ECONOMIC GROWTH

- Understand what causes differences in income over time and across countries
- Sources of economy’s output: factors of production (K, L) and production technology

→ differences in income must come from differences in K, L, and technology
- The Solow-Swan model shows how saving, population growth, and technological progress affect the level of an economy’s output and its growth over time

1. THE ACCUMULATION OF CAPITAL

- How the supply and demand for goods and services determine the accumulation of capital

(1) The Supply of Goods and the Production Function

- Aggregate production function: \( Y = F(K, L) \)

1) Constant Returns to Scale
   → allow us to analyze all quantities relative to the size of the labor force
   → \( y = f(k) \)
      where \( y = Y/L \): output per worker
      \( k = K/L \): capital per worker
      \( f(k) = F(K/L, 1) \): capital per worker

2) Positive Marginal Product
   → \( MPK = f(k+1) - f(k) > 0 \)
3) Diminishing Marginal Product

when k is low → the average worker has only a little capital to work with, so an extra unit of capital is very useful and produces a lot of additional output

when k is high → the average worker has a lot of capital to work with, so an extra unit of capital increases production only slightly

(2) The Demand for Goods and the Consumption Function

- Demand (No gov’t, closed economy): \( y = c + i \)
- Consumption per person: \( c = (1-s)y \), \( s = \) saving rate

\[ i = sy = sf(k) \quad [\text{figure 7-2, p.184}] \]

- \( s \) is also the fraction of output devoted to investment
- Allocation of output between consumption and saving is determined by saving rate \( s \)

(3) Growth in the Capital Stock and the Steady State

- Capital stock is a key determinant of the economy’s output
- Change in capital stock → economic growth
  1) Investment: expenditure on new plant and equipment
  2) Depreciation: wearing out of old capital

\[ \Delta k = i - \delta k = sf(k) - \delta k \]

- Steady-state level of capital \((k^*)\): [figure 7-4, p.186]
  \[ \Delta k = 0 \text{ at } k^* \]
  \[ “\text{Long-run equilibrium of the economy”} \]
- Stability of a steady-state $k^*$
  Investment $>\text{depreciation} \rightarrow k \uparrow$
  Investment $<\text{depreciation} \rightarrow k \downarrow$

  Once the capital stock reaches the steady state, investment equals depreciation, and there is no pressure for the capital stock to change

- A numerical example
  \[ Y = K^{1/2}L^{1/2}, \quad s = 0.3, \quad \delta = 0.1 \rightarrow k^* = ? \]

(4) How Saving Affects Growth

- Different saving rates $\rightarrow$ international differences in output?
- An increase in saving rate
  \[ s \uparrow \rightarrow \text{Investment} > \text{depreciation} \rightarrow k \uparrow \text{until the} \]
  economy reaches the new steady-state $k^*$

- Saving rate is a key determinant of the steady-state capital stock
  $\rightarrow$ If $s$ is high (low), the economy will have a large (small) capital stock and a high (low) level of output

- Persistent gov’t budget deficits reduce national saving and crowd out investment $\rightarrow$ lower capital stock $\rightarrow$ lower national income

- Problem: “temporary” effect on growth rate
  $\rightarrow$ high rate $s$ of saving lead to high growth temporarily, but the economy eventually approaches a steady state in which capital and output are constant
  $\rightarrow$ \textit{CANNOT} explain sustained economic growth
2. The Golden Rule Level of Capital

- Is higher saving always good?
- Optimal amount of capital accumulation from the standpoint of economic well-being

1) Comparing Steady State

- Assume that a benevolent policy maker can set the economy’s saving rate at any level, thus steady-state $k^*$
- Choose $k^*$ with the highest level of consumption
  \[ \text{"Golden Rule Level of Capital" (}k^g\text{)} \]
- Since $c = y - i$, steady-state consumption is
  \[ c^* = f(k^*) - \delta k^* \]
- An increase in $k^*$ has two opposing effects
  - More output
  - Replacement of capital that is wearing out
- If $k < k^g$, $k \uparrow$ will raise output more than depreciation, so that consumption rise \( \rightarrow \) the production function is steeper than the $\delta k^*$ line
- Therefore, at the Golden Rule level of capital, the production function and the $\delta k^*$ line have the same slope, and consumption is at its greatest level
  \[ MPK = \delta \]

2) Transition to the Golden Rule Steady State

- Starting with too much capital
- Starting with too little capital
3. Population Growth

- Another possibility of the sustained growth?
- The rate of population growth = $n$ (US:1%)

