Chapter 6
Long-Run Economic Growth
Chapter Outline

• The Sources of Economic Growth
• Growth Dynamics: The Solow Model
• Government Policies to Raise Long-Run Living Standards
Long-Run Economic Growth

- Introduction
  - Countries have grown at very different rates over long spans of time (Table 6.1)
  - We would like to explain why this happens
Table 6.1 Economic Growth in Eight Major Countries, 1870–2005

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>3,645</td>
<td>5,715</td>
<td>7,493</td>
<td>23,868</td>
<td>1.4%</td>
</tr>
<tr>
<td>Canada</td>
<td>1,695</td>
<td>4,447</td>
<td>7,437</td>
<td>24,200</td>
<td>2.0</td>
</tr>
<tr>
<td>France</td>
<td>1,876</td>
<td>3,485</td>
<td>5,270</td>
<td>21,662</td>
<td>1.8</td>
</tr>
<tr>
<td>Germany</td>
<td>1,821</td>
<td>3,648</td>
<td>3,881</td>
<td>19,325</td>
<td>1.8</td>
</tr>
<tr>
<td>Japan</td>
<td>737</td>
<td>1,385</td>
<td>1,926</td>
<td>21,610</td>
<td>2.5</td>
</tr>
<tr>
<td>Sweden</td>
<td>1,664</td>
<td>3,096</td>
<td>6,738</td>
<td>22,310</td>
<td>1.9</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3,191</td>
<td>4,921</td>
<td>6,907</td>
<td>21,931</td>
<td>1.4</td>
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<tr>
<td>United States</td>
<td>2,445</td>
<td>5,301</td>
<td>9,561</td>
<td>31,242</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Note: Figures are in U.S. dollars at 1990 prices, adjusted for differences in the purchasing power of the various national currencies.

The Sources of Economic Growth

• Production function

\[ Y = AF(K, N) \]  \hspace{1cm} (6.1)

• Decompose into growth rate form: the growth accounting equation

\[ \frac{\Delta Y}{Y} = \frac{\Delta A}{A} + a_K \frac{\Delta K}{K} + a_N \frac{\Delta N}{N} \]  \hspace{1cm} (6.2)

• The \( a \) terms are the elasticities of output with respect to the inputs (capital and labor)
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
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 $a_K \frac{\Delta K}{K}$ and $a_N \frac{\Delta N}{N}$, respectively
    • Calculate productivity growth as the residual: $\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - a_K \frac{\Delta K}{K} - a_N \frac{\Delta N}{N}$
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:
- output growth \( \frac{\Delta Y}{Y} = 40\% \);
- capital growth \( \frac{\Delta K}{K} = 20\% \);
- 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:
- contribution to output growth = \( a_k \frac{\Delta K}{K} = 0.3 \times 20\% = 6\% \);
- contribution to output growth = \( a_N \frac{\Delta N}{N} = 0.7 \times 30\% = 21\% \).

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

Example:
- productivity growth = \( \frac{\Delta A}{A} = \frac{\Delta Y}{Y} - a_k \frac{\Delta K}{K} - a_N \frac{\Delta N}{N} \)
  = \( 40\% - 6\% - 21\% = 13\% \).
The Sources of Economic Growth

• Growth accounting and the productivity slowdown
  – Denison’s results for 1929–1982 (text 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
Table 6.3 Sources of Economic Growth in the United States (Denison) (Percent per Year)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Labor growth</td>
<td>1.42</td>
<td>1.40</td>
<td>1.13</td>
<td>1.34</td>
<td>0.96</td>
</tr>
<tr>
<td>Capital growth</td>
<td>0.11</td>
<td>0.77</td>
<td>0.69</td>
<td>0.56</td>
<td>0.80</td>
</tr>
<tr>
<td>Total input growth</td>
<td>1.53</td>
<td>2.17</td>
<td>1.82</td>
<td>1.90</td>
<td>1.76</td>
</tr>
<tr>
<td>Productivity growth</td>
<td>1.01</td>
<td>1.53</td>
<td>-0.27</td>
<td>1.02</td>
<td>0.99</td>
</tr>
<tr>
<td>Total output growth</td>
<td>2.54</td>
<td>3.70</td>
<td>1.55</td>
<td>2.92</td>
<td>2.75</td>
</tr>
</tbody>
</table>

The Sources of Economic Growth

- Productivity growth is major difference
  - Entire period: 1.02%
  - 1929–1948: 1.01%
  - 1948–1973: 1.53%
  - 1973–1982: −0.27%

- Productivity growth slowdown occurred in all major developed countries
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
The Sources of Economic Growth

