

EIGHTH EDITION

MACROECONOMICS

N. GREGORY MANKIW

Harvard University

Worth Publishers

- c. Boeing sells an airplane to Air France.
 - d. Boeing sells an airplane to Amelia Earhart.
 - e. Boeing builds an airplane to be sold next year.
5. Find data on GDP and its components, and compute the percentage of GDP for the following components for 1950, 1980, and the most recent year available.
- a. Personal consumption expenditures
 - b. Gross private domestic investment
 - c. Government purchases
 - d. Net exports
 - e. National defense purchases
 - f. Imports

Do you see any stable relationships in the data? Do you see any trends? (*Hint:* You can find the data at www.bea.gov, which is the Web site of the Bureau of Economic Analysis.)

6. Consider an economy that produces and consumes bread and automobiles. In the following table are data for two different years.

| Good | 2000 | | 2010 | |
|-------------|----------|----------|----------|----------|
| | Quantity | Price | Quantity | Price |
| Automobiles | 100 | \$50,000 | 120 | \$60,000 |
| Bread | 500,000 | \$10 | 400,000 | \$20 |

- a. Using 2000 as the base year, compute the following statistics for each year: nominal GDP, real GDP, the implicit price deflator for GDP, and a fixed-weight price index such as the CPI.
 - b. How much did prices rise between 2000 and 2010? Compare the answers given by the Laspeyres and Paasche price indexes. Explain the difference.
 - c. Suppose you are a senator writing a bill to index Social Security and federal pensions. That is, your bill will adjust these benefits to offset changes in the cost of living. Will you use the GDP deflator or the CPI? Why?
7. Abby consumes only apples. In year 1, red apples cost \$1 each, green apples cost \$2 each, and Abby buys 10 red apples. In year 2, red apples

cost \$2, green apples cost \$1, and Abby buys 10 green apples.

- a. Compute a consumer price index for apples for each year. Assume that year 1 is the base year in which the consumer basket is fixed. How does your index change from year 1 to year 2?
 - b. Compute Abby's nominal spending on apples in each year. How does it change from year 1 to year 2?
 - c. Using year 1 as the base year, compute Abby's real spending on apples in each year. How does it change from year 1 to year 2?
 - d. Defining the implicit price deflator as nominal spending divided by real spending, compute the deflator for each year. How does the deflator change from year 1 to year 2?
 - e. Suppose that Abby is equally happy eating red or green apples. How much has the true cost of living increased for Abby? Compare this answer to your answers to parts (a) and (d). What does this example tell you about Laspeyres and Paasche price indexes?
8. Consider whether each of the following events is likely to increase or decrease real GDP. In each case, do you think economic well-being most likely changes in the same direction as real GDP? Why or why not?
- a. A hurricane in Florida forces Disney World to shut down for a month.
 - b. The discovery of a new, easy-to-grow strain of wheat increases farm harvests.
 - c. Increased hostility between unions and management sparks a rash of strikes.
 - d. Firms throughout the economy experience falling demand, causing them to lay off workers.
 - e. Congress passes new environmental laws that prohibit firms from using production methods that emit large quantities of pollution.
 - f. More high school students drop out of school to take jobs mowing lawns.

KEY CONCEPTS

| | | |
|--|---|--------------------------|
| Factors of production | Marginal product of capital (<i>MPK</i>) | Interest rate |
| Production function | Real rental price of capital | Nominal interest rate |
| Constant returns to scale | Economic profit versus accounting profit | Real interest rate |
| Factor prices | Cobb–Douglas production function | National saving (saving) |
| Competition | Disposable income | Private saving |
| Profit | Consumption function | Public saving |
| Marginal product of labor (<i>MPL</i>) | Marginal propensity to consume (<i>MPC</i>) | Loanable funds |
| Diminishing marginal product | | Crowding out |
| Real wage | | |

QUESTIONS FOR REVIEW

1. What determines the amount of output an economy produces?
2. Explain how a competitive, profit-maximizing firm decides how much of each factor of production to demand.
3. What is the role of constant returns to scale in the distribution of income?
4. Write a Cobb–Douglas production function for which capital earns one-fourth of total income.
5. What determines consumption and investment?
6. Explain the difference between government purchases and transfer payments. Give two examples of each.
7. What makes the demand for the economy's output of goods and services equal the supply?
8. Explain what happens to consumption, investment, and the interest rate when the government increases taxes.

