OVS452 Intermediate Economics II
VSE NF, Spring 2008
Lecture Notes #6
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7 Economic Growth I - Motivation

7.1 Introduction

Importance of sustained economic growth: Great **absolute differences** in the standards of living measured by GDP per capita: [1]

- GDP p.c. of USA in 2007 (in 1996 prices) was $42,897 ($10^{th}$ highest in the world)
- Russia - $13,401, South Africa - $10,483, China - $8,511, India - $3,825, Dem. republic of Congo - $390, Liberia - $386 (i.e. $1.06 a day)
- corresponding differences in nutrition, literacy, infant mortality, life expectancy and other measures of well-being
- Czech Republic - $21,929, Slovak Republic - $17,284

Small **differential in growth rates** implies huge differences in final outcomes when compounded over long periods of time (centuries):

- With GDP p.c $3,300 in 1870, US was growing at average rate 1.886% per year in period 1870 - 2007[2]
- Though experiment 1: If the growth rate would be 0.886%, then GDP p.c. would be $11,049 (i.e. 26% of the actual value)
  - similar GDP p.c. level to Cuba, Mexico and Turkmenistan
- Though experiment 2: If the growth rate would be 2.886%, then GDP p.c. would be $162,664 (i.e. 3.8 times the actual value)

[1] Data are from version 6.3 of Penn World Tables, http://pwt.econ.upenn.edu.

[2] Let y_0 be the GDP p.c. at year 0, y_T the GDP p.c. at year T, and x the average annual growth rate over that period. Then, $y_T = (1+x)^T y_0$. We can compute x by taking logarithms, getting $\ln y_T - \ln y_0 = T\ln(1+x) \approx Tx$, or $x \approx (\ln y_T - \ln y_0)/T$.

Even in the horizon of **2 generations**, growth rates matter:

- If the Czech Republic would grow at the same average rate as throughout the period 2000-2007 (i.e. 3.9%), in 30 years it would triple its real GDP p.c.
- However, if the Slovak Republic would grow at the same average rate as throughout the period 2000-2007 (i.e. 4.7%), in 30 years it would attain 4 times its real GDP p.c. and it would "catch on" the Czech Republic.

7.2 World Distribution of Income and Growth Rates

High **cross-country dispersion** in the level of income - GDP p.c., persistent with time

- **Figure 1** distribution of GDP p.c. in 1960 across 113 countries from the Penn World Tables 6.1.
  - richest country - Switzerland ($\$15,000$), poorest - Tanzania ($381)
  - wealthiest countries: OECD + Latin America (Venezuela, Argentina); poorest countries: Africa (Tanzania, Uganda) and Asia (China, India, Indonesia)
- **Figure 2** - distribution of GDP p.c. in 2000 across 150 countries from the Penn World Tables 6.1.
  - richest country - Luxembourg ($\$44,000$), poorest - Tanzania ($482)
  - wealthiest countries: OECD + East Asia (Taiwan, Japan, Singapore); poorest countries: sub-Saharan Africa (Tanzania, Uganda); Latin America + Asia: mid-range
- **Comparison:**
  - similar cross-country dispersion of income over this period
  - mean of GDP p.c. in 2000 was 2.5 higher than in 1960 (compare $\$8,490$ and $\$3,390$)
  - change of relative position of countries (drop of Argentina, Venezuela, Israel or RSA; rise of China, India, Singapore) due to **differences in the rate of economic growth**
- **Figure 3** - distribution of growth rate of GDP p.c. from 1960 - 2000.
  - range from -3.2% for the Democratic Republic of Kongo to 6.4% for Taiwan
  - growth miracles: Singapore (6.2%), South Korea (5.9%), Hong Kong (5.4%), Thailand, Japan (after WWII), China, Ireland
  - growth disasters: sub-Saharan Africa (Niger, Angola, Madagascar, Nigeria, Rwanda) + Latin America (Venezuela, Bolivia, Peru, Argentina)

7.2.1 Convergence: Do the poor countries catch up rich countries, i.e. do they tend to grow faster?

(+ rationale)

- **Unconditional convergence:** $\Delta \ln y_{2000-1960} = \alpha + \boldsymbol{\beta} \ln y_{1960}$
  - Figure 4, based on Penn World Tables data, shows that average growth rate over the period 1960-2000 has little (and slightly positive) correlation with initial level of GDP p.c.
- **Conditional convergence:** $\Delta \ln y_{2000-1960} = \alpha + \boldsymbol{\beta} \ln y_{1960} + \gamma \mathbb{X}_{1960}$, where $\mathbb{X}_{1960}$ is a set of country-specific controls (education, fiscal and monetary policy, competition level, etc.) - we compare countries with similar starting characteristics
  - After conditioning on the underlying characteristics, the countries with lower initial income tend to grow faster than their rich counterparts. For illustration, see Figure 5 for evidence of convergence within OECD countries and Figure 6 for the convergence among US states (both with apparent negative correlation).

