

Lectures on Economic Growth

Topic: The Solow Model - adding Human Capital

an upper intermediate course offered at the 7th semester at the

Economics Department, University of Piraeus



Outline

Today, we discuss the accumulation of another form of capital: that of human capital.

We will show, how the addition of human capital to the Solow model, makes it more realistic.

- we focus on human capital, which relates to:
 - Health and productivity
 - Education as an accumulable factor

How much variation does Solow explain?

Suppose we take this model at face value and use it to explain the difference between The Netherlands ($y = 12,858$) and India ($y = 1,068$) in 1990.

An empirically reasonable value for α is $1/3$, about the share of capital income in GDP.

For the two countries, there must hold

$$\frac{y_{\text{NL}}}{y_{\text{India}}} = \frac{12,858}{1,068} = 12.04 = \frac{k_{\text{NL}}^{\frac{1}{3}}}{k_{\text{India}}^{\frac{1}{3}}} = \left(\frac{k_{\text{NL}}}{k_{\text{India}}} \right)^{\frac{1}{3}}$$

This means that the relative level of capital $k_{\text{NL}}/k_{\text{India}}$ is $(12.04)^3 \approx 1745$.

That seems like a bit much.

If capital levels in The Netherlands are 1745 times those in India, how about the return to capital?

$$r = \frac{dF}{dK} = \alpha k^{\alpha-1}$$

and so

$$\frac{r_{\text{India}}}{r_{\text{NL}}} = \frac{\alpha k_{\text{India}}^{\alpha-1}}{\alpha k_{\text{NL}}^{\alpha-1}} = \left(\frac{k_{\text{India}}}{k_{\text{NL}}} \right)^{\alpha-1} \approx 145.$$

Notice: this difference gets more reasonable as α goes up. So if the share of accumulable resources increases, the model is better able to explain differences.

For $\alpha = 2/3$, $k_{\text{NL}}/k_{\text{India}} \approx 42$ and $r_{\text{India}}/r_{\text{NL}} \approx 3.5$.

One way to reconcile Solow with income differences is to find ways to increase α .

Human Capital

We next talk of chapter 6 of Weil, which is about Human Capital.

Notice that we are adding a factor to the production function: what goes in and can the different inputs explain different levels of output?

We go from

$$Y = F(K, L)$$

to

$$Y = F(K, L \cdot h)$$

Human Capital

We discuss two kinds of HC:

- ① Education, skill accumulation (this is regular HC)
- ② Individual health

Note: for a range of GDP/capita (from subsistence to relatively well off), a person's economic output is a positive function of his/her health.

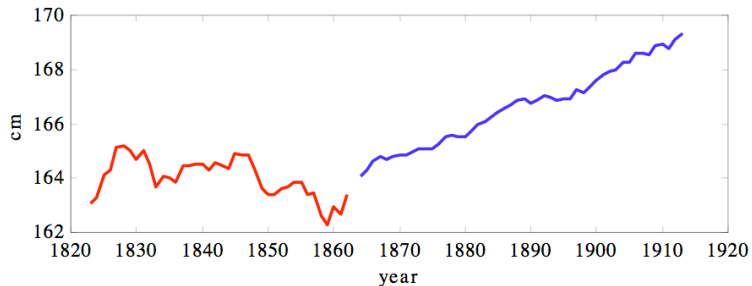
Vice versa, health is an increasing function of personal income. This is true (on average) even at high incomes.

In this model, we do not need to consider personal choice: health (h) and GDP/cap (y) are forced upon the agents here.

h is a function of y

Health improves as income goes up; check life expectancy in developed countries.

A nice way to track the development of health over time is by looking at average height. Data goes back very far (thanks to the army).



Source: Jacobs and Tassenaar, 2002

Average heights of Dutch conscripts at age 19 (before 1862) and at age 20 (after 1862)

y is a function of h

Your productivity suffers if h is low. One example: the eradication of the hookworm parasite in the southern USA in the early 20th century.

