9 Economic Growth I

9.1 Motivation

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)

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[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 2000-2004 (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.

9.2 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)

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

9.3 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

9.4 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.
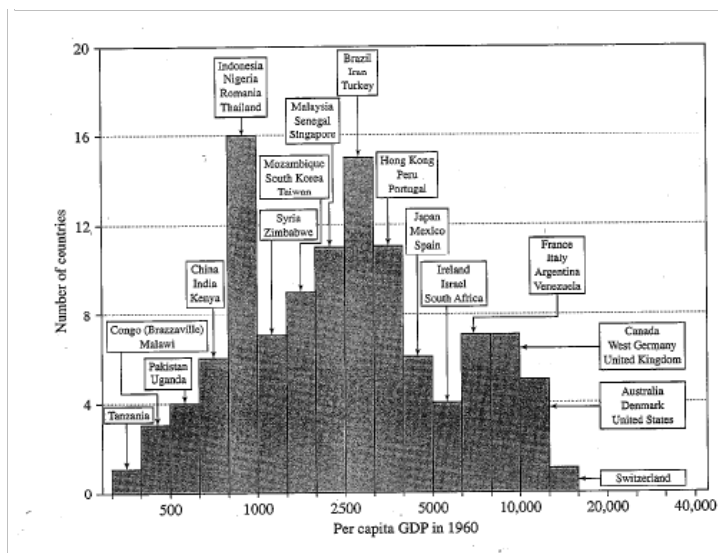

Figure 2: Histogram for GDP p.c. in 2000 (reproduced from Barro, 2003). The data for 150 countries are taken from Penn World Tables 6.1. Representative countries within each group are labeled.
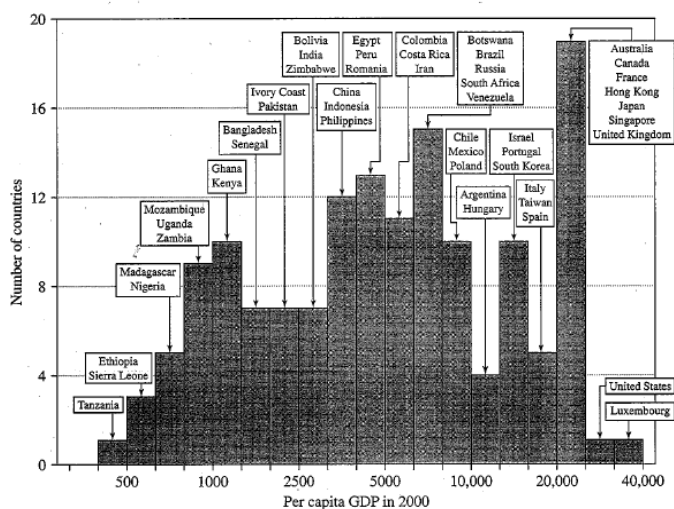
Figure 3: Histogram for growth rates of GDP p.c. from 1960-2000 (reproduced from Barro, 2003). The data for 150 countries are computed from the values of GDP p.c. shown in Figures 1 and 2. Representative countries within each group are labeled.
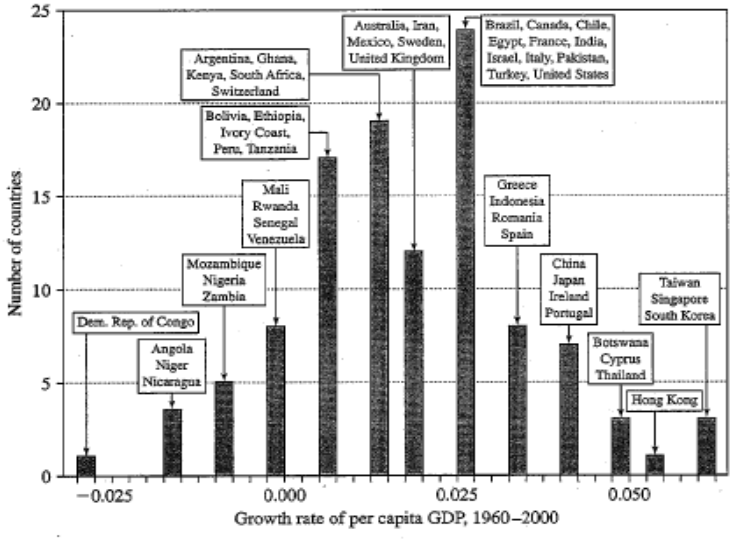