What are the factors behind the differences in economic growth, and how can we control them?

- government policies with effects on long-term growth
- evaluation framework = models

7.3 Stylized Facts - Building Blocks of Models

Kaldor (1963) - balanced growth in the long run

1. Output per worker Y/L (GDP p.c.) grows over time and the growth rate does not tend to diminish
2. Physical capital per worker K/L grows over time
3. The capital to output ratio K/Y is nearly constant $\Rightarrow$ capital and output grow at the same rate
4. The return to capital (r) is roughly constant
5. The income shares of labor and capital (wL/Y and rK/Y) stay roughly constant
6. The level as well as the growth rate of output per worker differs substantially across countries.

$\Rightarrow$ applies to **developed countries**
$\Rightarrow$ explained by Solow model

7.4 Figures

Figure 1: Histogram for GDP p.c. in 1960 (reproduced from Barro, 2003). The data for 113 countries are taken from Penn World Tables 6.1. Representative countries within each group are labeled.

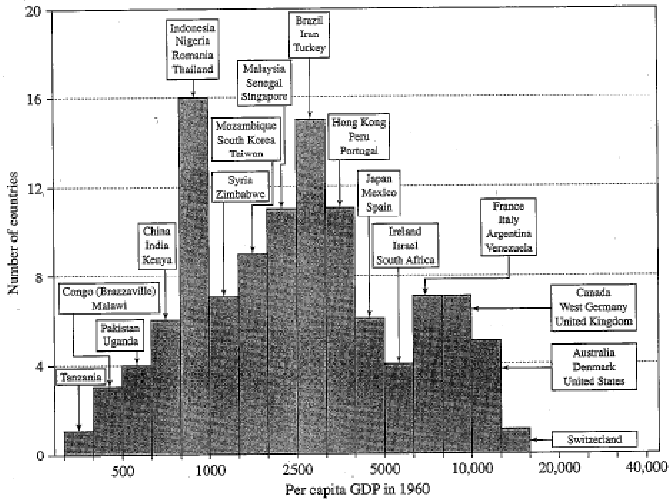


Figure 2: Histogram for GDP p.c. in 2000 (reproduced from Barro, 2003). The data for 150 countries are taken from Penn World Tables 6.1. Representative countries within each group are labeled.

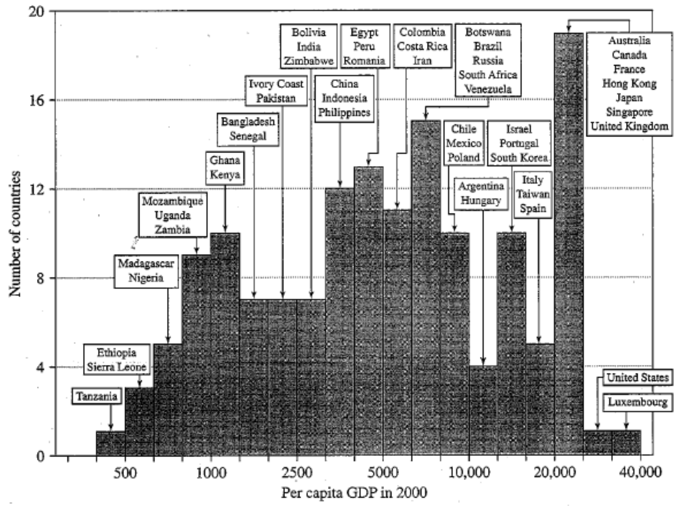


Figure 3: Histogram for growth rates of GDP p.c. from 1960-2000 (reproduced from Barro, 2003). The data for 150 countries are computed from the values of GDP p.c. shown in Figures 1 and 2. Representative countries within each group are labeled.