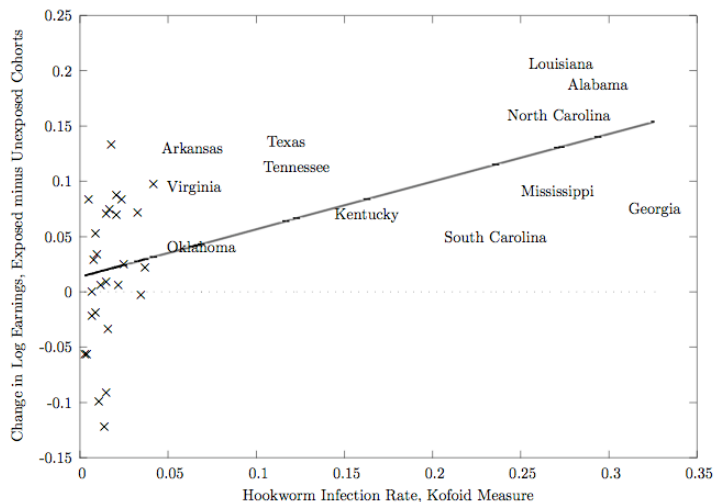
This parasite leads to anemia, tiredness and abdominal pain. In 1909, the Rockefeller Sanitary Commission for the Eradication of Hookworm Disease started work to eradicate it from the Southern United States, where it was prevalent.



Source: US Center for Disease Control

In this diagram, the vertical axis is the difference in log earnings for cohorts born before and after the eradication. The horizontal scale is the infection rate.

Figure 4: Comparison of Fully Exposed versus Unexposed Cohorts, by State of Birth



Malnutrition Is Cheating Its Survivors, and Africa's Future

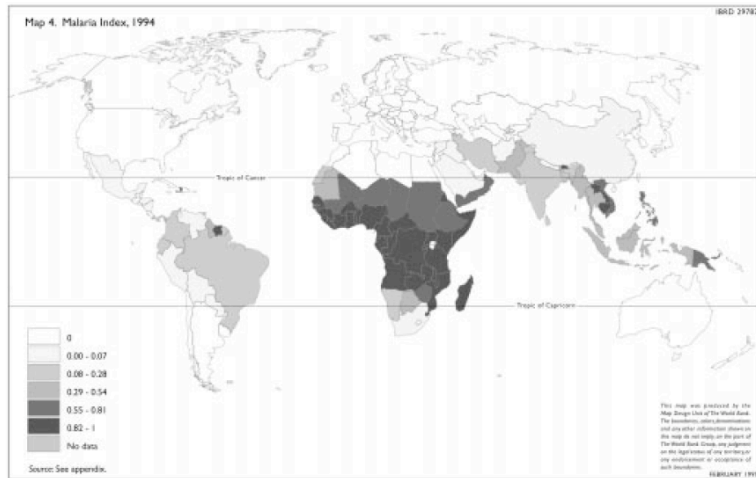


[...] almost half of Ethiopia's children are malnourished, and most do not die. Some suffer a different fate. Robbed of vital nutrients as children, they grow up stunted and sickly, weaklings in a land that still runs on manual labor. Some become intellectually stunted adults, shorn of as many as 15 I.Q. points, unable to learn or even to concentrate, inclined to drop out of school early.

Source: New York Times

y is a function of h

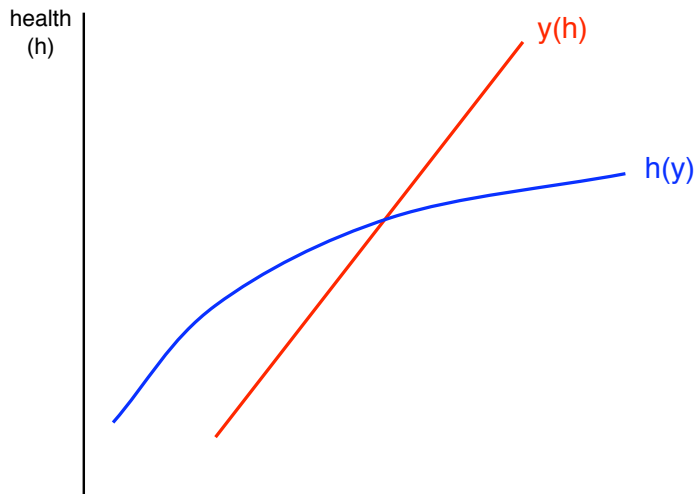
Sachs et al (1998) compute that countries in the tropics, on average, have a GDP that is 26% lower.