PROBLEMS AND APPLICATIONS

1. Use the neoclassical theory of distribution to predict the impact on the real wage and the real rental price of capital of each of the following events:
 - a. A wave of immigration increases the labor force.
 - b. An earthquake destroys some of the capital stock.
 - c. A technological advance improves the production function.
 - d. High inflation doubles the prices of all factors and outputs in the economy.
2. Suppose the production function in medieval Europe is $Y = K^{0.5}L^{0.5}$, where K is the amount of land and L is the amount of labor. The economy begins with 100 units of land and 100 units of labor. Use a calculator and equations in the chapter to find a numerical answer to each of the following questions.
 - a. How much output does the economy produce?
 - b. What are the wage and the rental price of land?
 - c. What share of output does labor receive?
 - d. If a plague kills half the population, what is the new level of output?
 - e. What is the new wage and rental price of land?
 - f. What share of output does labor receive now?

8. The government raises taxes by \$100 billion. If the marginal propensity to consume is 0.6, what happens to the following? Do they rise or fall? By what amounts?
- Public saving
 - Private saving
 - National saving
 - Investment
9. Suppose that an increase in consumer confidence raises consumers' expectations about their future income and thus increases the amount they want to consume today. This might be interpreted as an upward shift in the consumption function. How does this shift affect investment and the interest rate?
10. Consider an economy described by the following equations:
- $$Y = C + I + G$$
- $$Y = 5,000$$
- $$G = 1,000$$
- $$T = 1,000$$
- $$C = 250 + 0.75(Y - T)$$
- $$I = 1,000 - 50r$$
- In this economy, compute private saving, public saving, and national saving.
 - Find the equilibrium interest rate.
 - Now suppose that G rises to 1,250. Compute private saving, public saving, and national saving.
 - Find the new equilibrium interest rate.
11. Suppose that the government increases taxes and government purchases by equal amounts. What happens to the interest rate and investment in response to this balanced-budget change? Explain how your answer depends on the marginal propensity to consume.
12. When the government subsidizes investment, such as with an investment tax credit, the subsidy often applies to only some types of investment. This question asks you to consider the effect of such a change. Suppose there are two types of investment in the economy: business investment and residential investment. The interest rate adjusts to equilibrate national saving and total investment, which is the sum of business investment and residential investment. Now suppose that the government institutes an investment tax credit only for business investment.
- How does this policy affect the demand curve for business investment? The demand curve for residential investment?
 - Draw the economy's supply and demand for loanable funds. How does this policy affect the supply and demand for loanable funds? What happens to the equilibrium interest rate?
 - Compare the old and the new equilibria. How does this policy affect the total quantity of investment? The quantity of business investment? The quantity of residential investment?
13. Suppose that consumption depends on the interest rate. How, if at all, does this alter the conclusions reached in the chapter about the impact of an increase in government purchases on investment, consumption, national saving, and the interest rate?
14. Macroeconomic data do not show a strong correlation between investment and interest rates. Let's examine why this might be so. Use our model in which the interest rate adjusts to equilibrate the supply of loanable funds (which is upward sloping) and the demand for loanable funds (which is downward sloping).
- Suppose the demand for loanable funds is stable but the supply fluctuates from year to year. What might cause these fluctuations in supply? In this case, what correlation between investment and interest rates would you find?
 - Suppose the supply of loanable funds is stable but the demand fluctuates from year to year. What might cause these fluctuations in demand? In this case, what correlation between investment and interest rates would you find now?
 - Suppose that both supply and demand in this market fluctuate over time. If you were to construct a scatterplot of investment and the interest rate, what would you find?
 - Which of the above three cases seems most empirically realistic to you?

QUESTIONS FOR REVIEW

- Describe the functions of money.
- What is fiat money? What is commodity money?
- What are open-market operations, and how do they influence the money supply?
- Explain how banks create money.
- What are the various ways in which the Federal Reserve can influence the money supply?
- Why might a banking crisis lead to a fall in the money supply?