Figure 4: Convergence of GDP across countries: Growth rate from 1960 to 2000 over the initial level of real GDP p.c. for 114 countries (reproduced from Barro, 2003).
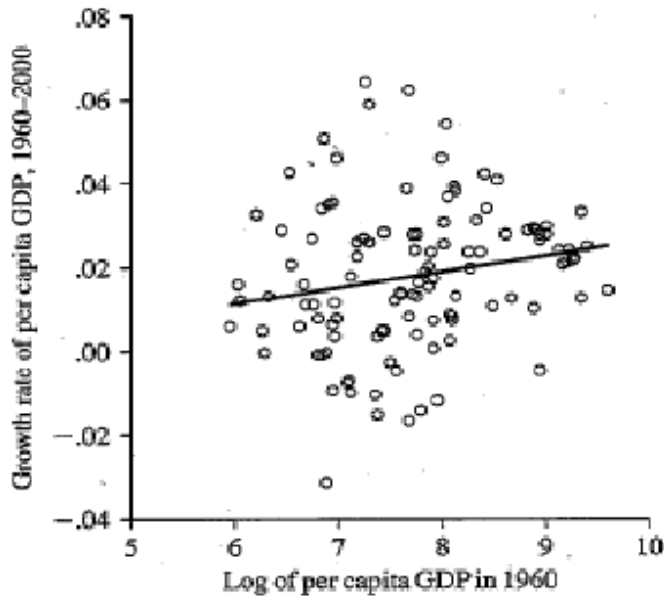
Figure 5: Convergence of GDP across OECD countries: Growth rate from 1960 to 2000 over the initial level of real GDP p.c. for 18 countries (reproduced from Barro, 2003).
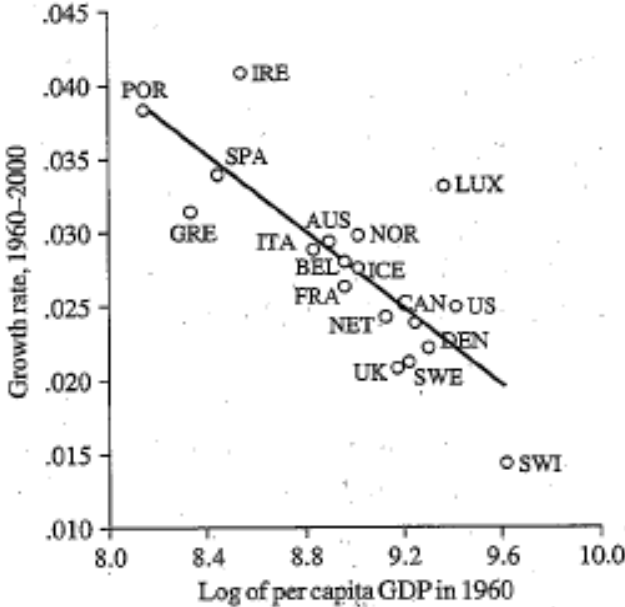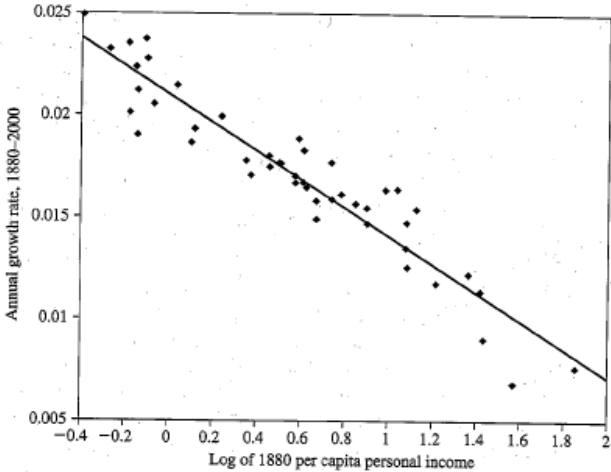