Source: Gallup, Sachs and Mellinger, 1998

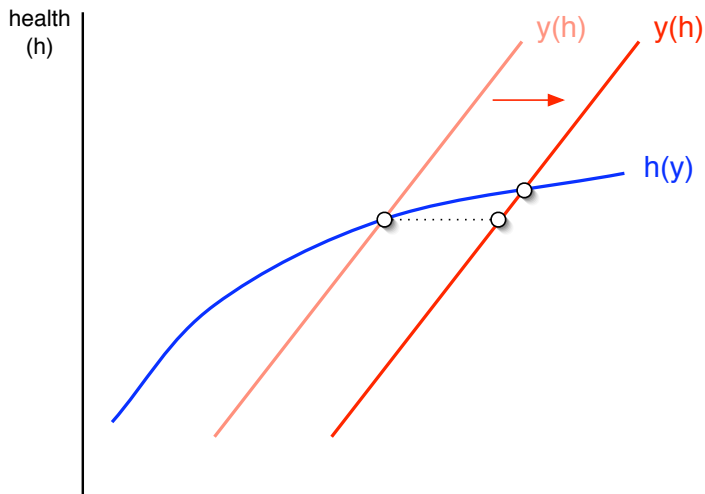
y and h jointly determined

With health and income both endogenous, you have to solve them simultaneously.



A multiplier effect

Changing the position of one curve leads to a multiplier effect (remember Macro 2) and an identification problem.



Human capital proper

In the field, HC is usually understood to be ones stock of skills and knowledge, built up through education. It is a lot like physical capital:

- Capital is productive.
- Capital is itself produced.
- Capital is rival in its use.
- Capital earns a return (as rent, or by being sold).
- Capital wears out.

Deciding to invest in HC is much like deciding to invest in physical capital: you weigh the return on investment.

Deciding to get education

Education is an investment: sacrifice today to garner returns tomorrow. There exists a rational optimal amount of education.

- costs of education
 - opportunity costs of time
 - (possibly subsidized) costs of school
- benefits of education for the student
 - Your future wage increases
 - (enjoyment)
- benefits for society at large
 - informed citizenship
 - externalities for others

Deciding on education is like deciding on any type of investment: check the rate of return.

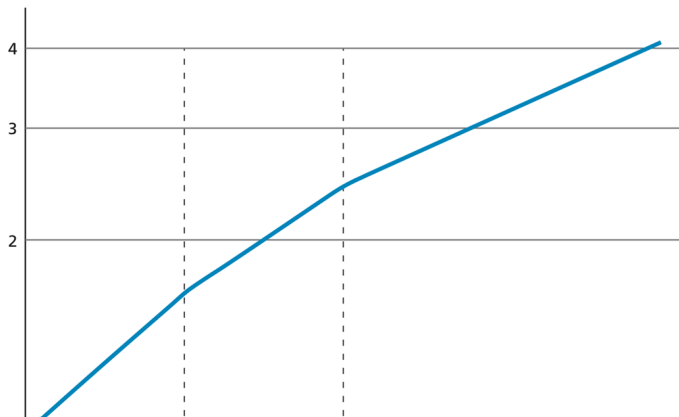
Wages and education

What are the benefits of education? Weil has the following:

FIGURE 6.6

Effect of Education on Wages

Wage relative to no schooling (ratio scale)



The rate of return on education

Weil's graph is good for computing productivity based on years of schooling.

It is not a good estimate for the return to schooling. There are at least two problems:

- People who go to college are not a random ability sample!
- Information problems: (limited) schooling may be a way to allocated rationed jobs.

or: economics is not an experimental science.

(is this an argument for lower scholarships? Depends on external effects and credit constraints.)

A traditional regression

We can assume that there are no selection effects and estimate

$$\ln(w) = \alpha + \beta S + sE + \lambda E^2 + \delta X$$

where S is years of education, E is experience and X are controlling variables.

D. Webbink, CPB (2004): compared to mavo-4, vwo graduates make 28% more. Hbo graduates make 45% more, University graduates make 82% more.