PROBLEMS AND APPLICATIONS

- What are the three functions of money? Which of the functions do the following items satisfy? Which do they not satisfy?
 - A credit card
 - A painting by Rembrandt
 - A subway token
- Explain how each of the following events affects the monetary base, the money multiplier, and the money supply.
 - The Federal Reserve buys bonds in an open-market operation.
 - The Fed increases the interest rate it pays banks for holding reserves.
 - The Fed reduces its lending to banks through its Term Auction Facility.
 - Rumors about a computer virus attack on ATMs increase the amount of money people hold as currency rather than demand deposits.
 - The Fed flies a helicopter over 5th Avenue in New York City and drops newly printed \$100 bills.
- An economy has a monetary base of 1,000 \$1 bills. Calculate the money supply in scenarios (a)–(d) and then answer part (e).
 - All money is held as currency.
 - All money is held as demand deposits. Banks hold 100 percent of deposits as reserves.
 - All money is held as demand deposits. Banks hold 20 percent of deposits as reserves.
 - People hold equal amounts of currency and demand deposits. Banks hold 20 percent of deposits as reserves.
 - The central bank decides to increase the money supply by 10 percent. In each of the above four scenarios, how much should it increase the monetary base?
- As a Case Study in the chapter discusses, the money supply fell from 1929 to 1933 because both the currency–deposit ratio and the reserve–deposit ratio increased. Use the model of the money supply and the data in Table 4–2 to answer the following hypothetical questions about this episode.
 - What would have happened to the money supply if the currency–deposit ratio had risen but the reserve–deposit ratio had remained the same?
 - What would have happened to the money supply if the reserve–deposit ratio had risen but the currency–deposit ratio had remained the same?
 - Which of the two changes was more responsible for the fall in the money supply?
- To increase tax revenue, the U.S. government in 1932 imposed a 2-cent tax on checks written on bank account deposits. (In today's dollars, this tax would amount to about 34 cents per check.)
 - How do you think the check tax affected the currency–deposit ratio? Explain.
 - Use the model of the money supply under fractional-reserve banking to discuss how this tax affected the money supply.
 - Many economists believe that a falling money supply was in part responsible for the severity of the Great Depression of the 1930s. From this perspective, was the check tax a good policy to implement in the middle of the Great Depression?
- Give an example of a bank balance sheet with a leverage ratio of 10. If the value of the bank's assets rises by 5 percent, what happens to the value of the owners' equity in this bank? How large a decline in the value of bank assets would it take to reduce this bank's capital to zero?

2. A newspaper article once reported that the U.S. economy was experiencing a low rate of inflation. It said that "low inflation has a downside: 45 million recipients of Social Security and other benefits will see their checks go up by just 2.8 percent next year."
- Why does inflation affect the increase in Social Security and other benefits?
 - Is this effect a cost of inflation, as the article suggests? Why or why not?
3. Suppose a country has a money demand function $(M/P)^d = kY$, where k is a constant parameter. The money supply grows by 12 percent per year, and real income grows by 4 percent per year.
- What is the average inflation rate?
 - How would inflation be different if real income growth were higher? Explain.
 - How do you interpret the parameter k ? What is its relationship to the velocity of money?
 - Suppose, instead of a constant money demand function, the velocity of money in this economy was growing steadily because of financial innovation. How would that affect the inflation rate? Explain.
4. During World War II, both Germany and England had plans for a paper weapon: they each printed the other's currency, with the intention of dropping large quantities by airplane. Why might this have been an effective weapon?
5. Suppose that the money demand function takes the form
- $$(M/P)^d = L(i, Y) = Y/(5i)$$
- If output grows at rate g , at what rate will the demand for real balances grow (assuming constant nominal interest rates)?
 - What is the velocity of money in this economy?
- If inflation and nominal interest rates are constant, at what rate, if any, will velocity grow?
 - How will a permanent (once-and-for-all) increase in the level of interest rates affect the level of velocity? How will it affect the subsequent growth rate of velocity?
6. In each of the following scenarios, explain and categorize the cost of inflation.
- Because inflation has risen, the L.L. Bean Company decides to issue a new catalog quarterly rather than annually.
 - Grandma buys an annuity for \$100,000 from an insurance company, which promises to pay her \$10,000 a year for the rest of her life. After buying it, she is surprised that high inflation triples the price level over the next few years.
 - Maria lives in an economy with hyperinflation. Each day after being paid, she runs to the store as quickly as possible so she can spend her money before it loses value.
 - Warren lives in an economy with an inflation rate of 10 percent. Over the past year, he earned a return of \$50,000 on his million-dollar portfolio of stocks and bonds. Because his tax rate is 20 percent, he paid \$10,000 to the government.
 - Your father tells you that when he was your age, he worked for only \$3 an hour. He suggests that you are lucky to have a job that pays \$7 an hour.
7. When Calvin Coolidge was vice president and giving a speech about government finances, he said that "inflation is repudiation." What might he have meant by this? Do you agree? Why or why not? Does it matter whether the inflation is expected or unexpected?
8. Some economic historians have noted that during the period of the gold standard, gold discoveries were most likely to occur after a long deflation. (The discoveries of 1896 are an example.) Why might this be true?

