Economic Growth
Chapter 5 : The role of education and human capital

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Education and growth

- Quantitative accumulation of production factors is not enough to assure a sustained growth of per capita GDP.
- Quid of an increase in the quality of the factors ?
- Labor force becoming more and more qualified thanks to education ?
- $\rightarrow$ Accumulation of human capital (H)
- Extending the Solow model with human capital accumulation

References : Education, human capital and growth

- Mankiw, G., D. Romer, D. Weil, 1992, “A Contribution to the Empirics of Economic Growth”, *Quarterly Journal of Economics*, 107, 407-438
- Lucas, R., 1988, “On the Mechanics of Economic Development”, *Journal of Monetary Economics*, 22, 3-42

- Let's assume now that we take into account the qualifications of the workers, and only qualified labor H participates to the production :

$$Y = K^{\alpha}\left(AH\right)^{1-\alpha} \tag{1}$$

- where A again represents the technological level, and benefits from a technical progress at a constant, and exogenous, rate : $g = \dot{A}/A$.

- Workers of this country can increase their qualifications by dedicating a share u of their time to education (instead of participating in production).
- This education time allows them to increase their qualifications, and hence the human capital of the economy (H) that participates to the production :

$$H_t = h(u) L_t, \qquad h \geq 1$$

where L represents the labor force without any qualification, and h is the qualification level of the labor force.
- **Assumption :** The impact of education time on qualification is consisting with stylized facts on the labor market (*see* below) :

$$h = e^{\psi u} \Rightarrow H_t = e^{\psi u} \cdot L_t$$

where ψ is a positive constant factor.

Education and human capital building

- If $u = 0$, $H = L$, and the production cannot benefit from any qualification of the labor.
- If $u > 0$, $H > L$, and the effective labor force participating to production is higher (this effective labor force increases with u)
- How the education level influences the qualifications, and hence wages ?
- Stylized fact in labor markets studies : every supplementary year of schooling brings a wage increase of 10%
- Hence our functional form, that gives :

$$\log H = \psi u + \log L \Rightarrow \frac{\partial \log H}{\partial u} = \frac{\partial H / \partial u}{H} = \psi$$

- For a given level of the basic labor level (L), an infinitesimal increase of the education effort u yields a constant growth rate of qualifications (and hence wages) : ψ.

- The physical capital again accumulates thanks to investment financed by savings :

$$\dot{K} = sY - \delta K \qquad (2)$$

- and the intensive form of the production function is given by :

$$y \equiv \frac{Y}{L} = k^{\alpha} (Ah)^{1-\alpha} \qquad (3)$$

- s, u, δ are exogenous and specific to the county
- Consequently h is constant too, and the model is similar to solow with TP.
- $\rightarrow$ y and k grow at a constant rate g.

- Following the approach explained in the mimeo in French, we can solve the model, but building the state variables that will be constant on the BGP :

$$\tilde{y} \equiv y/Ah, \; \tilde{k} \equiv k/Ah, \quad \tilde{y} = \tilde{k}^{\alpha} \tag{4}$$

GDP and capital per unit of **effective** labor (taking into account TP, and qualifications)

- and the fundamental equation of the per capita dynamics with these variables :

$$\dot{\tilde{k}} = s\tilde{y} - (n + \delta + g)\,\tilde{k} \tag{5}$$

- On the BGP, we will by construction have $\dot{\tilde{k}}/\tilde{k} = 0$.
- And we can obtain the following property :

$$\frac{\tilde{k}^*}{\tilde{y}^*} = \frac{s}{n + \delta + g} \Rightarrow \left(\frac{\tilde{k}^*}{\tilde{y}^*}\right)^{\alpha} = \left(\frac{s}{n + \delta + g}\right)^{\alpha}$$

- By dividing both sides of equation (4) by $\tilde{y}^{\alpha}$:

$$\tilde{y}^{*^{1-\alpha}} = \left(\frac{\tilde{k}^*}{\tilde{y}^*}\right)^{\alpha} = \left(\frac{s}{n+\delta+g}\right)^{\alpha}$$

- we can determine the level of the GDP per unit of effective labor on the BGP :

$$\tilde{y}^* = \left(\frac{s}{n+\delta+g}\right)^{\alpha/(1-\alpha)}$$

- And the corresponding level of the per capita GDP is given by

$$y_t^* = hA_t\tilde{y}^* = \left(\frac{s}{n+\delta+g}\right)^{\alpha/(1-\alpha)} \cdot h \cdot A_t \tag{6}$$

y grows at the same speed as A on the BGP, as in the Solow model.

