Chapter 6 Lecture - Long-Run Economic Growth

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Table 6.1 Economic Growth in Eight Major Countries, 1870–2008

Country	Levels of real GDP per capita 1870	1913	1950	2008	Annual growth rate 1870–2008
Australia	3,273	5,157	7,412	25,301	1.5%
Canada	1,695	4,447	7,291	25,267	2.0
France	1,876	3,485	5,186	22,223	1.8
Germany	1,839	3,648	3,881	20,801	1.8
Japan	737	1,387	1,921	22,816	2.5
Sweden	1,359	3,073	6,769	24,409	2.1
United Kingdom	3,190	4,921	6,939	23,742	1.5
United States	2,445	5,301	9,561	31,178	1.9

Note: Figures are in U.S. dollars at 1990 prices, adjusted for differences in the purchasing power of the various national currencies.
Source: Data from Angus Maddison, *Statistics on World Population, GDP, and Per Capita GDP, 1–2008 AD* (February 2010, vertical file, copyright Angus Maddison), available at *www.ggdc.net/maddison.*

http://www.tradingeconomics.com/country-list/gdp-annual-growth-rate

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Explaining the Sources of Growth

- Try to decompose the growth in income into growth in labor, growth in the capital stock, and growth in productivity
- It is a somewhat mechanical exercise, but an interesting descriptive tool
- Assume the following production function: Y = AF(K,N)
- "A" represents the technological level, usually called Total Factor Productivity
- We want to decompose the changes in Y into changes in A, K, and N

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Mathematics

Let y = ln x

By definition $\frac{dy}{dx} = \frac{d \ln x}{dx} = \frac{1}{x}$

or $d \ln x = \frac{dx}{x}$ We look at $\frac{dx}{x}$ as $\frac{\Delta x}{x}$ for small changes in x.

Assuming a Cobb-Douglass production function and taking the natural log of output

$$Y = AK^{a}N^{1-a} \Leftrightarrow \ln Y = \ln A + \alpha \ln K + \beta \ln N$$

Taking total *derivative*

$$d \ln Y = d \ln A + \alpha \; d \ln K + \beta \; d \ln N$$

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \alpha \frac{\Delta K}{K} + \beta \frac{\Delta N}{N}$$

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- Expression allows one to decompose the changes in Y, and, besides, to estimate the changes in "Total Factor Productivity"
- Decompose into growth rate form: the growth accounting equation

$$\Delta Y/Y = \Delta A/A + a_K\, \Delta K/K + a_N\, \Delta N/N$$

- The a terms are the elasticities of output with respect to the inputs (capital and labor)
- We can estimate shifts in the production function due to greater efficiency in the use of inputs
- We only need data readily available to do that: income, capital, and labor growth rates, and wages and interest rates

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The Sources of Economic Growth

- Interpretation
  - A rise of 10% in A raises output by 10%
  - A rise of 10% in K raises output by a_K times 10%
  - A rise of 10% in N raises output by a_N times 10%
- Both a_K and a_N are less than 1 due to diminishing marginal productivity

Word of caution: "A" actually includes a span of different factors, and also measurement error in other variables. Things that will end up captured in "A" may be related to government policies, technological improvements, corruption, more intense use of existing inputs, etc. Indeed, "A" summarizes everything that we don't know about.

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The Sources of Economic Growth

- Growth accounting
  - Four steps in breaking output growth into its causes (productivity growth, capital input growth, labor input growth)
    - Get data on $\Delta Y/Y$, $\Delta K/K$, and $\Delta N/N$, adjusting for quality changes
    - Estimate a_K and a_N from historical data
    - Calculate the contributions of K and N as $a_K\, \Delta K/K$ and $a_N\, \Delta N/N$, respectively
    - Calculate productivity growth as the residual: $\Delta A/A = \Delta Y/Y - a_K\, \Delta K/K - a_N\, \Delta N/N$

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Table 6.2 The Steps of Growth Accounting: A Numerical Example

Step 1. Obtain measures of output growth, capital growth, and labor growth over the period to be studied.