KEY CONCEPTS

| | | |
|---------------------------------|---------------------|-------------------------|
| Net exports | Balanced trade | Nominal exchange rate |
| Trade balance | Small open economy | Real exchange rate |
| Net capital outflow | World interest rate | Purchasing-power parity |
| Trade surplus and trade deficit | | |

QUESTIONS FOR REVIEW

1. What are the net capital outflow and the trade balance? Explain how they are related.
2. Define the nominal exchange rate and the real exchange rate.
3. If a small open economy cuts defense spending, what happens to saving, investment, the trade balance, the interest rate, and the exchange rate?
4. If a small open economy bans the import of Japanese DVD players, what happens to saving, investment, the trade balance, the interest rate, and the exchange rate?
5. According to the theory of purchasing-power parity, if Japan has low inflation and Mexico has high inflation, what will happen to the exchange rate between the Japanese yen and the Mexican peso?

PROBLEMS AND APPLICATIONS

1. Use the model of the small open economy to predict what would happen to the trade balance, the real exchange rate, and the nominal exchange rate in response to each of the following events.
 - a. A fall in consumer confidence about the future induces consumers to spend less and save more.
 - b. A tax reform increases the incentive for businesses to build new factories.
 - c. The introduction of a stylish line of Toyotas makes some consumers prefer foreign cars over domestic cars.
 - d. The central bank doubles the money supply.
 - e. New regulations restricting the use of credit cards increase the demand for money.
2. Consider an economy described by the following equations:

$$Y = C + I + G + NX,$$

$$Y = 5,000,$$

$$G = 1,000,$$

$$T = 1,000,$$

$$C = 250 + 0.75(Y - T),$$

$$I = 1,000 - 50r,$$

$$NX = 500 - 500\epsilon,$$

$$r = r^* = 5.$$
 - a. In this economy, solve for national saving, investment, the trade balance, and the equilibrium exchange rate.
 - b. Suppose now that G rises to 1,250. Solve for national saving, investment, the trade balance, and the equilibrium exchange rate. Explain what you find.
 - c. Now suppose that the world interest rate rises from 5 to 10 percent. (G is again 1,000.) Solve for national saving, investment, the trade balance, and the equilibrium exchange rate. Explain what you find.
3. The country of Leverett is a small open economy. Suddenly, a change in world fashions makes the exports of Leverett unpopular.
 - a. What happens in Leverett to saving, investment, net exports, the interest rate, and the exchange rate?
 - b. The citizens of Leverett like to travel abroad. How will this change in the exchange rate affect them?
 - c. The fiscal policymakers of Leverett want to adjust taxes to maintain the exchange rate at its previous level. What should they do? If they do this, what are the overall effects on saving, investment, net exports, and the interest rate?

