Chapter 3: Economic Growth

Chapter Summary:

The chapter discusses the importance of economic growth for raising living standards over time and provides a basic framework for understanding the sources of economic growth. Statistics are provided which allow for international comparisons of growth rates and GDP; the patterns emerging from the data are discussed. The neoclassical theory of growth is described using the **Solow model**. Beginning with **the production function** that exhibits **diminishing returns** to each input and **constant returns to scale**, the **steady state** level of income, is described, as are the basic components of **growth accounting**. These concepts are essential both for understanding and motivating the more complex material found in the next two chapters.

Outline:

I. The Importance of Economic Growth

II. Facts About Economic Growth
- A. World Economic Growth, 1960-2000
- B. World Poverty and Income Inequality
- C. Long Term Growth in the U.S. and Other Wealthy Countries
- D. Patterns of World Economic Growth

III. Theory of Economic Growth
- A. The Production Function
- B. Growth Accounting
- C. The Solow Growth Model
    1. Growth Rate of the Capital Stock
    2. Growth Rate of Labor
    3. Growth Rate of Capital and Output Per Worker
    4. The Transition and the Steady State

Teaching Tips:

1. -"The Rule of 70" is a rough method of demonstrating how small changes in the economic growth rate lead to large changes in living standards over time. The approximate number of years it takes for income to double is given by the ratio 70/r, where r is the growth rate. Since 70 is a good number to use for an average lifetime, the growth rate is an estimate of the number of times income

will double during a person's lifetime. Ask them to make a hypothetical comparison of a few countries that begin with $5,000 in current GDP per person but grow at rates of 1%, 2%, 3% and 4% annually. After 70 years, the approximate income in each country will be $10,000, $20,000, $40,000, and $80,000. Have them graph the income level against the growth rate to show the nonlinear effects of compounding.

2. As a way of motivating the material, have the students "guess" the purchasing power in the major regions of the world. Then have them check their answers against the data found in the chapter. Did they accurately rank the regions? Did they come close to the actual purchasing power?

3. The material in this chapter introduces some algebraic symbols with which economists are very familiar. However, students will have trouble keeping track of what all these letters stand for. If you can reserve a space on the board with a key to the symbols used (K=capital, Y= Income, etc.) your students will be able to keep up. You may also copy the key provided on page x of this manual, which includes all the symbols used in the text in the order in which they are introduced.

4. After discussing the equations introduced in the text using algebraic symbols, instructors might consider using numerical examples to have the students graph a simple production function. Numerical examples are less abstract and therefore easier for many students to relate to.

5. Much of the excitement and controversy in macroeconomics comes from the way in which the economy is modeled, but students are less likely to be enthusiastic by the intricacies of model building. So the temptation for the instructor is to gloss over the modeling process or simplify it to the extent that it loses its intrinsic interest. This temptation to "dumb down" the presentation must be avoided if the student is to grasp the process of discovery and argument used by practicing economists. At the same time, the possibility of confusion and boredom is very real. That is why the "back to reality" boxes provide in the text are valuable. Each instructor should incorporate a discussion of these examples into their lecture, and seek to develop additional "back to reality" examples as much as possible.

6. Remind students of the law of diminishing returns to capital. Ask them what would happen to their test scores if they had to share their textbook with a friend on the night before an exam. What about sharing with 3, 10, or 20?

Answers to Review questions, pg. 62

1. A production function associates a particular level of output with each possible combination of inputs and technology. Growth of output is proportional to changes in the level of technology, but because of diminishing returns, output grows less than proportionately to changes in each input.

2. Marginal product of capital is the additional output obtained from an additional unit of capital employed. Average Product of Capital is the total output divided by the total amount of capital employed. Since the average product includes the effects of all the previous units of capital employed, it may differ considerably from the marginal product. Although it is theoretically possible for the average product to be less than the average product, that is ruled out in our model by the assumption that diminishing returns to capital sets in immediately- every unit of capital employed contributes less than all that came before it, so the marginal product is always less than the average.

3. In our model we assumed that the labor force was growing ($n>0$). In this case a positive savings rate is necessary, but not sufficient to raise the level of capital per worker. The savings rate must be sufficiently large to replace worn out capital, and add additional capital to keep up with the rate of growth in the labor force, as summarized in equation (3.16) Applying a little algebra to equation (3.16) shows that for $\Delta k/k$ to be positive, $s(y/k)-s\delta-n>0$, or that $s > n/((y/k)-\delta)$ if $(y/k)-\delta)$ is positive. (If $(y/k)-\delta)$ were negative, then capital stock would shrink regardless of the saving rate).