• Application: the recent surge in U.S. productivity growth
  – Labor productivity growth increased sharply in the second half of the 1990s
  – Labor productivity and TFP have grown steadily over the past 20 years, with only labor productivity showing evidence of a pickup in the late 1990s (Fig. 6.1)
Figure 6.1 Productivity Levels, 1947-2005
Productivity

• Graph suggests that labor productivity growth increased, but not total factor productivity
• Look at growth rates in Fig. 6.2
Figure 6.2 Productivity Growth, 1948-2005
Productivity

• Note the widening gap between labor productivity growth and TFP growth since 1995
Productivity

• How can we relate this graph to our model?
• Use equations to relate the differing productivity concepts:

\[
\frac{\Delta Y}{Y} - \frac{\Delta N}{N} = \frac{\Delta A}{A} + a_K \left( \frac{\Delta K}{K} - \frac{\Delta N}{N} \right)
\]
Productivity

\[
\frac{\Delta Y}{Y} - \frac{\Delta N}{N} = \frac{\Delta A}{A} + a_K \left( \frac{\Delta K}{K} - \frac{\Delta N}{N} \right)
\]

Labor Productivity  TFP  Growth rate of K/N
Productivity

- So, 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
Productivity

• 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
Productivity

• Why was there such a lag between investment in ICT and growth in productivity?
• Intangible capital
  – R&D
  – Firm reorganization
  – Worker training
Productivity

• 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
Growth Dynamics: The Solow Model

• Three 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?
  – Are there economic forces that will allow poorer countries to catch up to richer countries?
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 $G = 0$
    $$C_t = Y_t - I_t$$ (6.4)
  – 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 Solow Model

• The per-worker production function
  \[ y_t = f(k_t) \]  \hspace{1cm} (6.5)

• Assume no productivity growth for now (add it later)

• Plot of per-worker production function (Fig. 6.3)

• Same shape as aggregate production function
Figure 6.3 The per-worker production function

Per-worker production function, \( y_t = f(k_t) \)

Output per worker, \( y_t \)

Capital–labor ratio, \( k_t \)
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, \( dK_t \)
    • Expand so the capital stock grows as the economy grows, \( nK_t \)

\[
I_t = (n + d)K_t \quad (6.6)
\]
The Solow Model

• From Eq. (6.4),
  \[ C_t = Y_t - I_t = Y_t - (n + d)K_t \]  \hspace{1cm} (6.7)

• In per-worker terms, in steady state
  \[ c = f(k) - (n + d)k \]  \hspace{1cm} (6.8)

• Plot of \( c \), \( f(k) \), and \( (n + d)k \) (Fig. 6.4)
Figure 6.4 The relationship of consumption per worker to the capital–labor ratio in the steady state.
The Solow Model

- 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
The Solow Model

- Reaching the steady state
  - Suppose saving is proportional to current income:
    \[ S_t = sY_t, \quad (6.9) \]
    where \( s \) is the saving rate, which is between 0 and 1

- Equating saving to investment gives
  \[ sY_t = (n + d)K_t \quad (6.10) \]
The Solow Model

- Putting this in per-worker terms gives

\[ sf(k) = (n + d)k \]  \hspace{1cm} (6.11)

- Plot of \( sf(k) \) and \( (n + d)k \) (Fig. 6.5)
Figure 6.5 Determining the capital–labor ratio in the steady state
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
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 Solow Model

- The fundamental determinants of long-run living standards
  - The saving rate
  - Population growth
  - Productivity growth
The Solow Model

• 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 (Fig. 6.6)
Figure 6.6 The effect of an increased saving rate on the steady-state capital–labor ratio
The Solow Model

- The fundamental determinants of long-run living standards
- The saving rate
  - 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
The Solow Model

• The fundamental determinants of long-run living standards
  – Population growth
    • Higher population growth means a lower capital-labor ratio, lower output per worker, and lower consumption per worker (Fig. 6.7)
Figure 6.7 The effect of a higher population growth rate on the steady-state capital–labor ratio
The Solow Model

• The fundamental determinants of long-run living standards
  – 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

- The fundamental determinants of long-run living standards
  - Population growth
    - 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
The Solow Model

• The fundamental determinants of long-run living standards
  – 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 (Fig. 6.8)
Figure 6.8 An improvement in productivity

Output per worker, $y$

New per-worker production function, $y = f_2(k)$

Productivity increases

Initial per-worker production function, $y = f_1(k)$

Capital–labor ratio, $k$
The Solow Model

- The fundamental determinants of long-run living standards
  - Productivity growth
    - 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 (Fig. 6.9)
Figure 6.9 The effect of a productivity improvement on the steady-state capital–labor ratio

1. Productivity increases

2. Capital–labor ratio increases
The Solow Model

• The fundamental determinants of long-run living standards
  – 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
## The Fundamental Determinants of Long-Run Living Standards

