

Chapter 4 Part 2 : Endogenous Growth Model

EE312

Macroeconomics, Stephen Williamson, Chapter 7,8

2015

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- Chapter 4: Growth Model
 - 4.1 Solow Growth Model
 - 4.2 Endogenous Growth Model

Outline (this part)

- Introduction :
 - Solow growth predictions
 - Growth facts
 - Growth in Solow model
- Endogenous growth

Endogenous Growth

- 1 Definition : human capital accumulation
- 2 Representative consumer : accumulation of human capital
- 3 The representative firm
 - 1 The firm's profit function
 - 2 Demand for efficiency units of labor
 - 3 Determination of the real wage
- 4 Competitive equilibrium
- 5 Growth of human capital
- 6 Factors in human capital growth
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- 10 No convergence
- 11 Human capital externality

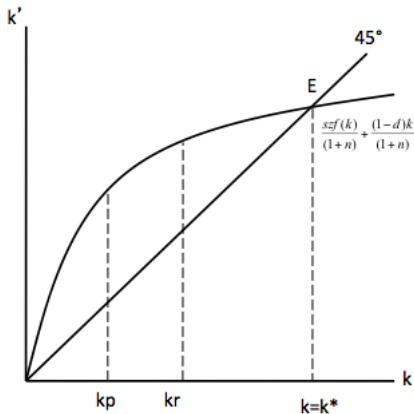
Solow growth predictions ((1) Absolute convergence, (2) Conditional Convergence)

(1) Absolute convergence

- If two countries start with:
 - the same population growth rate (n), saving rate (s) and total factor productivity (z),
 - but different per capita incomes (y), e.g., rich versus poor countries;
 - they will converge to the same steady-state k^* , y^* and c^* —
Absolute convergence.
- The poor country will have temporary higher growth and catch up with the rich.
- Absolute convergence (convergence in k^* , y^* and c^*),
 - Convergence in y^* , Convergence in output growth path

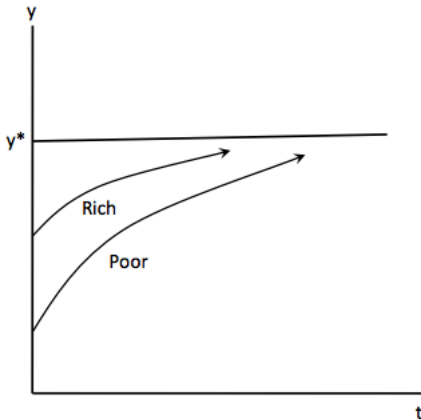
Absolute convergence

- The rich starts at k_r while the poor starts at k_p (with the same s , n and z).
- They converge to k^* and y^* in the long run.



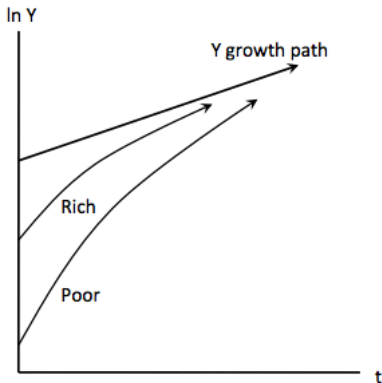
Convergence in per capita income

- The rich and the poor converge to the same level of y^* .



Convergence in output growth path

- The rich and the poor converge to the long-run growth rate (n) of aggregate output (Y).



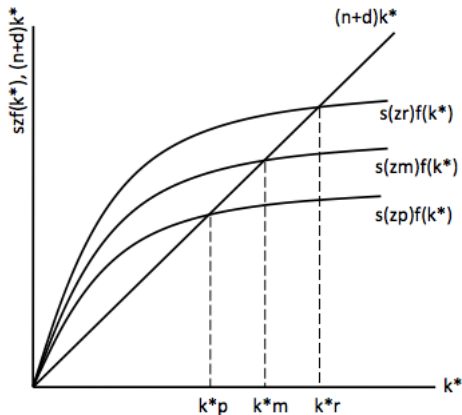
Solow growth predictions: (2) Conditional convergence

- With differences in n , z and s , the steady-state k^* , y^* , c^* are different.
 - Each country has its own steady state.
 - The steady-state growth rate of aggregates (K , Y) is still n for each country.
- Countries are predicted to converge to their own steady state.
- Disparity among countries due to different values of n , z and s .