Figure 6: Convergence of personal income across US states: Growth rate of personal income from 1880 to 2000 over the initial level of personal income for 47 states (reproduced from Barro, 2003).

10 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

10.1 STEP 1: Accumulation of capital

### 10.1.1 Assumptions of the model:

- **Neoclassical production function:** $Y = F(K, L)$

  - Ass.1: Constant returns to scale - i.e. $zY = F(zK, zL)$
    - allows us to analyze the per capita quantities: output per worker $y = Y/L$ and capital per worker $k = K/L$
    - take $z = 1/L => Y/L(=: y) = F(K/L, 1)(=: f(k))$

  - Ass.2: Marginal product is positive and diminishing
    - applies also for transformed function - $f'(k) > 0, f''(k) < 0$

  - Ass.3: Inada conditions + essentiality
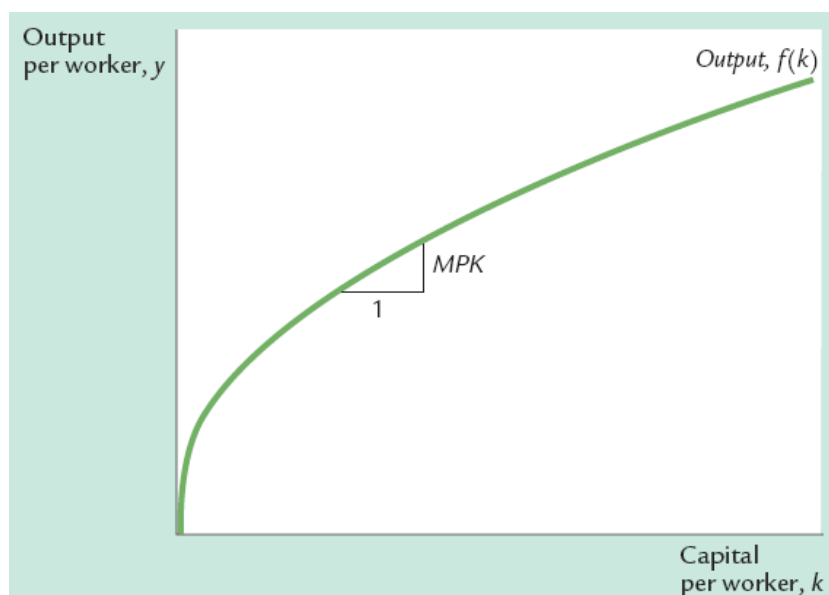
- output is divided between consumption and investment: $y = c + i$

- HHs save a constant fraction of their income $s \in (0, 1)$: $i = sy$, $c = (1 - s)y$