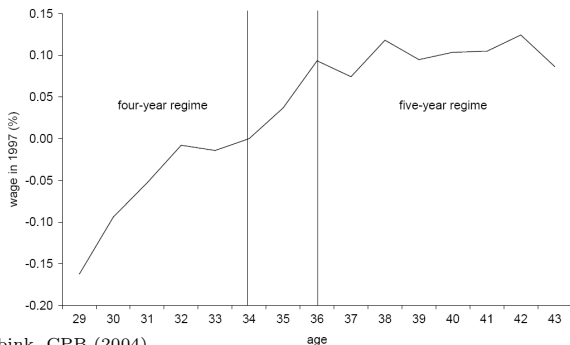
But is it worth your time? Return to university education: 10.5% for men and 12.0% for women.

A natural experiment

Fortunately, nature (or the Dutch government) sometimes deals us a natural experiment. 1982: Dutch university education went from 5 to 4 years. What happened to the wages of graduates?

D. Webbink, CPB (2004): the fifth year of university lead to 7 to 9% higher wages. Notice this is lower than 10-12%; some effect of ability is

Figure 5.1 Earnings of university graduates by age



present. Webbink, CPB (2004)

Aside: getting an M.Sc.

When should you stop educating yourself fulltime? When costs $>$ benefits.

$$w + c > \sum_{\tau=\text{age}+1}^{65} \text{return} \left[\frac{1}{(1+r-s)^{\tau-\text{age}}} w \cdot L \right]$$

with r the market interest rate and s macro wage growth.

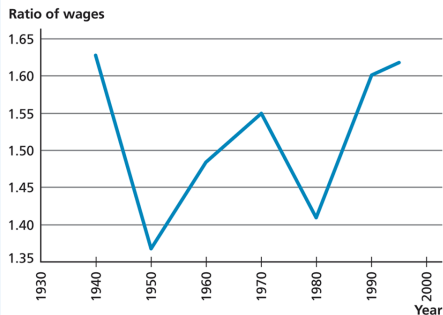
With $(w + c)/w = 1.2$, $r - s = 0.025$ and a plausible path for L , a 21 year old person should get an extra year if the return is at least 5.07%. A 30 year old person should get one of the return is more than 5.5%.

The college premium

The effect of going to college (4 years) in the US has not been constant over time:

FIGURE 6.8

Ratio of College Wages to High-School Wages

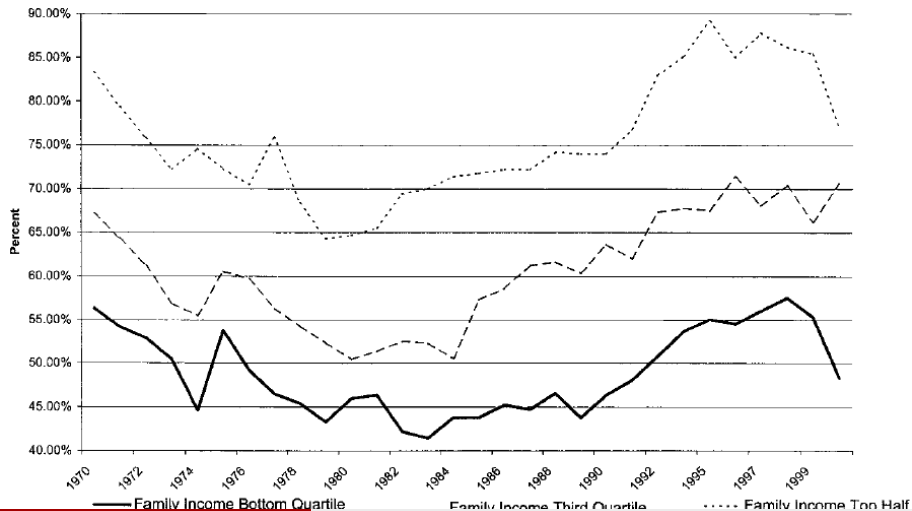


Source: Autor, Katz, and Krueger (1998).

Why: skill-biased technical change.

The college premium and enrollment

Heckman (2003) shows that this lead to increased education especially for the well-to-do.



Heckman

What is keeping children from low-income families out of college?