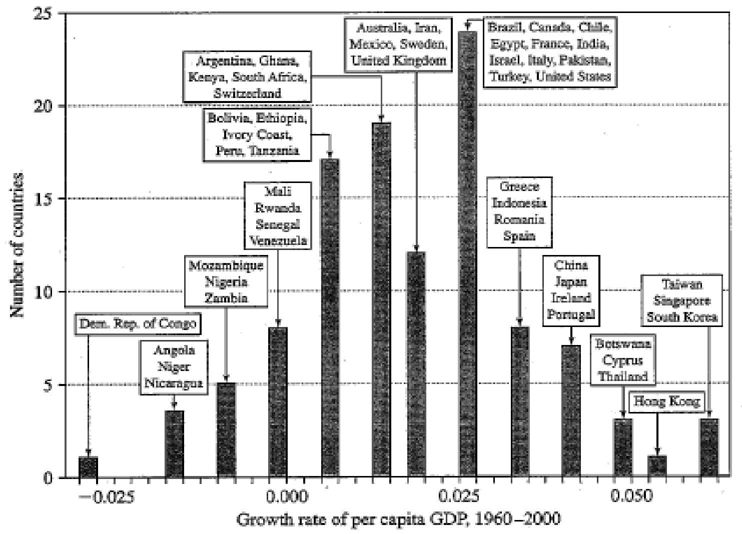


Figure 4: Convergence of GDP across countries: Growth rate from 1960 to 2000 over the initial level of real GDP p.c. for 114 countries (reproduced from Barro, 2003).

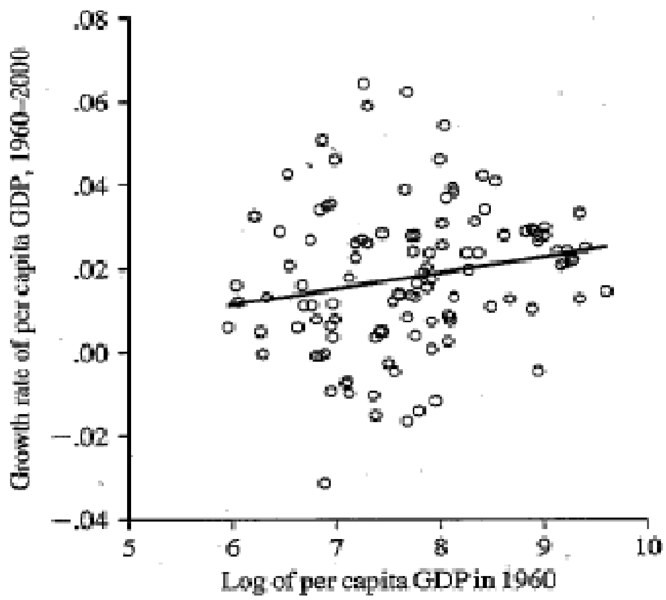


Figure 5: Convergence of GDP across OECD countries: Growth rate from 1960 to 2000 over the initial level of real GDP p.c. for 18 countries (reproduced from Barro, 2003).

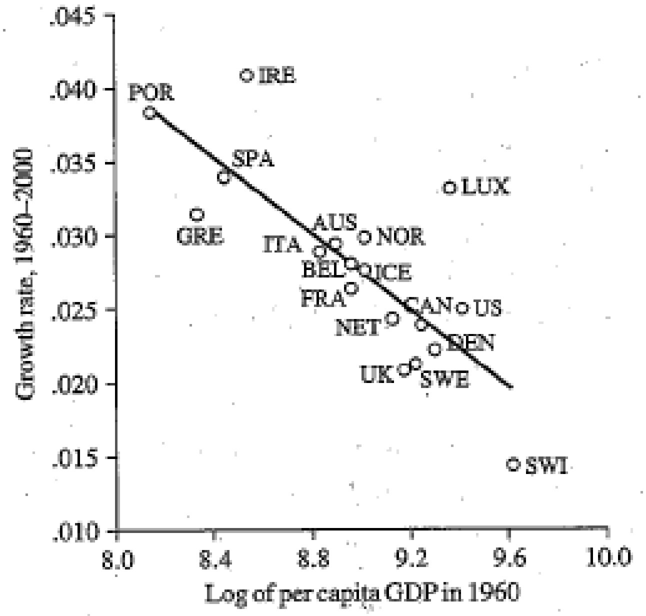
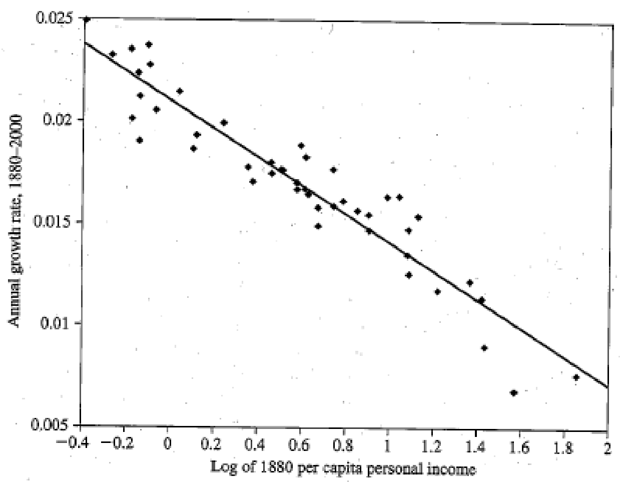


Figure 6: Convergence of personal income across US states: Growth rate of personal income from 1880 to 2000 over the initial level of personal income for 47 states (reproduced from Barro, 2003).