Solow growth predictions Vs. Growth Facts

- Absolute convergence has occurred among rich countries.
- No absolute convergence between rich and poor countries. Exception is East Asia.
- No absolute convergence among poor countries.
- Great diversity among poor countries.
- Why no absolute convergence?
 - Countries have different s , n and z .
 - Each country has different steady-state k^* , y^* , c^* .
 - Each country is moving towards its own steady-state — **Conditional convergence**.
 - But differences in s and n are not large enough to explain all international disparity.
 - **Difference in access to technology (z)?**

- Countries with different z 's will not converge to the same k^* and y^* .
- p = poor
- m = medium
- r = rich



Disparity due to different z 's

- Different levels of total factor productivity (z) will perpetuate differences in capital per worker (k^*), per capita income (y^*) . . .
- despite the same saving rate (s) and population growth (n).

Barriers to technology adoption

- **Labor legislation:** strong labor unions obstruct adoption of new technology.
- **Trade protectionism:** domestic firms with market power lack incentives to innovation.
- **Political corruption:** government's protection of inefficient firms.
- **Undeveloped financial system:** poor resource allocation mechanism.

How to catch up?

- Promotion of more competition among firms.
 - Liberalization and competition policy.
 - More pressure and incentive for firms to innovation.
- Free trade for greater international competition.
- Privatization of state enterprises.
 - State enterprises guarantee employment at the expense of efficiency.

- The Solow model does not explain the mechanism of growth itself.
 - Growth depends on exogenous factors.
 - Total factor productivity (z) is exogenously determined.
 - z depends on R&D by firms, education, training.
 - These are partly affected by government policy.
 - Government policy to raise z and long-term growth?

- Explanation of growth within the model.
- Total factor productivity (z) depends on ‘human capital accumulation’.
- **Human capital**: the accumulated stock of skills and education workers have at a point in time.
 - Higher human capital; more production; more production of new human capital — faster growth over time.

1. Human capital accumulation

- The higher human capital, the more efficiency the production of human capital has.
 - Better schooling, more future production, better passing on skills and knowledge.
- **Human capital is an investment.**
 - Opportunity cost of education and training — sacrifice of current consumption.
 - Benefits: more future production and consumption.

- Knowledge is '**non-rivalry**': one's acquisition of knowledge does not reduce others' ability to acquire the same knowledge.
- Human capital accumulation is **NOT subject to diminishing marginal returns**.
- No limit on how productive a person can become, given increasing knowledge and skills.
- **Unbounded growth** in endogenous models.
- Growth in Solow model is limited:
 - **Diminishing returns** on physical capital accumulation — rivalry in resource uses.

2. The representative consumer

- The consumer allocates time between work and accumulating human capital.
- H^S = efficiency units of current human capital;
- u = time allocated to work;
- w = the real wage;
- C = current consumption;
- The **budget constraint** is total labor earnings:

$$C = uwH^S \tag{1}$$

Accumulation of human capital

- The consumer trades off current consumption for future consumption by accumulating human capital:
- $H^{s'}$ = future human capital;
- $(1 - u)$ = time allocated to human capital accumulation;
- b = efficiency of human capital accumulation technology; $b > 0$.

$$H^{s'} = (1 - u)bH^s \quad (2)$$

3. The representative firm

- The firm's production function using efficiency units of labor:
- Y = current output;
- z = marginal product of efficiency units of labor, where $z > 0$;
- uH^d = current input of efficiency units of labor:

$$Y = zuH^d \tag{3}$$

The firm's profit function

- uH^d is also the firm's demand for the efficiency units of labor.
- The function is characterized by **constant returns to scale** (CRS) — only one input.

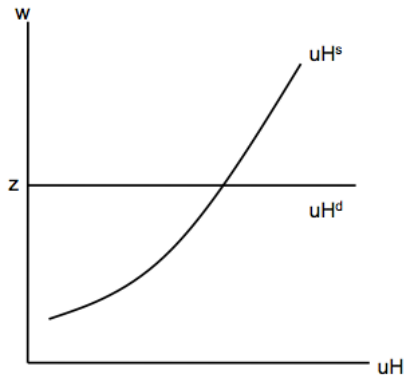
$$\begin{aligned}\pi &= Y - wuH^d \\ \pi &= zuH^d - wuH^d \\ \pi &= (z - w)uH^d\end{aligned}$$

$$\pi = (z - w)uH^d \quad (4)$$

- $(z - w) < 0$, $\pi < 0$; the firm hires no units of labor; or $uH^d = 0$.
- $(z - w) > 0$, $\pi > 0$; the firm hires infinite units.
- $z = w$, $\pi = 0$; the firm is indifferent.
- The demand curve is infinitely elastic at $w = z$.

Determination of the real wage

- uH^d is horizontal at $w = z$.
- The real wage equals z , the marginal product of uH^s . Assume uH^s with slope > 0 .