Example:

$$\text{output growth} = \frac{\Delta Y}{Y} = 40\%;$$

$$\text{capital growth} = \frac{\Delta K}{K} = 20\%;$$

$$\text{labor growth} = \frac{\Delta N}{N} = 30\%.$$

Step 2. Using historical data, obtain estimates of the elasticities of output with respect to capital and labor, a_K and a_N.

Example: $a_K = 0.3$ and $a_N = 0.7$.

Step 3. Find the contributions to growth of capital and labor.

Example:

$$\text{contribution to output growth of growth in capital} = a_K \frac{\Delta K}{K} = 0.3 \times 20\% = 6\%;$$

$$\text{contribution to output growth of growth in labor} = a_N \frac{\Delta N}{N} = 0.7 \times 30\% = 21\%.$$

Step 4. Find productivity growth as the residual (the part of output growth not explained by capital or labor).

Example:

$$\text{productivity growth} = \frac{\Delta A}{A} = \frac{\Delta Y}{Y} - a_K \frac{\Delta K}{K} - a_N \frac{\Delta N}{N}$$

$$= 40\% - 6\% - 21\% = 13\%.$$

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Table 6.3 Sources of Economic Growth in the United States (Denison) (Percent per Year)

- Growth accounting and the productivity slowdown
  - Denison's results for 1929–1982 (Table 6.3)
    - Entire period output growth 2.92%; due to labor 1.34%; due to capital 0.56%; due to productivity 1.02%
    - Pre-1948 capital growth was much slower than post-1948
    - Post-1973 labor growth slightly slower than pre-1973

	(1) 1929–1948	(2) 1948–1973	(3) 1973–1982	(4) 1929–1982	(5) 1982–2011
Source of Growth					
Labor growth	1.42	1.40	1.13	1.34	0.99
Capital growth	0.11	0.77	0.69	0.56	1.18
Total input growth	1.53	2.17	1.82	1.90	2.17
Productivity growth	1.01	1.53	–0.27	1.02	1.06
Total output growth	**2.54**	**3.70**	**1.55**	**2.92**	**3.23**

Sources: Columns (1)–(4) from Edward F. Denison, *Trends in American Economic Growth, 1929–1982*, Washington, D.C.: The Brookings Institution, 1985, Table 8.1, p. 111. Column (5) from Bureau of Labor Statistics Web site, Multifactor Productivity Trends, Table XG, available at *ftp://ftp.bls.gov/pub/special.requests/opt/mp/prod3.mfptablehis.zip*

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The Sources of Economic Growth

- Application: the post-1973 slowdown in productivity growth
  - What caused the decline in productivity?
    - Measurement—inadequate accounting for quality improvements
    - The legal and human environment—regulations for pollution control and worker safety, crime, and declines in educational quality
    - Oil prices—huge increase in oil prices reduced productivity of capital and labor, especially in basic industries
    - New industrial revolution—learning process for information technology from 1973 to 1990 meant slower growth

https://www.conference-board.org/data/economydatabase/

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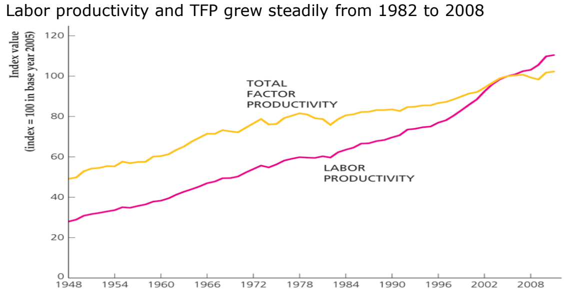
Figure 6.1 Productivity Levels, 1948-2011

- Labor productivity growth increased sharply in the second half of the 1990s
- Labor productivity and TFP grew steadily from 1982 to 2008



Sources: Labor productivity: Bureau of Labor Statistics, Nonfarm Business Sector: Output Per Hour of All Persons, available at *research.stlouisfed.org/fred2/series/OPHNFB. Total factor* productivity: Bureau of Labor Statistics, Multifactor Productivity Trends, Table XG, available at *ftp://ftp.bls.gov/pub/special.requests/opt/mp/prod3.mfptablehis.zip*