8 Economic Growth II - Solow model

- 3 main sources of growth - capital, people, technolog. progress
- SOLOW: how these three interact and affect national output; build up in steps

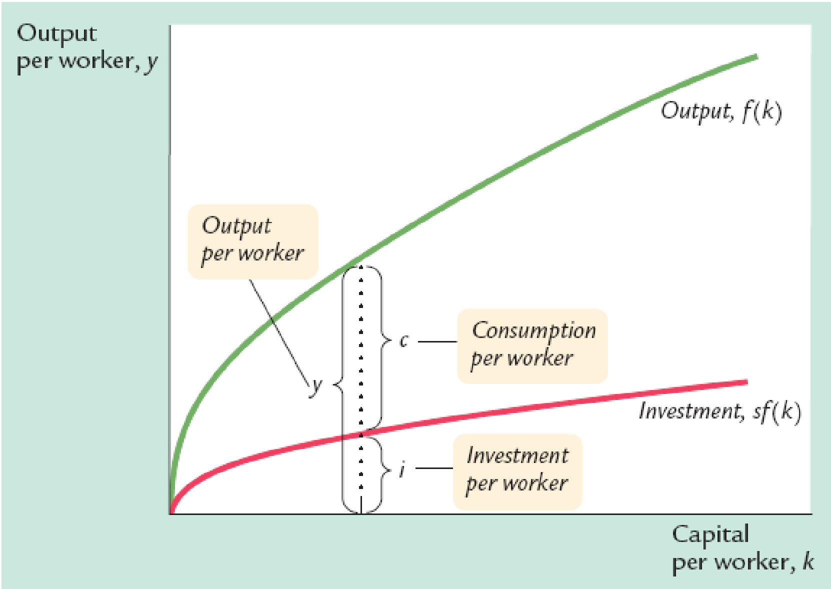
8.1 STEP 1: Accumulation of capital

8.1.1 Assumptions of the model:

- **Neoclassical production function:** $Y = F(K, AL)$
  - firms hire people (L) and capital (K) to produce good (Y) by production technology ($F(\cdot)$)
  - have access to knowledge (A) that makes the production more effective (labor-augmenting or Harrod-neutral technological change)
  - let's assume (for a while) that both labor force and efficiency of production are constant over time
  - Ass.1: Constant returns to scale - i.e. $zY = F(zK, zAL)$
    - allows us to analyze the per capita quantities: output per effective worker $y = Y/AL$ and capital per effective worker $k = K/AL$
    - take $z = 1/AL => Y/AL(=: y) = F(K/AL, 1)(=: f(k)$
  - Ass.2: Marginal product is positive and diminishing
    - applies also for transformed function - $f'(k) > 0, f''(k) < 0$
  - Ass.3: Inada conditions + essentiality
- output is divided between consumption and investment: $y = c + i$
- HHs save a constant fraction of their income $s \in (0, 1)$: $i = sy,\ c = (1 - s)y$

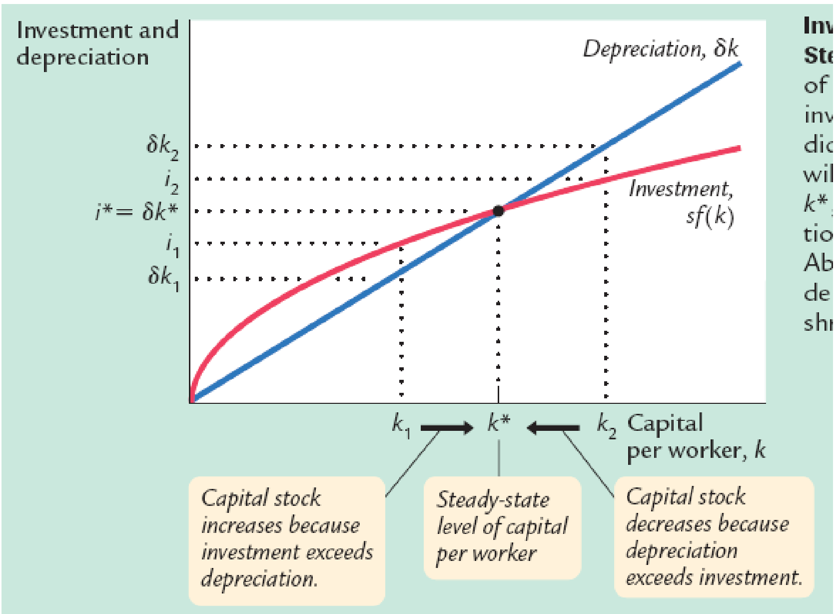
8.1.2 Basic analysis:

- capital stock of economy changes over time
  - increases due to investment - new plants and equipment
  - decreased due to depreciation - wearing out of capital
- Investment: $i = sf(k)$
- Depreciation: fraction δ of capital stock "disappears" δk



- **change of capital stock** = investment - depreciation

  $\Delta k = sf(k) - \delta k$



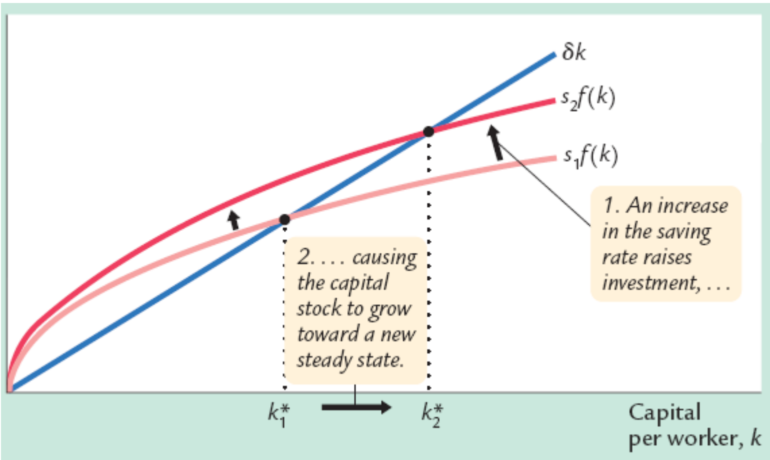
- **STEADY STATE:** there exist single capital stock k^* for which amount of depreciation equals the invested amount

  $\exists! k^* : \Delta k = 0$ or $sf(k) = \delta k$

- if economy is in steady-state, it will stay there
- if economy starts with any other level of capital, it will converge to steady state (stable equilibrium)

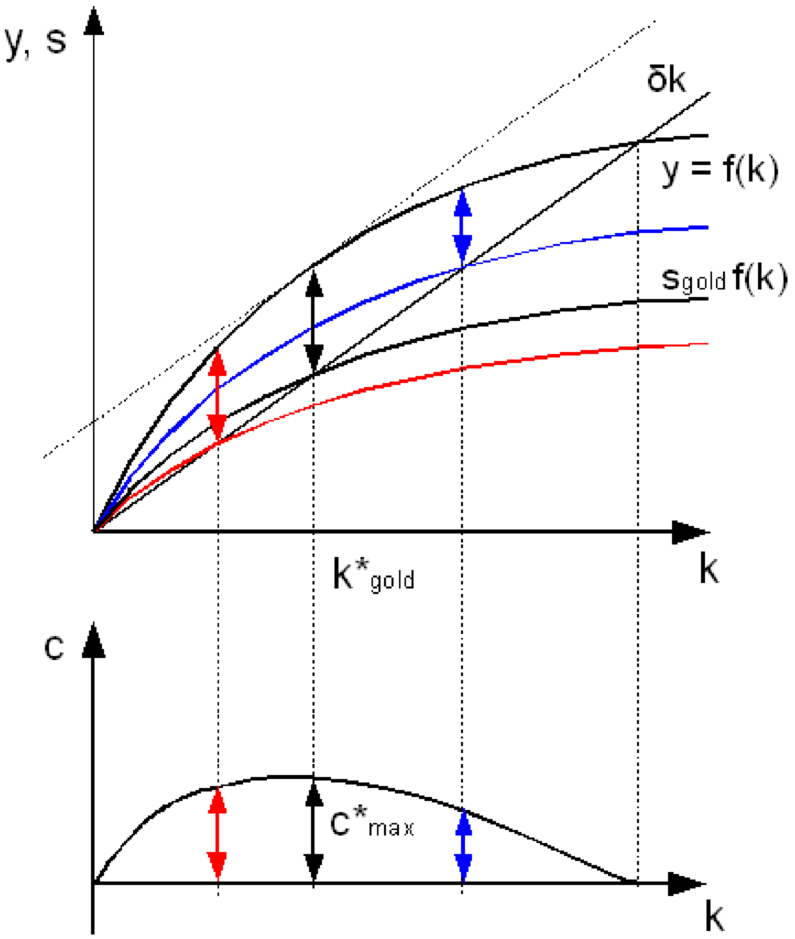
- **Prediction of model:**
  - in the long run, all economies will converge to their respective steady state
  - if country starts from relatively lower level of capita per person, it will grow faster (Japan, Germany after WWII)