4. Competitive equilibrium

- The market clears at $w = z$ where $uH^d = uH^s$.
- Equilibrium consumption and growth of human capital accumulation:

$$C = zuH.$$

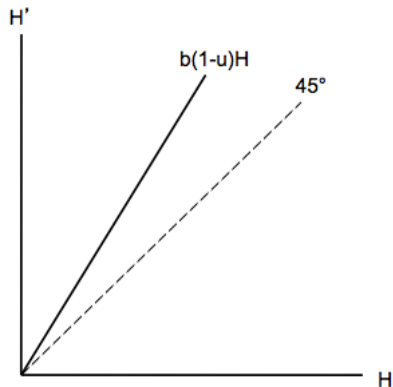
$$H' = b(1 - u)H.$$

$$\frac{H'}{H} - 1 = b(1 - u) - 1,$$

where $b(1 - u) - 1$ is constant.

5. Growth of human capital

- H' is a function of H where $H' > H$.
- Slope = $b(1-u) = 1 + \text{rate of growth of human capital}$.



6. Factors in human capital growth

$$\frac{H'}{H} - 1 = b(1 - u) - 1, \quad (5)$$

- $\frac{H'}{H}$ is higher if b increases or u decreases.
 - b = efficiency of human capital accumulation technology (or efficiency of the education sector).
 - u = time spent on current output production.
 - Falling u (or rising $1-u$) = more time spent on human capital accumulation.

7. Consumption and output growth

- Current consumption $C = zuH$ also holds for future consumption $C' = zuH'$.
 - So consumption grows at the same rate of $b(1-u)$ as human capital.
- Output also grows at the same rate as $Y = C$ in every period.

$$\frac{C'}{C} - 1 = \frac{zuH'}{zuH} - 1 = \frac{H'}{H} - 1 = b(1 - u) - 1 \quad (6)$$

8. Source of growth

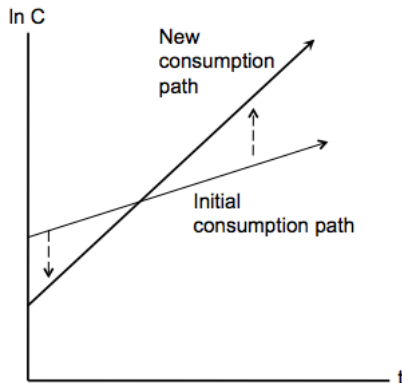
- **b and z are fixed:** constant technology.
- No population growth.
- Growth is determined inside the model, by the value of b and u .
- **Growth is unbounded** because human capital accumulation is not subject to diminishing returns to scale.
 - Output grows in proportion to human capital, given u .

9. Government policy on growth

- Government can increase growth:
 - Increases in b , the efficiency of human capital accumulation technology (education policy).
 - Reduction in u , taxes or subsidies to education.
 - Higher $b(1-u)$, higher growth of human capital, consumption and output.
- But current consumption must be sacrificed as u is lower, given initial human capital (H).

Lower u and consumption

- a lower u results in lower current consumption but higher consumption in the long run.



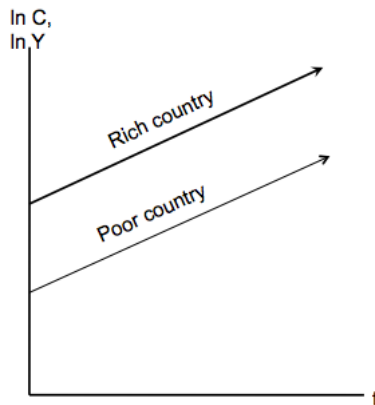
- Government's education policy (raising b) involves expenses of current resources and lower current consumption.
- Higher long-run growth is desirable?
 - This depends on the consumer's preference on current and future consumption.
 - The consumer may be worse off if current consumption is actually preferred.

9. No convergence

- Countries with all identical characteristics except differences in initial human capital will not converge on the levels of consumption and income.
 - **Poor countries:** low $Y = C = zuH$;
 - **Rich countries:** high $Y = C = zuH$.
 - But their C and Y grow at the same rate of $b(1-u)$.

Rich and poor do not converge.

- The Y and Y time paths do not converge despite the same growth rate of $b(1-u)$.



10. Human capital externalities

- The endogenous model explains the lack of convergence among poor countries and between rich and poor countries.
- But convergence occurs among rich countries, why? — Human capital externalities.
 - Contact with others with higher human capital increases our own human capital.
 - Capital and labor are highly mobile; skills are more easily transferred in rich countries.

- More opportunities and contact make levels of human capital in rich countries converge.
 - Convergence of income per worker.
- Lack of human capital externalities in poor countries.
 - Less contact with developed countries.
 - People with high human capital move to developed countries (i.e., brain drains).
 - Differences in human capital persist.