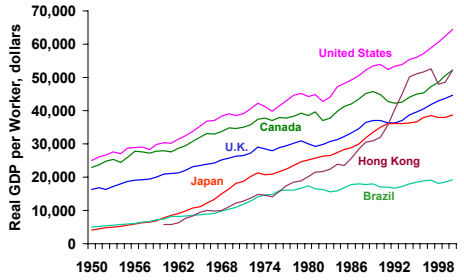
Intermediate Macroeconomics

Chapter 3
Long-Run Economic Growth

Long-run Economic Growth

1. Growth accounting
2. Empirical results
3. Neoclassical growth model
4. Neoclassical growth model golden rule
5. Endogenous growth model
6. Government policy and growth

1. Growth Accounting
Growth in six countries



1. Growth Accounting
Growth accounting equation

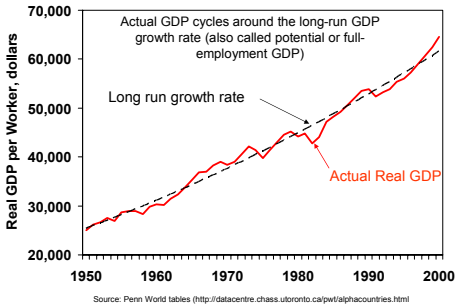
$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \varepsilon_K \frac{\Delta K}{K} + \varepsilon_L \frac{\Delta L}{L}$$

Output growth rate
- = Productivity growth rate, $\Delta A/A$
  - + Capital growth rate, $\Delta K/K$
    - x elasticity of output with respect to capital, ε_K
  - + Labor growth rate, $\Delta L/L$
    - x elasticity of output with respect to labor, ε_L

2. Empirical Results
Solow and Denison studies

	Solow	Denison
Period covered	1909 – 1949	1929 - 1982
Output growth	2.9%	2.9%
Capital growth	0.3%	0.6%
Labor growth	1.1%	1.3%
Productivity growth	1.5%	1.0%

3. Neoclassical Growth Model
Growth in Actual and Potential U.S. GDP



Source: Penn World tables (http://datacentre.chass.utoronto.ca/pwt/alphacountries.html

3. Neoclassical Growth Model
Start with growth accounting equation

Assumption 1. No technological change:

$$\frac{\Delta Y}{Y} = \varepsilon_K \frac{\Delta K}{K} + \varepsilon_L \frac{\Delta L}{L}$$

where, $\frac{\Delta A}{A} = 0$

3. Neoclassical Growth Model
Steady State

Assumption 2. Steady State - a condition of constant rates of growth in economic measures. With no technological change, a steady state is represented by identical constant growth rates in population, total output, and the level of capital.

$$\frac{\Delta L}{L} = \frac{\Delta K}{K} = n = \text{population growth rate}$$

3. Neoclassical Growth Model
Constant returns to scale

Assumption 3. Constant returns to scale production function.

$\varepsilon_K + \varepsilon_L = 1$

3. Neoclassical Growth Model
Neoclassical growth equation result

$$\frac{\Delta Y}{Y} = \varepsilon_K \frac{\Delta K}{K} + \varepsilon_L \frac{\Delta L}{L}$$
$$= \varepsilon_K n + \varepsilon_L n$$
$$= (\varepsilon_K + \varepsilon_L) n$$
$$= n$$
$$= \text{population growth rate}$$

The growth rate of output is independent of savings or the level of capital.

3.. Neoclassical Growth Model
Simple model implications

- Aggregate output grows at the same rate as population.*
- Per worker output remains unchanged.*
- The level of capital has no effect of aggregate or per worker output growth rates in steady state.**

* Unless there is technological change, i.e. an increase in productivity.

** An increase in the savings rate and capital-labor ratio provides a temporary boost to aggregate output and per worker output growth rates. Growth rates will return to original steady state levels but at a permanently higher output per worker level.

3. Neoclassical Growth Model
Constant returns to scale

Production function:

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

If constant returns:

$$zY = f(zK, zL)$$

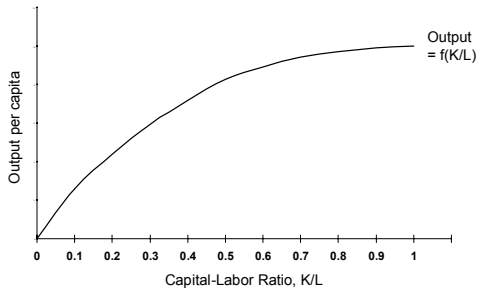
If $z = 1/L$:

$$\frac{Y}{L} = f\left(\frac{K}{L}, 1\right)$$

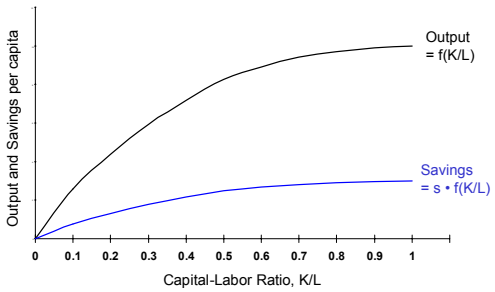
Or,

$$Y/L = f(K/L)$$

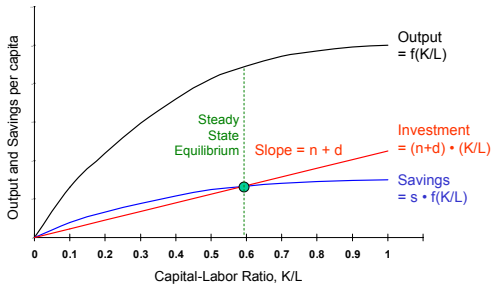
3. Neoclassical Growth Model
Per worker production function



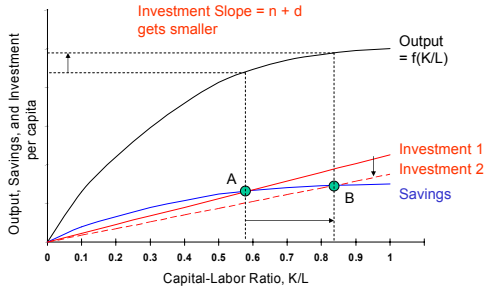
3. Neoclassical Growth Model
Savings per worker



3. Neoclassical Growth Model
Investment per worker



3. Neoclassical Growth Model
Effect of an decrease in population growth rate



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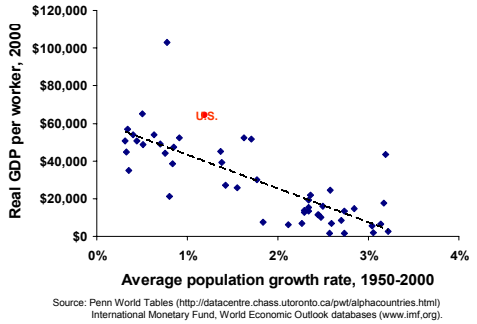
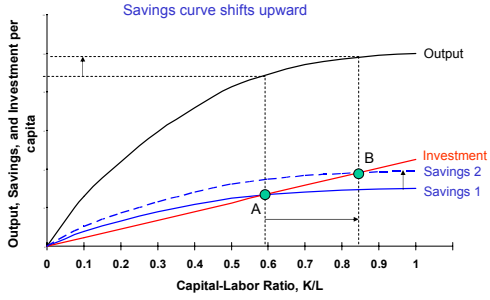
Effect of an decrease in population growth rate



Source: Penn World Tables (http://datacentre.chass.utoronto.ca/pwt/alphacountries.html)
International Monetary Fund, World Economic Outlook databases (www.imf.org).

3. Neoclassical Growth Model
Effect of an increase in the savings rate



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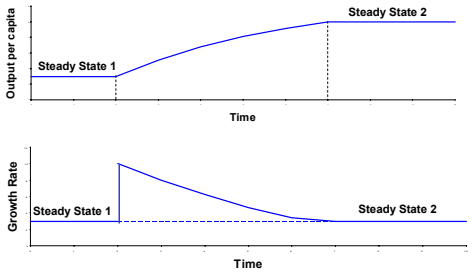
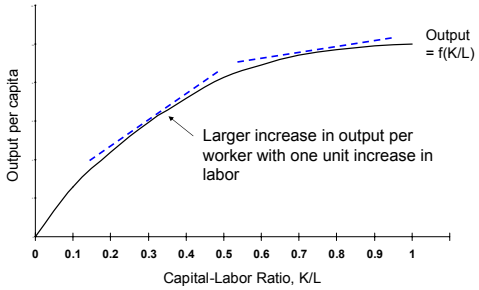
Effect of an increase in the savings rate



3. Neoclassical Growth Model
Declining marginal productivity of capital



3. Neoclassical Growth Model
Rich and Poor Convergence

- Poor countries:
  - Low capital-labor ratio
  - Each unit of new capital yields larger increase in output per worker
- Best place to invest is in labor markets with greatest marginal increase in output for each new unit of capital.
- Investment and wealth should grow faster in poor than rich countries.