- **Effect of savings:** as key determinant of capital stock
  - higher saving rate => higher steady state level of capital and output per capita
  - increase in saving rate => temporary increase in growth rate of economy



8.1.3 Golden Rule level of capital:

- different saving rates lead to different steady states - with corresponding steady state level of capital, output and consumption.
- Questions: How do we compare these different steady states? What is optimal from HH's point of view?
- Answer: Choose saving rate (and corresponding capital level) that **maximizes the consumption**.

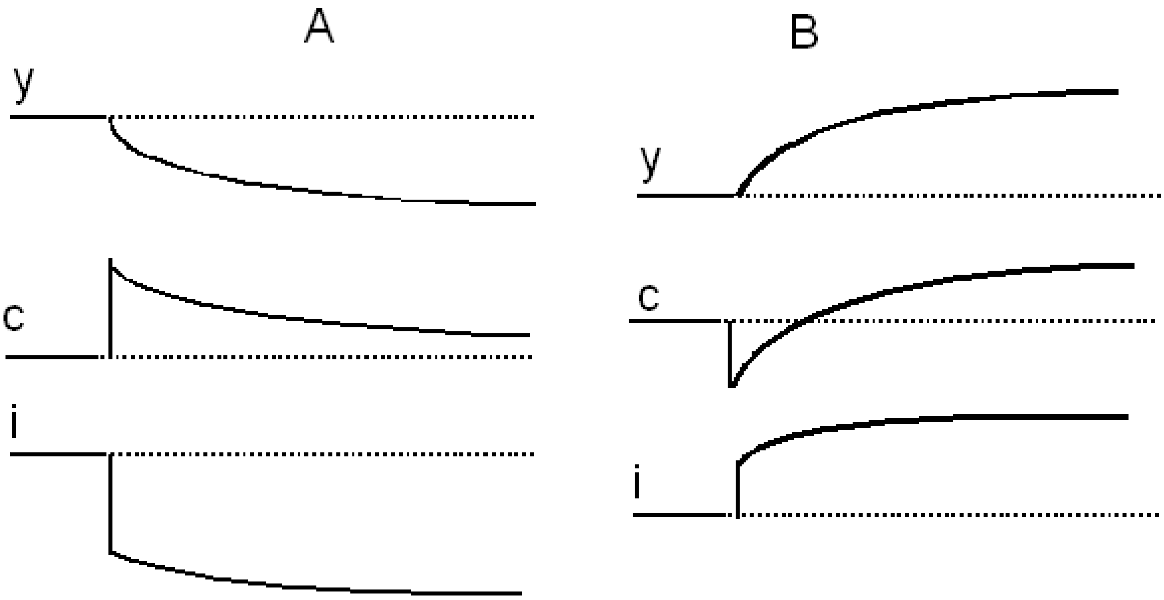


- Computation:
  - $y = c + i$
  - in the steady state: $i = sf(k^*) = \delta k^*$
  - therefore, consumption can be expressed as $c^* = f(k^*) - \delta k^*$

– Maximum:

$$\frac{\partial c^*}{\partial k^*} = 0\Big|_{k^*=k^*_{gold}} \quad \rightarrow \quad f'(k^*_{gold}) - \delta = 0$$

- Intuition:
  - small s => small k^* => small y^* => small consumption
  - high s => high k^* => high y^* and high depreciation δk^* => high investment needed to cover for depreciation => small consumption



- **Transition:** what are the costs of transition to optimal steady state?
  - A. starting with **too much capital**=> POLICY = reduce saving rate
    - investment drops immediately
    - consumption jumps up - keeps over the initial level over all transition time
  - B. starting with t**oo low capital** => POLICY = increase saving rate
    - investment partially jumps up
    - consumption jumps down - first lower than initial level => then increases
  - tradeoff among welfare of different generations - decision depends on the weight that policy makers put on different generations