Heckman:

- Credit constraints? No: it is poverty in the early years that destroys skills.
- Bad secondary schools? No: extra grants do not pass cost/benefit test.
- Insufficient upbringing in early years? Yes: returns are the highest there, and families with low income typically stay in the stratum.

Policy suggestions: family intervention and selective immigration.

(Both have their own political problems.)

Education and wages

Weil uses the following figures, which agree well with Dutch data:

Years of education	Wage increase per year
1 – 4	13.4%
5 – 8	10.1%
9 – rest	6.8%

Wages are taken as an indication of productivity. There are decreasing returns to education.

How much of wages is human capital?

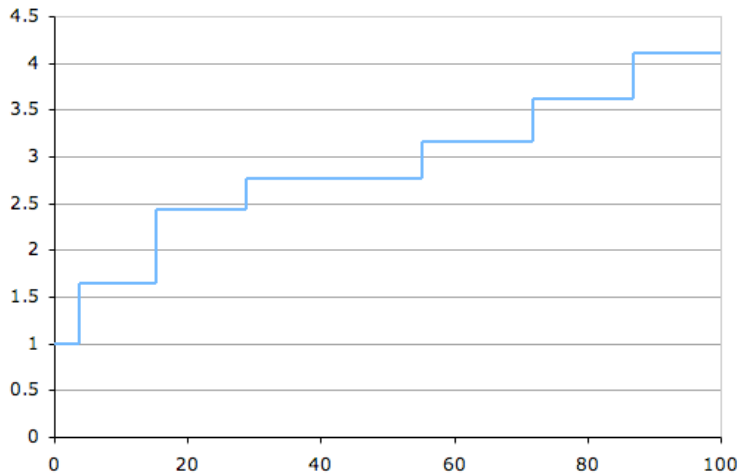
If you know how much education the labor force has had, you can compute the share of wages paid for raw labor, and the share paid to HC.

Highest education	Years	Relative wage	Percentage pop. (adv. cties)
None	0	1.00	3.7
Some primary	4	1.65	11.7
Primary	8	2.43	13.4
Some secondary	10	2.77	26.5
Secondary	12	3.16	16.6
Some higher	14	3.61	15.1
Higher	16	4.11	13.0

This allows you to divide up the wage sum.

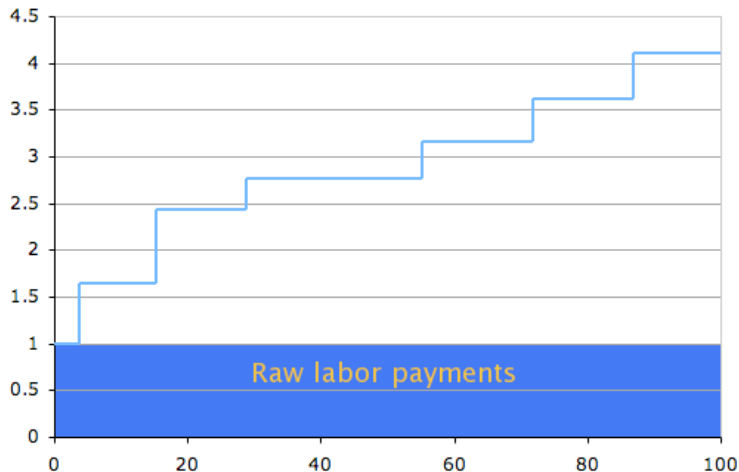
How much of wages is human capital?

Graph the distribution of relative wages from this table.



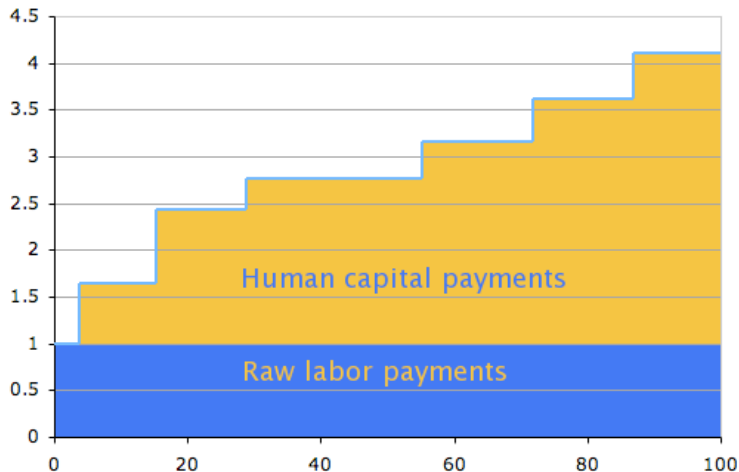
How much of wages is human capital?