4. Neoclassical Growth Model Golden Rule
Summary

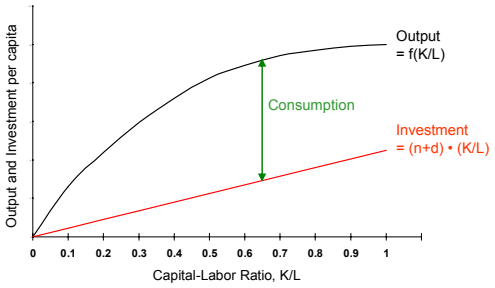
- Capital/Labor ratio that maximizes consumption in steady state.
- Implies an optimal rate of savings – a country can have too high a rate of savings.

4. Neoclassical Growth Model Golden Rule
Consumption

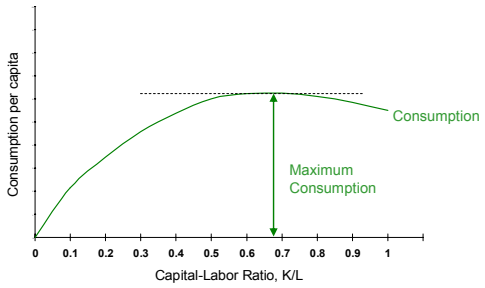
- Consumption is the difference between output and investment in steady state.

  $C = Y - I$

4. Neoclassical Growth Model Golden Rule
Consumption = Output - Investment



4. Neoclassical Growth Model Golden Rule Consumption per worker



5. Endogenous Growth Model

- Productivity growth:
  - Neoclassical model: productivity growth is exogenous; i.e., is given to us.
  - Endogenous growth model attempts to explain productivity growth within the model.
- Marginal productivity of capital:
  - Neoclassical model: decreasing
  - Endogenous growth model: constant or even increasing

5. Endogenous Growth Model Growth rate of output

- Output is proportional to the level of capital, which implies non-decreasing marginal productivity of capital:

$$Y = \alpha \cdot K$$

- The change in output is proportional to the change in capital:

$$\Delta Y = \alpha \cdot \Delta K$$

- The growth rate of output equals the growth rate of capital:

$$\frac{\Delta Y}{Y} = \frac{\Delta K}{K}$$

5. Endogenous Growth Model Savings = Investment

- Savings = investment:

$$S = I$$

- Savings is proportional to output:

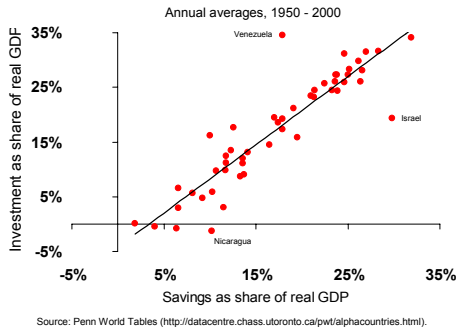
$$S = s \cdot Y$$
$$= s \cdot \alpha \cdot K$$

- Investment equals additions to the level of capital, ΔK, plus depreciation, d:

$$I = \Delta K + d \cdot K$$

- Thus, $s \cdot \alpha \cdot K = \Delta K + d \cdot K$

5. Endogenous Growth Model Savings versus Investment



Source: Penn World Tables (http://datacentre.chass.utoronto.ca/pwt/alphacountries.html).

5. Endogenous Growth Model Growth of output and rate of savings

- Rearrange to solve for the change in the capital stock:

$$\Delta K = s \cdot \alpha \cdot K - d \cdot K$$

- Divide both side by K:

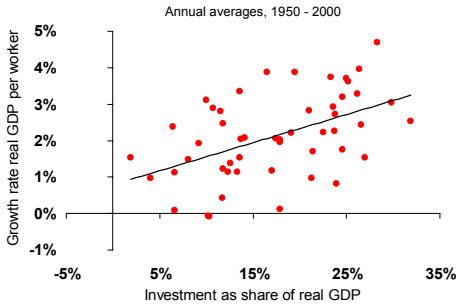
$$\frac{\Delta K}{K} = s \cdot \alpha - d$$

- Substitute into the equation for the growth rate of output:

$$\frac{\Delta Y}{Y} = s \cdot \alpha - d$$

The growth rate of output is now a function of the savings rate.

5. Endogenous Growth Model
Effect of investment rate on GDP growth



Source: Penn World Tables (http://datacentre.chass.utoronto.ca/pwt/alphacountries.html).

6. Government Policies and Economic Growth
Summary

- Policies that promote savings and investment
  - Temporary boost to aggregate growth rates in simple model. Sustained boost in endogenous growth model.
  - Permanently higher output per worker as long as higher savings rate is sustained.
  - Current consumption sacrificed.
- Policies that raise productivity
  - Temporary increase to aggregate growth rates unless productivity growth rates sustained.
  - Sustained increase in output per worker.
  - No sacrifice of current consumption.