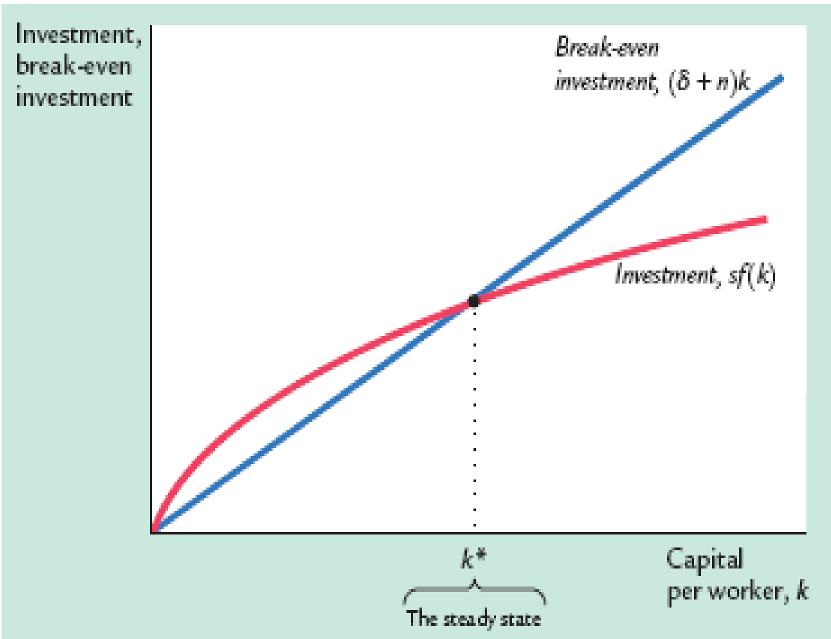
8.2 STEP 2: Population growth

- capital accumulation alone cannot explain sustained growth
  - eventually converge to steady state => capital and output p.c. are constant
  - with ass. on constant labor force => constant total output and capital
- assumption: population grows at constant rate n

8.2.1 Effect of population growth:

- with increasing population, capital per worker is decreasing
  - capital is distributed among larger population of workers
  - similar effect as depreciation
- new condition for steady state: investment = replacement of depreciation + capital for new workers

$$\Delta k = sf(k) - (\delta + n)k$$
$$\Delta k = 0 \quad \Leftrightarrow sf(k^*) = (\delta + n)k^*$$

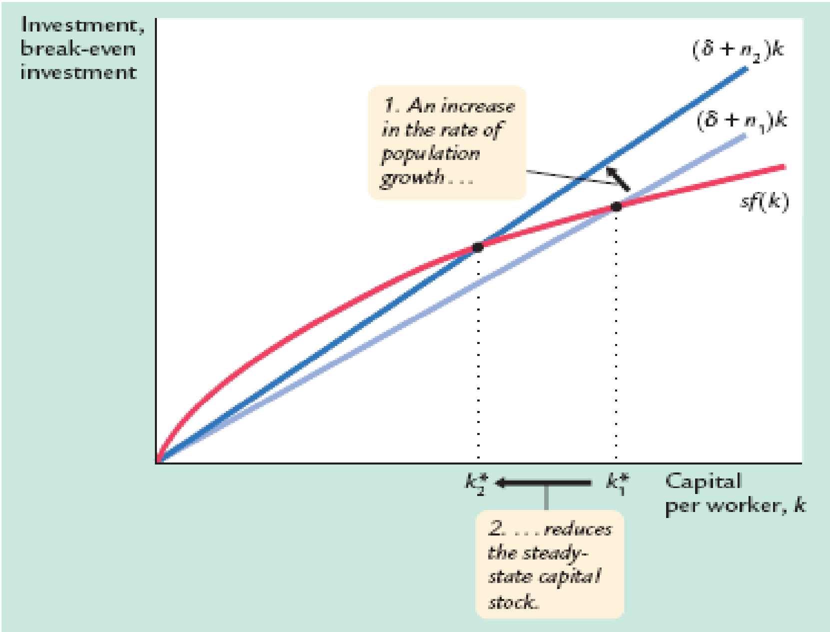


1. partial explanation of sustained economic growth
   - output and capital per worker is constant
   - total output and capital grow at rate n
2. higher population growth => lower level of GDP per capita