(1) The Steady State with Population Growth

- The growth in the number of workers causes capital per worker to fall
  \[ \Delta k = i - (\delta + n)k = sf(k) - (\delta + n)k \]
- \((\delta + n)k = \text{break-even investment: the amount of investment necessary to keep the capital stock per worker constant}\)
  
  Note that $nk$ is the amount of investment necessary to provide new workers with capital
- Steady-state level of capital ($k^*$): [Figure 7-11, p.201]
  \[ \Delta k = 0 \text{ at } k^* \]
- Stability of a steady-state $k^*$
  Investment $> \text{break-even investment} \rightarrow k \uparrow$
  Investment $< \text{break-even investment} \rightarrow k \downarrow$

(2) The Effect of Population Growth

- In the steady state, $k$ and $y$ are constant
  \[ \rightarrow \text{CANNOT explain sustained economic growth} \]
- However, $K$ and $Y$ must also growing at rate $n$
  \[ \rightarrow \text{CAN explain sustained growth in total output} \]
- An increase in population growth  [Figure 7-12, p.202]
  \[ \rightarrow \text{Countries with higher population growth will have lower levels of GDP per person} \]
- Golden Rule (consumption-maximizing) level of capital
  \[ \rightarrow MPK - \delta = n \]
4. Technological Progress in the Solow-Swan Model

- Introduce exogenous technological progress, which over time expands society’s ability to produce

(1) The Efficiency of Labor

- Labor-augmenting aggregate production function:
  \[ Y = F(K, E*L) \]
- \( E \) is the efficiency of labor or a society’s knowledge about production method and grows at some constant rate \( g \)
- \( E*L \) is the number of effective workers and grows at rate \( n+g \)

(2) The Steady State with Technological Progress

- Let \( k = K/(E*L) \) be capital per effective worker and \( y = f(k) = Y/(E*L) \) be output per effective worker
- The evolution of \( k \) over time
  \[ \Delta k = i - (\delta + n + g )k = sf'(k) - (\delta + n + g )k \]
- Break-even investment
  1) \( \delta k \) : replace depreciating capital
  2) \( nk \) : provide capital for new workers
  3) \( gk \) : provide capital for new effective workers created by technological progress
- Steady-state level of capital \( (k^*) \): [figure 8-1, p.209]
  \[ \Delta k = 0 \text{ at } k^* \]
(3) The Effect of Technological Progress

- In the steady state, \( K/(EL) \) and \( Y/(EL) \) are constant
- However, \( Y/L \) grows at rate \( g \) and \( Y \) grows at rate \( g+n \)
  \( \rightarrow CAN \) explain sustained growth in total output!
- Golden Rule (consumption-maximizing) level of capital
  \( \rightarrow MPK - \delta = n + g \)

5. POLICIES TO PROMOTE GROWTH

(1) Evaluating the Rate of Saving
- Is US economy at, above, or below the Golden rule steady state?
- Facts
  Rate of real GDP growth=3% \((n+g)\)
  Capital stock=2.5*GDP
  Depreciation =10% of GDP
  Capital income =30% of GDP
  \( \rightarrow MPK - \delta = 8% > n + g = 3% \)
- Capital stock in the US economy is well below the Golden rule level
- Changing the rate of saving

(2) Allocating the Economy’s Investment
- Physical capital or Human capital?
- Human capital: the knowledge and skills that workers acquire through education
- Technological externality (knowledge spillover) \( \rightarrow \) the social returns to capital exceed the private returns, and the benefits of increased capital accumulation to society are greater than the Solow model suggests
(3) Encouraging Technological Progress
- The Solow model takes technological progress as exogenous
  → Determinants of technological progress?

6. FROM GROWTH THEORY TO GROWTH EMPIRICS

(1) Balanced Growth
- Technological progress causes the values of many variables to rise together in the steady state
- The Solow model’s prediction is consistent with LR data for the US economy
  → $Y/L$ and $K/L$ grow at the rate of technological progress

(2) Convergence (Catch-up)
- Economies converge over time?
- Little evidence of (absolute) convergence: countries that start off poor do not grow faster on average than countries that start off rich
- The economies of the world appear to be converging to their own steady states, which in turn are determined by saving, population growth, and education
  → Conditional convergence

(3) Factor Accumulation Versus Production Efficiency
- International differences in income per person can be attributed to
  1) Differences in the factors of production
  2) Differences in the efficiency
1) and 2) are positively correlated: countries with high levels of physical and human capital also tend to use those factors efficiently