Our fundamental question

For a given value of A, this equation now gives a complementary explanation on the income differences between countries :

Proposition

Income levels of countries are positively correlated with their investment rates in physical capital, their TP, and their education time, while the correlation is negative with the demographic growth rate.

Does this new answer correspond to what we observe in data ?

Empirical application

- Since all incomes increase in time, it would be better to use the relative incomes of the countries.
- We can define the per capita income of each country relative to the USA :

$$\hat{y}^* = \frac{y^*}{y^*_{USA}}$$

which would give in the model (6) :

$$\hat{y}^* = \left(\frac{\hat{s}}{\hat{x}}\right)^{\alpha/(1-\alpha)} \cdot \hat{h}\hat{A} \tag{7}$$

where $(\hat{\ })$ indicates the value of te variable relative to the one of the USA, and we note $x \equiv n + g + \delta$.

- $\rightarrow \hat{y}^*$ will only be constant if the country grows at the same speed as the USA.

- We will assume that the speed of the technical progress is the same between all countries.
- In fact, if for two countries B and C, if $g_B > g_C$ then $\lim_{t\to\infty}(y_B - y_C) = \infty$, which is not empirically observed.
- So the speed of the TP is not a very acceptable source of diversity between countries.
- Technology transfers should somewhat equilibrate the divergence between countries, otherwise we would observe very quickly increasing divergence $\rightarrow$ we hence assume the same g between countries.
- We will reconsider later the inclusion of technological diversity.

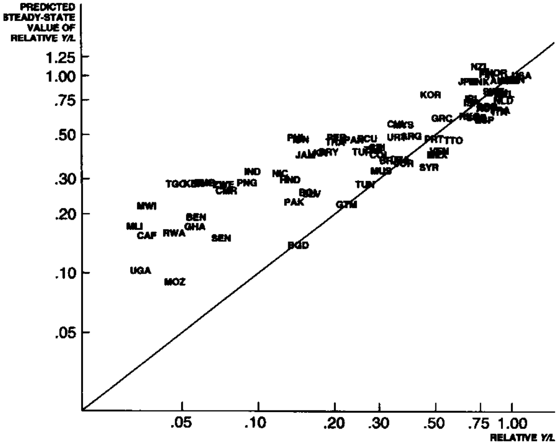
Empirical application

Under these assumptions, we choose the values of the parameters in order to compute equation (7) for all countries :

- $\alpha = 1/3$ (value generally observed in the empirical estimation of macro production functions, and corresponds to the share of capital in the GDP) ;
- $u =$ average years of schooling of the active population of the country ;
- $\psi = 10\%$ (each supplementary school year yielding an average wage increase of 10%) ;
- $g + \delta = 7.5\%$ for all countries ;
- A identical for all countries (we hence eliminate technology diversity for now).

Empirical validation of the model ?

The following figure compares the theoretical value predicted by the model ($\hat{y}^*$) with the value empirically observed ($\hat{y}$) using a 45° diagram :



Results :

- Globally pretty close estimation of the relative GDPs
- But strong over estimation for countries like Uganda or Mozambique
- and for the poorest countries generally
- **Remark :** Of course, assuming that they have the same technological level as the USA is too optimistic

Technological diversity ?