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Figure 6.2 Productivity Growth, 1949-2011

Sources: Labor productivity: Bureau of Labor Statistics, Nonfarm Business Sector: Output Per Hour of All Persons, available at *research. stlouisfed.org/fred2/series/ OPHNFB. Total factor* productivity: Bureau of Labor Statistics, Multifactor Productivity Trends, Table XG, available at *ftp://ftp.bls.gov/pub/special.requests/opt/mp/prod3.mfptablehis.zip*

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Productivity

- Labor productivity growth exceeds TFP growth because of faster growth of capital relative to growth of labor
- ICT growth (information and communications technology) may have been a prime reason
- Why did ICT growth contribute to U.S. productivity growth, but not in other countries?
  - Government regulations
  - Lack of competitive pressure
  - Available labor force
  - Ability to adapt quickly

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Productivity

- Why was there such a lag between investment in ICT and growth in productivity?
  - Intangible capital
    - R&D
    - Firm reorganization
    - Worker training
- Similar growth in productivity experienced in past
  - Steam power, railroads, telegraph in late 1800s
  - Electrification of factories after WWI
  - Transistor after WWII
- What matters most is ability of economy to adapt to new technologies

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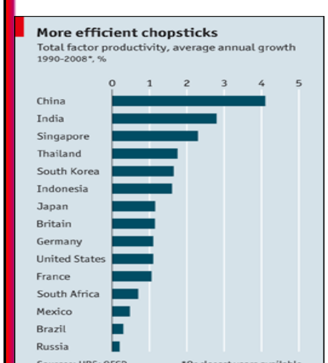
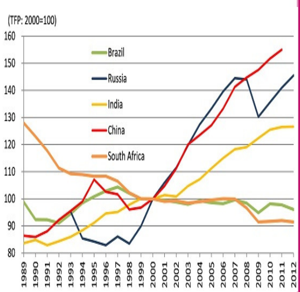
Total Factor Productivity





http://www.bruegel.org/nc/blog/detail/article/1218-decoded-brics/

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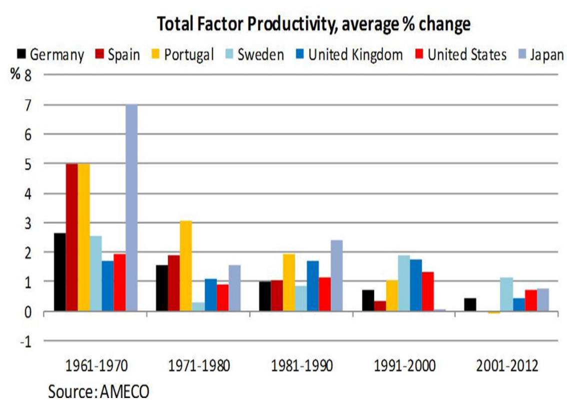

http://www.macrometria.pt/2013/03/05/total-factor-productivity/

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Long-Run Growth: The Solow Model

- Two basic questions about growth
  - What's the relationship between the long-run standard of living and the saving rate, population growth rate, and rate of technical progress?
  - How does economic growth change over time? Will it speed up, slow down, or stabilize?

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The Solow Model

- Setup of the Solow model
- Basic assumptions and variables
  - Population and work force grow at same rate n
  - Economy is closed and $G = 0$

    $C_t = Y_t - I_t$
  - Rewrite everything in per-worker terms:

    $y_t = Y_t/N_t$; $c_t = C_t/N_t$; $k_t = K_t/N_t$
  - k_t is also called the capital-labor ratio
- The per-worker production function $y_t = f(k_t)$
- Assume no productivity growth for now (add it later)

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Proof: The per-worker production function $y_t = f(k_t)$