Identify each person's raw labor pay. This area is 100.



How much of wages is human capital?

Compute the area of the HC component and normalize.



How much of wages is human capital?

The area of the HC component is 189.37, relative to 100 for raw labor.

Normalize this to 65.4% and 34.6%.

Remember that on average, the share of physical capital in production is $\frac{1}{3}$, labor gets $\frac{2}{3}$.

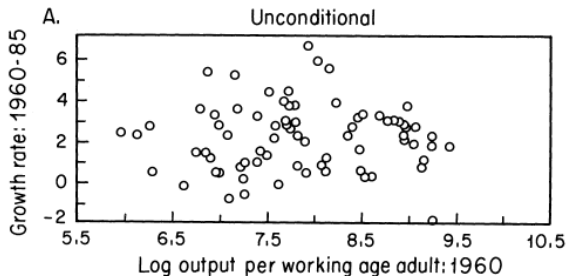
This turns out to be: raw labor 0.22, physical capital 0.33, human capital 0.44.

Accumulable factors turn out to be responsible for about $\frac{3}{4}$ of production.

Mankiw, Romer, Weil

Weil contends that differences in the rate of capital ($2\times$) accumulation largely determine the steady state.

So do we find conditional β -convergence? 75 countries, growth rate 1960-1985.



Certainly no absolute β -convergence.

Partialling out

Suppose the relationship you are interested in has the form

$$Y_i = c + \alpha X_i + \beta Z_i + \epsilon_i$$

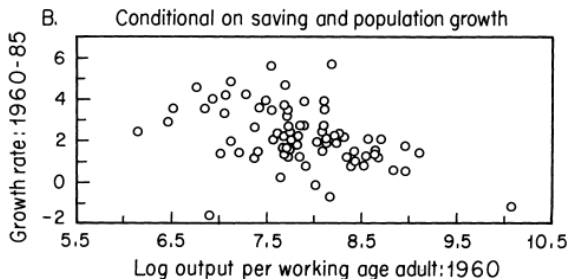
Plotting X_i versus Y_i may not show any pattern if there is a lot of variation in Z_i . You can partial out Z_i by regressing both Y_i and X_i on it and using the errors of those regressions (i.e., the unexplained part) as the new Y'_i and X'_i .

$$\begin{aligned} Y'_i &= Y_i - \hat{\beta}Z_i & X'_i &= (X_i|Z_i) \\ Y'_i &= c + \alpha X'_i + \epsilon'_i \end{aligned}$$

Now a relationship should be visually apparent.

Mankiw, Romer, Weil

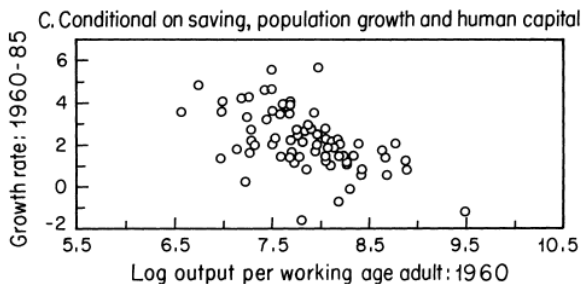
Replot the sample but partial out capital saving rates s_k and population growth n .



Conditional β -convergence? (conditional on s_k)

Mankiw, Romer, Weil

Replot the sample but partial out human capital saving rates s_h as well.



Conditional β -convergence. (conditional on s_k , n and s_h)

References

- Solow, R. (1956). "A Contribution to the Theory of Economic Growth". The Quarterly Journal of Economics, Vol. 70, No. 1, pp. 65-94.
- Mankiw, N.G., D. Romer and D. N. Weil (1992). "A Contribution to the Empirics of Economic Growth". The Quarterly Journal of Economics, Vol. 107, No. 2, pp.. 407-437.