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

→ $i = sy = sf(k)$ [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]

→ $\Delta k = 0$ at k^*

→ "Long-run equilibrium of the economy"

- Stability of a steady-state k^*

  Investment > depreciation → k ↑

  Investment < depreciation → k ↓

  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

  $Y = K^{1/2}L^{1/2}$, $s = 0.3$, $\delta = 0.1$ → $k^* = ?$

(4) How Saving Affects Growth

- Different saving rates → international differences in output ?
- An increase in saving rate

  s↑ → Investment > depreciation → k ↑ until the economy reaches the new steady-state k^*
- Saving rate is a key determinant of the steady-state capital stock

  → 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 → lower capital stock → lower national income
- Problem: "*temporary*" effect on growth rate

  → 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

  → ***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
  → ***"Golden Rule Level of Capital"*** (k^g)
- 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 → the production function is steeper than the δk^* line
- Therefore, at the Golden Rule level of capital, the production function and the δk^* 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
  → $\Delta k = i - (\delta + n)k = sf(k) - (\delta + n)k$
- $(\delta + n)k$ = 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]
  → $\Delta k = 0$ at k^*
- Stability of a steady-state k^*
  Investment > break-even investment → $k \uparrow$
  Investment < break-even investment → $k \downarrow$

(2) The Effect of Population Growth

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

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) δk : 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]
  → $\Delta k = 0$ 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*
  → ***CAN*** explain sustained growth in total output!
- Golden Rule (consumption-maximizing) level of capital
  → $MPK - \delta = n + g$

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

→ $MPK - \delta = 8\% > n + g = 3\%$

- 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) → 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