We assume Cobb-Douglass production function with constant returns to scale

$$\text{Let} \quad Y = K^{\alpha} N^{1-\alpha}$$

$$y = \frac{Y}{N} = \frac{K^{\alpha} N^{1-\alpha}}{N} = K^{\alpha} N^{-\alpha}$$

$$y = \frac{K^{\alpha}}{N^{\alpha}} = \left(\frac{K}{N}\right)^{\alpha} = k^{\alpha}$$

$$y = f(k)$$

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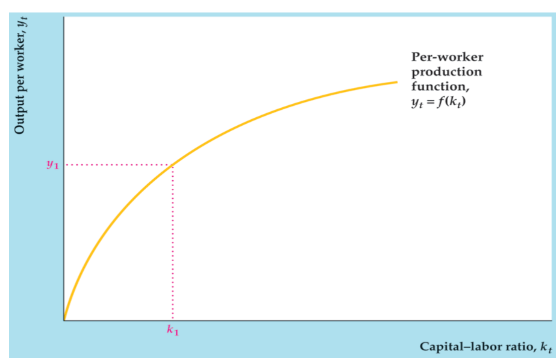
Figure 6.3 The per-worker production function



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The Solow Model

- Steady states
  - Steady state: y_t, c_t, and k_t are constant over time
  - Gross investment must
    - Replace worn out capital, dK_t *d = rate of depreciation*
    - Expand so the capital stock grows as the economy grows, nK_t

    $I_t = (n + d)K_t$ *n = growth rates of economy*
- From before, since $Y_t = C_t + I_t = C_t + (n + d)K_t$

  $C_t = Y_t - I_t = Y_t - (n + d)K_t$

  In per-worker terms, in steady state

  $c = f(k) - (n + d)k$
- Plot of c, $f(k)$, and $(n + d)k$

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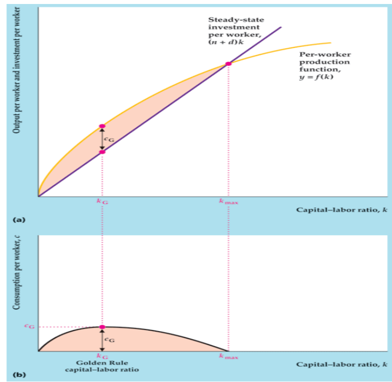
Figure 6.4 The relationship of consumption per worker to the capital–labor ratio in the steady state



- **Increasing k will increase c up to a point**
  - **This is k_G in the figure, the Golden Rule capital-labor ratio**
  - **For k beyond this point, c will decline**
  - **But we assume henceforth that k is less than k_G, so c always rises as k rises**

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The Solow Model

- Reaching the steady state
  - Suppose saving is proportional to current income:

    $S_t = sY_t$,

  where s is the saving rate, which is between 0 and 1
- Equating saving to investment gives

  $sY_t = (n + d)K_t$
- Putting this in per-worker terms gives

  $sf(k) = (n + d)k$

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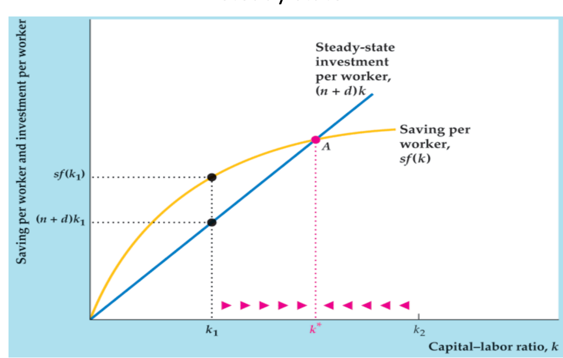
Figure 6.5 Determining the capital–labor ratio in the steady state



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The Solow Model

- The only possible steady-state capital-labor ratio is k^*
- Output at that point is $y^* = f(k^*)$; consumption is
  $c^* = f(k^*) - (n + d)k^*$
- If k begins at some level other than k^*, it will move toward k^*
  - For k below k^*, saving > the amount of investment needed to keep k constant, so k rises
  - For k above k^*, saving < the amount of investment needed to keep k constant, so k falls

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The Solow Model

- To summarize:
  With no productivity growth, the economy reaches a steady state, with constant capital-labor ratio, output per worker, and consumption per worker
- The fundamental determinants of long-run living standards
- **The saving rate**
  - Higher saving rate means higher capital-labor ratio, higher output per worker, and higher consumption per worker
  - Should a policy goal be to raise the saving rate?
    - Not necessarily, since the cost is lower consumption in the short run
    - There is a trade-off between present and future consumption