4. A positive saving rate cannot guarantee growth in the long run, due to diminishing returns. The average product of capital would continue to fall and the amount of depreciation would increase as the capital stock grew larger. Eventually, the capital stock would reach a point where all the savings would be needed simply to replace the depreciated capital stock and keep up with the growth in the labor force, nothing left over to increase the capital per worker. At that point the economy will have reached the "steady state."

Answers to Problems for discussion, pg. 63

6. Constant returns to scale implies that for our production function Y=A*F(K,L) has the property that xY=A*F(xK,xL) for any constant x.

Now if we choose x=1/L, then Y/L=A*F(K/L,L/L) = A*F(K/L,1)=A*f(k), where F(K/L,1) defines a new function in the variable K/L=k. We denote the new function F(K/L,1)= f(k), so that A*F(K/L,1)=A*f(k).

7. a. A=the state of technology, K is the capital stock, and L is the labor force.

b. A is a scalar factor, so that when A increases by "x percent", Y will increase by "x percent."

c. A marginal product that is always positive implies that each additional unit of input will increase output by some positive amount.

d. It means that each additional unit of input is associated with a smaller increase in output than the previous unit. $MPK=\alpha(K^{\alpha}L^{1-\alpha})/K$. Since α is less than 1, an increase in the value of K will cause the denominator to increase faster than the numerator in this equation, and the MPK will diminish as K increases.

e. Yes. Constant returns to scale implies that if we multiply each input by a particular factor, output will increase by the same factor. If we multiply the inputs by a factor of x, we get:

$$A(xK)^{\alpha}(xL)^{1-\alpha}$$
$$=Ax^{\alpha}x^{1-\alpha}K^{\alpha}L^{1-\alpha}$$
$$=xAK^{\alpha}L^{1-\alpha}$$
$$=xY$$

8.

Increase in variable:	Effect on k*:
a. Saving rate (s)	increase
b. Technology (A)	increase
c. depreciation rate (δ)	decrease
d. pop. growth rate (n)	decrease

9. a. In the steady state, $sy/k-s\delta-n=0$ and $y/k=Ak^{\alpha}/k = Ak^{\alpha-1}$. Combining these two expressions yields $sAk^{\alpha-1}=s\delta+n$; or $k^{\alpha-1}=(s\delta+n)/sA$. Raising each side by the exponent $1/(\alpha-1)$ yields: $k^*=[(s\delta+n)/sA]^{1/(\alpha-1)}$. Substituting this into the production function yields $y^*=k^{*\alpha}=[(s\delta+n)/sA]^{\alpha/(\alpha-1)}$.

   b. $c^*=(1-s)(y^*-\delta k^*)$ Since savings in the steady state is just sufficient to replace capital, we have $s(y^*-\delta k^*)=nk^*$, so that $c^*= y^*-\delta k^*-nk^*$.

   c. $\Delta k/k= sy/k-s\delta-n= sAk^{\alpha-1}-s\delta-n$ or $sA/k^{1-\alpha}-s\delta-n$. Since k appears in the denominator of the first term, larger values of k imply smaller growth rates. Because of diminishing returns, y must grow more slowly as you near the steady state, first because of diminishing returns to k and also because k grows more slowly.

10. a. Using the results from problem number 9 above, but substituting $\alpha=1$, we get $\Delta k/k= sA-s\delta-n$; k grows at a constant rate. The s(y/k) curve is a horizontal line with vertical intercept at sA.

   b. $\Delta k/k= sA-s\delta-n$; Since $y=Ak$, $\Delta y=A\Delta k$ and $\Delta y/y=A\Delta k/Ak$ or $\Delta k/k$. Output per worker will also grow at a constant rate (equal to the growth rate in capital).

   c. There is no diminishing returns to capital in this case. There are several possible plausible explanations for this assumption; one is that there is "learning by doing", so that as the economy industrializes knowledge multiplies rapidly and augments capital. Perhaps social institutions also develop along with capital (for example, the development of legal corporations and contract law). Even with this broader understanding of the process of capital accumulation, it would seem as though diminishing returns to capital would set in at some point.