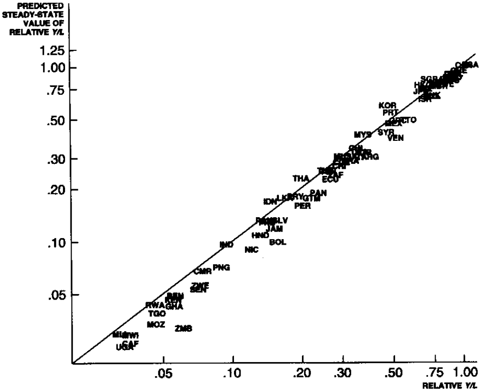
- We could compute for each country, using the production function (3), the value of A that would correspond to the observed level of the per capita GDP :

$$A = \left(\frac{y}{k}\right)^{\alpha/(1-\alpha)} \cdot \frac{y}{h}$$

since we know the values of all other variables for each country

- After having estimated the value of A in 1990, and incorporated in the computation of $\hat{y}^*$, we obtain the following empirical adjustment.

Adjustment after calibrating for A :



- We get a much better correspondence after taking into account technological heterogeneity
- A bit too much, maybe ?
- Is this surprising, given the computation of As ?
- We nevertheless another explanation (equation 6) of the diversity of situations between countries : investment on education and human capital.

Human capital and technical progress

- Human capital can also influence the productivity **indirectly**
- by helping the workers to better cope with change and new technologies
- Nelson & Phelps (1966) explore this idea with a simple exogenous growth model
- $\rightarrow$ Average human capital level of the economy could allow a quicker catch-up the technological frontier
- We follow here the simplified version by Acemoglu (2009).

- The output of the economy at each moment is given by

$$Y_t = A_t L,$$

  where L is the constant labour supply, and A_t is the technological level of the economy.
- Labour is the only production factor, and there is no capital accumulation.
- $\rightarrow$ Growth only if A_t increases in time

- The world technological frontier is given by $\mathcal{A}_t$, and it evolves exogenously :

$$\gamma_{\mathcal{A}} = \frac{\dot{\mathcal{A}}_t}{\mathcal{A}_t} = \gamma \Rightarrow \mathcal{A}_t = e^{\gamma t}\mathcal{A}_0,\ \mathcal{A}_0 > 0. \tag{8}$$

- Let h represent the average human capital of the labour force.
- h does not directly enhance labour productivity (it does not appear in the production function)
- but it helps the country to benefit from frontier technology :

$$\dot{A}_t = gA_t + \phi(h)\,\mathcal{A}_t,\ A_0 \in \left]0, \mathcal{A}_0\right[, g < \gamma$$

g measures the autonomous technical progress of the country, resulting from learning by doing or other local sources.

- The second source of technical progress comes from the implementation of frontier technology, and it depends on the human capital of the economy :

$$\phi(0) = 0, \phi(h) = \gamma - g > 0, \forall h > \bar{h} > 0 \tag{9}$$

  - Economy grows at speed g if low human capital $\left(h \leq \bar{h}\right)$
  - When enough human capital $\left(h > \bar{h}\right)$, quicker growth below the frontier
  - Growth rate converges on γ when the catching-up is finished

$$\frac{\dot{A}}{A} = g + (\gamma - g)\frac{\mathcal{A}_t}{A_t}\begin{cases} > \gamma & \textit{if } A_t < \mathcal{A}_t \\ = \gamma & \textit{if } A_t = \mathcal{A}_t \end{cases}$$

because

$$(\gamma - g)\left(\frac{\mathcal{A}_t}{A_t} - 1\right) \geq 0$$

- Here the growth is again exogenously pulled by the progress of the frontier technology
- but the ability to benefit from it depend on the presence of human capital
- Countries with low human capital cannot benefit enough from external technical progress
- and they can be trapped below the world frontier
- Farmers with enough education are more likely to adopt new agricultural technologies and seeds, in developing countries

ACEMOGLU, DARON. 2009. *Introduction to Modern Economic Growth*. Princeton :NJ : Princeton University Press.

NELSON, R. R., & PHELPS, E. S. 1966. Investment in humans, technological diffusion, and economic growth. *American Economic Review*, **56**, 69–75.