labour productivity by employing additional labour will then be written as, $MPL.\Delta L_{(t)}$ and that of capital will be $MPK.\Delta K_{(t)}$.

Here, Δ stands for change.

In the production function $Y_{(t)}=F(K_{(t)}, P_{(t)}, E_{(t)})$, if $Y_{(t)}$ is the output in time period 't',

$K_{(t)}$ is physical capital in time 't'

$P_{(t)}$ is labour force in time 't', and

$E_{(t)}$ is a measure of knowledge in time 't' and; if we there is no change in E over time then output is a function of labour and capital alone.

Hence, we can express the change in output as a function of change in productivity of capital and labour as,

$\Delta Y_{(t)}= MPK.\Delta K_{(t)}+MPL.\Delta P_{(t)}$

If we divide this equation by $Y_{(t)}$ throughout and multiply and divide by $K_{(t)}$ and $P_{(t)}$ their respective terms, we get,

$$\frac{\Delta Y_{(t)}}{Y_{(t)}} = \frac{MPK.K_{(t)}}{Y_{(t)}} \frac{\Delta K_{(t)}}{K_{(t)}} + \frac{MPL.P_{(t)}}{Y_{(t)}} \frac{\Delta P_{(t)}}{P_{(t)}}$$

Now, under assumption of constant returns to scale, and under perfect competition, factors of production are paid according to marginal productivity. Hence, wage rate = MPL and per unit rent on capital = MPK. And, 'K' amount of capital in time period 't' will get $MPK.K_{(t)}$ total income while, 'P' amount of labour in time period 't' will get $MPL.P_{(t)}$ total income.

Thus, $\frac{MPK.K_{(t)}}{Y_{(t)}}$ is nothing but the share of capital income in the national income. Let us denote it as, $\sigma_{K(t)}$.

Likewise, $\frac{MPL.P_{(t)}}{Y_{(t)}}$ is the share of labour income in the national income. Let us denote this as, $\sigma_{P(t)}$.

Thus, our previous equation becomes,

$$\frac{\Delta Y_{(t)}}{Y_{(t)}} = \sigma_{k(t)} \frac{\Delta K_{(t)}}{K_{(t)}} + \sigma_{P(t)} \frac{\Delta P_{(t)}}{P_{(t)}}$$

When $\frac{\Delta Y_{(t)}}{Y_{(t)}}$ > the right hand side then we can conclude that there is growth in the total factor productivity. That is, output increased more than the growth of inputs because of increase in the total productivity of factors.

Thus, $\frac{\Delta Y_{(t)}}{Y_{(t)}} = \sigma_{k(t)} \frac{\Delta K_{(t)}}{K_{(t)}} + \sigma_{P(t)} \frac{\Delta P_{(t)}}{P_{(t)}} + TFPG$

Where, TFPG is total factor productivity growth.

The World Bank attributed the growth of output of the East Asian Countries during the nineties to such growth in total factor productivity.

6. Summary

So dear friends may we spend some time recollecting what we learnt in this lecture?

We have learnt that capital and technology contribute differently to the growth process of developing countries than the way they contribute to that of developed countries.

There is an enhancement in knowledge with investment in human capital. And, investment in knowledge has many social benefits or externalities. Private costs of knowledge creation are high and if the social benefits are more than the private benefits, the private sector will not invest in knowledge creation. However, without investment in knowledge the process of development may slow down. Countries show remarkable growth when the total factor productivity increases.

We must remember the functions pertaining to investments in human and physical capital and the equations pertaining to total factor productivity.