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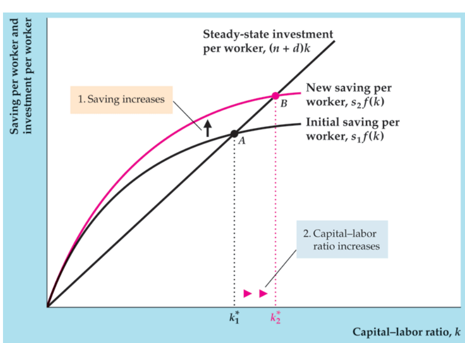
Figure 6.6 The effect of an increased saving rate on the steady-state capital–labor ratio



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The Solow Model

Population growth

- Should a policy goal be to reduce population growth?
  - Doing so will raise consumption per worker
  - But it will reduce total output and consumption, affecting a nation's ability to defend itself or influence world events
- The Solow model also assumes that the proportion of the population of working age is fixed
  - But when population growth changes dramatically this may not be true
  - Changes in cohort sizes may cause problems for social security systems and areas like health care
  - Higher population growth means a lower capital-labor ratio, lower output per worker, and lower consumption per worker

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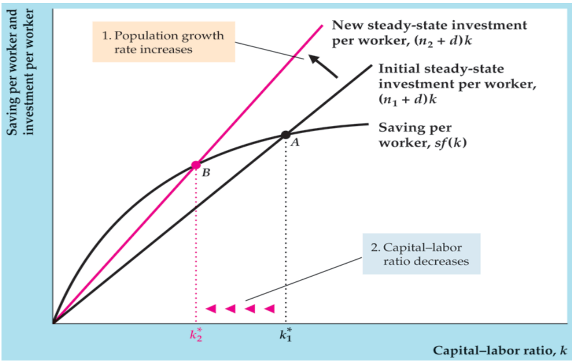
Figure 6.7 The effect of a higher population growth rate on the steady-state capital–labor ratio



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The Solow Model

Productivity growth

- The key factor in economic growth is productivity improvement
- Productivity improvement raises output per worker for a given level of the capital-labor ratio
- In equilibrium, productivity improvement increases the capital-labor ratio, output per worker, and consumption per worker
  - Productivity improvement directly improves the amount that can be produced at any capital-labor ratio
  - The increase in output per worker increases the supply of saving, causing the long-run capital-labor ratio to rise

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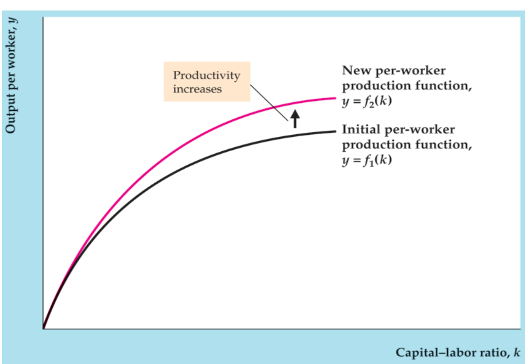
Figure 6.8 An improvement in productivity



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The Solow Model

Productivity growth

- Can consumption per worker grow indefinitely?
  - The saving rate can't rise forever (it peaks at 100%) and the population growth rate can't fall forever
  - But productivity and innovation can always occur, so living standards can rise continuously
- Summary: The rate of productivity improvement is the dominant factor determining how quickly living standards rise

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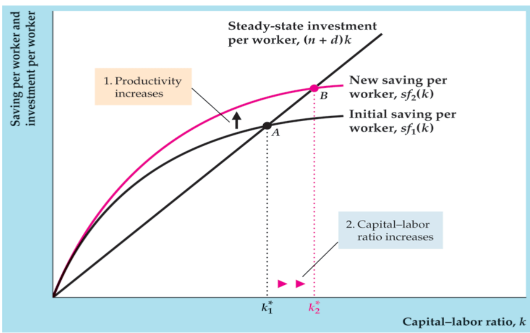
Chapter 6 Lecture - Long-Run Economic Growth

Figure 6.9 The effect of a productivity improvement on the steady-state capital–labor ratio



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Summary

The Fundamental Determinants of Long-Run Living Standards

An increase in	Causes long-run output, consumption, and capital per worker to	Reason
The saving rate, s	Rise	Higher saving allows for more investment and a larger capital stock.
The rate of population growth, n	Fall	With higher population growth more output must be used to equip new workers with capital, leaving less output available for consumption or to increase capital per worker.
Productivity	Rise	Higher productivity directly increases output; by raising incomes, it also raises saving and the capital stock.