10.1.2 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: $i = sf(k)$

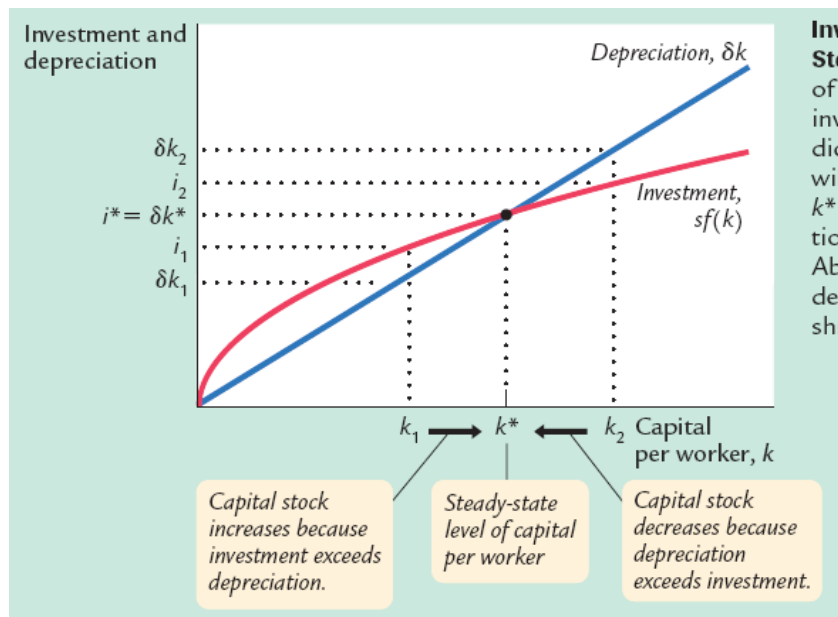- Depreciation: fraction δ of capital stock "disappears" δk
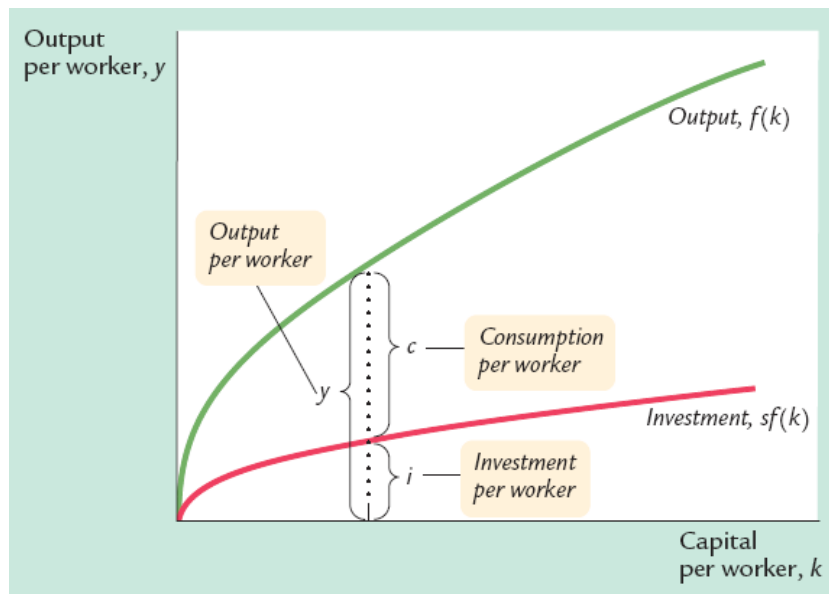
- **change of capital stock** $=$ investment - depreciation

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

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

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

  - 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)

Investment and depreciation

Depreciation, δk

δk_2

i_2

$i^* = \delta k^*$

i_1

δk_1

Investment, $sf(k)$

$k_1 \longrightarrow k^* \longleftarrow k_2$ Capital per worker, k

Capital stock increases because investment exceeds depreciation.

Steady-state level of capital per worker

Capital stock decreases because depreciation exceeds investment.

- **Effect of savings:** as key determinant of capital stock

    - higher saving rate $\Longrightarrow$ higher steady state level of capital and output per capita

    - increase in saving rate $\Longrightarrow$ temporary increase in growth rate of economy

δk

$s_2 f(k)$

$s_1 f(k)$

1. An increase in the saving rate raises investment, . . .

2. . . . . causing the capital stock to grow toward a new steady state.

$k_1^* \longrightarrow k_2^*$

Capital per worker, k

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