<table>
<thead>
<tr>
<th>An increase in</th>
<th>Causes long-run output, consumption, and capital per worker to</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>The saving rate, $s$</td>
<td>Rise</td>
<td>Higher saving allows for more investment and a larger capital stock.</td>
</tr>
<tr>
<td>The rate of population growth, $n$</td>
<td>Fall</td>
<td>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.</td>
</tr>
<tr>
<td>Productivity</td>
<td>Rise</td>
<td>Higher productivity directly increases output; by raising incomes, it also raises saving and the capital stock.</td>
</tr>
</tbody>
</table>
Application: The growth of China

• China is an economic juggernaut
• Population 1.3 billion people
• Starting with low level of GDP, but growing rapidly
  – About 1/9 of US GDP per capita in 1998
  – Growth in recent years is very rapid (Fig. 6.10)
Table 6.4 Economic Growth in China, the United States, and Japan

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</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>530</td>
<td>552</td>
<td>439</td>
<td>3,117</td>
<td>1.4%</td>
</tr>
<tr>
<td>Japan</td>
<td>737</td>
<td>1,385</td>
<td>1,926</td>
<td>20,084</td>
<td>2.6</td>
</tr>
<tr>
<td>United States</td>
<td>2,445</td>
<td>5,301</td>
<td>9,561</td>
<td>27,331</td>
<td>1.9</td>
</tr>
</tbody>
</table>

*Note:* Figures are in U.S. dollars at 1990 prices, adjusted for differences in the purchasing power of the various national currencies.

Figure 6.10 Real GDP growth in China and the United States, 1997-2005
China

- Fast output growth attributable to
  - Huge increase in capital investment
  - Fast productivity growth (in part from changing to a market economy)
  - Increased trade
China

• Investment
  – Investment is huge in China; at the cost of current consumption, so saving is high
China

• Inflation
  – Despite rapid growth, inflation has been low in recent years; even below U.S. in most years
China

• Inflation
  – Surge in inflation in 2004 worried many, who thought China would have to change value of currency significantly
  – But inflation fell in 2005
  – Big contrast with 1985-1995, when inflation averaged over 10% per year
China

• Large government debt
  – China’s government still owns huge firms (about 25% of all employment in nation)
  – Government deficit is quite large
  – But deficit is declining in recent years
China

- Increased trade
  - China’s exports were <10% of GDP in 1980s; now more than 30%
  - China exports many manufactured goods; imports agricultural products & raw materials
  - China runs a small trade surplus
China

- Labor
  - China has a huge labor force; comparative advantage in labor-intensive industries (and wages are low)
  - As China grows, wages and standard of living will rise
China

- Problems China faces
  - Weak banking system
  - Increasing income inequality
  - Much unemployment in rural areas
Endogenous Growth Theory

- Endogenous growth theory—explaining the sources of productivity growth
  - Aggregate production function
    \[ Y = AK \]  \hspace{1cm} (6.12)
Endogenous Growth Theory

• Constant $MPK$
  – Human capital
    • Knowledge, skills, and training of individuals
    • Human capital tends to increase in the same proportion as physical capital
  – Research and development programs
  – Increases in capital and output generate increased technical knowledge, which offsets decline in $MPK$ from having more capital
Endogenous Growth Theory

• Implications of endogenous growth
  – Suppose saving is a constant fraction of output: \( S = sAK \)
  – Since investment = net investment + depreciation, \( I = \Delta K + dK \)
  – Setting investment equal to saving implies:
    \[
    \Delta K + dK = sAK \quad (6.13)
    \]
Endogenous Growth Theory

• Implications of endogenous growth
• Rearrange (6.13):
  \[ \frac{\Delta K}{K} = sA - d \]  
  (6.14)
  – Since output is proportional to capital, \( \frac{\Delta Y}{Y} = \frac{\Delta K}{K} \), so
  \[ \frac{\Delta Y}{Y} = sA - d \]  
  (6.15)
  – Thus the saving rate affects the long-run growth rate (not true in Solow model)
Endogenous Growth Theory

• Summary
  – Endogenous growth theory attempts to explain, rather than assume, the economy’s growth rate
  – The growth rate depends on many things, such as the saving rate, that can be affected by government policies
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
Government Policies to Raise Long-Run Living Standards

• Policies to affect the saving rate
  – 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
Government Policies to Raise Long-Run Living Standards

• Policies to affect the saving rate
  – How can saving be increased?
    • 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
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
Government Policies to Raise Long-Run Living Standards

• Policies to raise the rate of productivity growth
  – 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
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
Government Policies to Raise Long-Run Living Standards

• Policies to raise the rate of productivity growth
  – Encouraging research and development
    • Government can encourage R and D through direct aid to research