- consistent with empirical data
- possible reverse causation

3. new equation for Golden Rule level of capital

$$MPK = f'(k) = \delta + n$$



8.3 STEP 3: Technological growth

8.3.1 Efficiency of labor

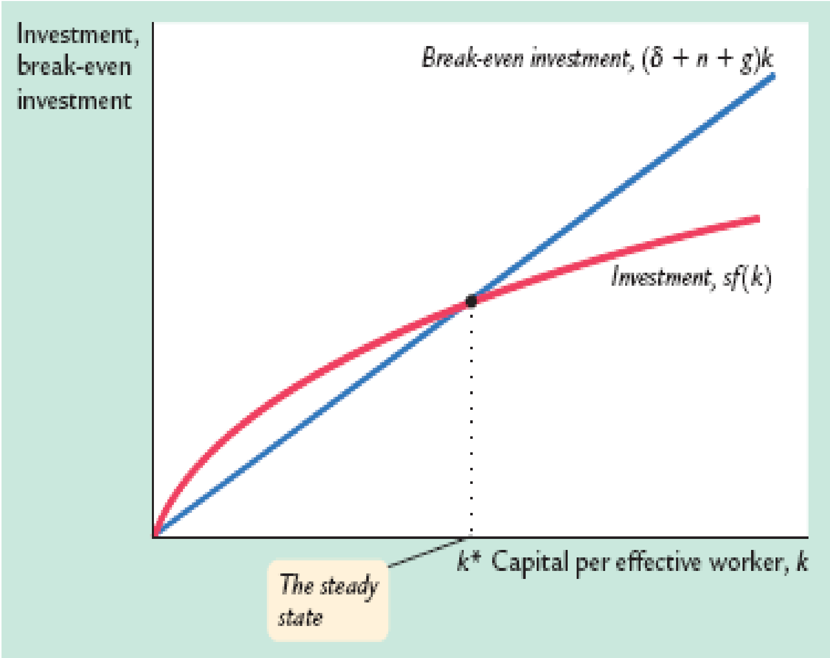
- Assumption: technological growth causes the efficiency A to grow **at constant rate g**
  - labor-augmenting technological progress
  - number of effective workers grows approx. at rate $n + g$

8.3.2 Effects of technological growth

- analogous to population growth

$$\begin{aligned}\Delta\hat{k} &= sf(\hat{k}) - (\delta + n + g)\hat{k} \\ \Delta\hat{k} &= 0 \quad \Leftrightarrow sf(\hat{k}^*) = (\delta + n + \mathbf{g})\hat{k}^*\end{aligned}$$

1. explanation of sustained economic growth



- total output and capital grow at rate n + g (like effective workers)
- output and capital per worker is growing at rate g

2. new equation for Golden Rule level of capital

$$MPK = f'(\hat{k}) = \delta + n + g$$

8.4 Endogenous growth models

- Solow-Swan model: s.s. growth rate of $Y/L = \frac{\Delta Y/L}{Y/L} = g$
- g - rate of technological progress, **EXO**GENOUSLY given + assumed to be positive and constant
- want to have growth **ENDO**GENOUS, i.e. we are able to explain it as the outcome of the decisions of agents within the model

Possible solutions:

- **AK models** - abandon diminishing returns to capital (DRC)
  - broad definition of capital (physical + **human**)
    - 1 sector: production of goods - basic model
    - 2 sectors: production of both goods and (human) capital - education
  - **learning-by-doing** + **spillovers** of knowledge

    * individual firms - DRC, aggregate level - CRC/IRC

- **R&D models** Advances in technology level determined by purposeful activity (explicitly model determinants of g)
  - expanding **variety** of products
  - **quality** improvements of existing products

8.4.1 Basic AK model

- production function: $Y = AK \quad => MPK = A > 0$
- abolished diminishing product of capital - A is positive constant => constant return to capital (CRC)
- accumulation of capital:

$$\begin{aligned}\Delta K &= sY - \delta K \\ \frac{\Delta K}{K} &= \frac{\Delta Y}{Y} = sA - \delta\end{aligned}$$

- as long as $sA > \delta$, economy grows forever
- saving decision alone leads to permanent growth

  Is CRC reasonable assumption?

  - NO, if we assume classical definition of capital - stock of plants and equipment.
  - YES, if we consider broad definition of capital - including knowledge (know-how).

8.4.2 2 sector model of Human capital

- 2 sectors: production of output (firms) and production of education or human capital (universities)
- production function - CRS

$$Y = F(K, (1-\mu)EL)$$

- accumulation of capital (physical + human):

$$\begin{aligned}\Delta E &= g(\mu)E \\ \Delta K &= sY - \delta K\end{aligned}$$

  - μ - fraction of labor force in universities
  - g - production of new knowledge, dependent on share of labor force in that sector

- persistent growth attained endogenously - production of knowledge on universities will explain g - otherwise similar to Solow
- two societal decision variables - s and μ