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Government Policies to Raise Long-Run Living Standards

Policies to affect the saving rate

- If the private market is efficient, the government shouldn't try to change the saving rate
  - The private market's saving rate represents its trade-off of present for future consumption
  - But if tax laws or myopia cause an inefficiently low level of saving, government policy to raise the saving rate may be justified
- How can saving be increased?
  - One way is to raise the real interest rate to encourage saving; but the response of saving to changes in the real interest rate seems to be small
  - Another way is to increase government saving
    - The government could reduce the deficit or run a surplus
    - But under Ricardian equivalence, tax increases to reduce the deficit won't affect national saving

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Government Policies to Raise Long-Run Living Standards

Policies to raise the rate of productivity growth

- Improving infrastructure
  - Infrastructure: highways, bridges, utilities, dams, airports
  - Empirical studies suggest a link between infrastructure and productivity
- U.S. infrastructure spending has declined in the last two decades

- Improving infrastructure
  - Would increased infrastructure spending increase productivity?
    - There might be reverse causation: Richer countries with higher productivity spend more on infrastructure, rather than vice versa
    - Infrastructure investments by government may be inefficient, since politics, not economic efficiency, is often the main determinant

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Government Policies to Raise Long-Run Living Standards

Policies to raise the rate of productivity growth

- Building human capital
  - There's a strong connection between productivity and human capital
  - Government can encourage human capital formation through educational policies, worker training and relocation programs, and health programs
  - Another form of human capital is entrepreneurial skill
  - Government could help by removing barriers like red tape
- Encouraging research and development
  - Support scientific research
  - Fund government research facilities
  - Provide grants to researchers
  - Contract for particular projects
  - Give tax incentives
  - Provide support for science education

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Application: The growth of China

- China is an economic juggernaut
- Population 1.4 billion people
- Real GDP per capita is low but growing
- Starting with low level of GDP, but growing rapidly

Levels of real GDP per capita

Country	1870	1913	1950	2008	Annual growth rate 1870–2008
China	530	552	448	6,725	1.9%
Japan	737	1,387	1,921	22,816	2.5
United States	2,445	5,301	9,561	31,178	1.9

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Source: Data from Angus Maddison, *Statistics on World Population, GDP, and Per Capita GDP, 1–2008 AD* (February 2010, vertical file, copyright Angus Maddison), available at *www.ggdc.net/maddison*.

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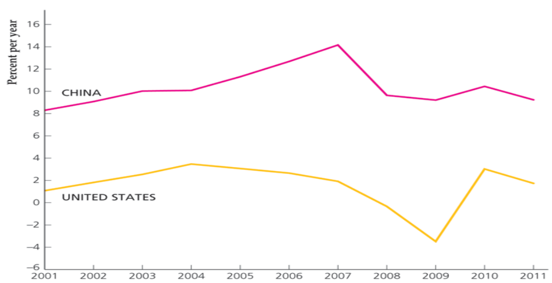
Figure 6.10 Real GDP growth in China and the United States, 2001-2011



Source: International Monetary Fund, World Economic Outlook, available at *http://www.imf.org/external/pubs/ft/weo/2012/01/weodata/index.aspx.*

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China

- Fast output growth attributable to
  - Huge increase in capital investment
  - Fast productivity growth (in part from changing to a market economy)
  - Increased trade
- Will China be able to keep growing rapidly?
  - Rapid growth because of
    - use of underemployed resources
    - using advanced technology developed elsewhere
    - making transition from centrally-planned economy to market economy
  - Such gains may not last
  - So, it may take China a long time to catch up with the rest of the developed world

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