4. In 2005, Federal Reserve Governor Ben Bernanke said in a speech: "Over the past decade a combination of diverse forces has created a significant increase in the global supply of saving—a global saving glut—which helps to explain both the increase in the U.S. current account deficit [a broad measure of the trade deficit] and the relatively low level of long-term real interest rates in the world today." Is this statement consistent with the models you have learned? Explain.
5. What will happen to the trade balance and the real exchange rate of a small open economy when government purchases increase, such as during a war? Does your answer depend on whether this is a local war or a world war?
6. A Case Study in this chapter concludes that if poor nations offered better production efficiency and legal protections, the trade balance in rich nations such as the United States would move toward surplus. Let's consider why this might be the case.
- If the world's poor nations offer better production efficiency and legal protection, what would happen to the investment demand function in those countries?
 - How would the change you describe in part (a) affect the demand for loanable funds in world financial markets?
 - How would the change you describe in part (b) affect the world interest rate?
 - How would the change you describe in part (c) affect the trade balance in rich nations?
7. The president is considering placing a tariff on the import of Japanese luxury cars. Using the model presented in this chapter, discuss the economics and politics of such a policy. In particular, how would the policy affect the U.S. trade deficit? How would it affect the exchange rate? Who would be hurt by such a policy? Who would benefit?
8. Suppose China exports TVs and uses the yuan as its currency, whereas Russia exports vodka and uses the ruble. China has a stable money supply and slow, steady technological progress in TV production, while Russia has very rapid growth in the money supply and no technological progress in vodka production. Based on this information, what would you predict for the real exchange rate (measured as bottles of vodka per TV) and the nominal exchange rate (measured as rubles per yuan)? Explain your reasoning. (*Hint:* For the real exchange rate, think about the link between scarcity and relative prices.)
9. Oceania is a small open economy. Suppose that a large number of foreign countries begin to subsidize investment by instituting an investment tax credit (while adjusting other taxes to hold their tax revenue constant), but Oceania does not institute such an investment subsidy.
- What happens to world investment demand as a function of the world interest rate?
 - What happens to the world interest rate?
 - What happens to investment in Oceania?
 - What happens to Oceania's trade balance?
 - What happens to Oceania's real exchange rate?
10. "Traveling in Mexico is much cheaper now than it was ten years ago," says a friend. "Ten years ago, a dollar bought 10 pesos; this year, a dollar buys 15 pesos." Is your friend right or wrong? Given that total inflation over this period was 25 percent in the United States and 100 percent in Mexico, has it become more or less expensive to travel in Mexico? Write your answer using a concrete example—such as an American hot dog versus a Mexican taco—that will convince your friend.
11. You read in a newspaper that the nominal interest rate is 12 percent per year in Canada and 8 percent per year in the United States. Suppose that international capital flows equalize the real interest rates in the two countries and that purchasing-power parity holds.
- Using the Fisher equation (discussed in Chapter 5), what can you infer about expected inflation in Canada and in the United States?
 - What can you infer about the expected change in the exchange rate between the Canadian dollar and the U.S. dollar?
 - A friend proposes a get-rich-quick scheme: borrow from a U.S. bank at 8 percent, deposit the money in a Canadian bank at 12 percent, and make a 4 percent profit. What's wrong with this scheme?

MORE PROBLEMS AND APPLICATIONS

1. If a war broke out abroad, it would affect the U.S. economy in many ways. Use the model of the large open economy to examine each of the following effects of such a war. What happens in the United States to saving, investment, the trade balance, the interest rate, and the exchange rate? (To keep things simple, consider each of the following effects separately.)
 - a. The U.S. government, fearing it may need to enter the war, increases its purchases of military equipment.
 - b. Other countries raise their demand for high-tech weapons, a major export of the United States.
 - c. The war makes U.S. firms uncertain about the future, and the firms delay some investment projects.
 - d. The war makes U.S. consumers uncertain about the future, and the consumers save more in response.
 - e. Americans become apprehensive about traveling abroad, so more of them spend their vacations in the United States.
 - f. Foreign investors seek a safe haven for their portfolios in the United States.
2. On September 21, 1995, "House Speaker Newt Gingrich threatened to send the United States into default on its debt for the first time in the nation's history, to force the Clinton Administration to balance the budget on Republican terms" (*New York Times*, September 22, 1995, p. A1). That same day, the interest rate on 30-year U.S. government bonds rose from 6.46 to 6.55 percent, and the dollar fell in value from 102.7 to 99.0 yen. Use the model of the large open economy to explain this event.

7. American and European labor markets exhibit some significant differences. In recent years, Europe has experienced significantly more unemployment than the United States. In addition, because of higher unemployment, shorter workweeks, more holidays, and earlier retirement, Europeans work fewer hours than Americans.

KEY CONCEPTS

| | | |
|------------------------------|-------------------------|---------------------------|
| Natural rate of unemployment | Unemployment insurance | Insiders versus outsiders |
| Frictional unemployment | Wage rigidity | Efficiency wages |
| Sectoral shift | Structural unemployment | Discouraged workers |

QUESTIONS FOR REVIEW

1. What determines the natural rate of unemployment?
2. Describe the difference between frictional unemployment and structural unemployment.
3. Give three explanations why the real wage may remain above the level that equilibrates labor supply and labor demand.
4. Is most unemployment long-term or short-term? Explain your answer.
5. Do Europeans work more or fewer hours than Americans? List three hypotheses that have been suggested to explain the difference.

PROBLEMS AND APPLICATIONS

1. Answer the following questions about your own experience in the labor force.
 - a. When you or one of your friends is looking for a part-time job, how many weeks does it typically take? After you find a job, how many weeks does it typically last?
 - b. From your estimates, calculate (in a rate per week) your rate of job finding f and your rate of job separation s . (*Hint:* If f is the rate of job finding, then the average spell of unemployment is $1/f$.)
 - c. What is the natural rate of unemployment for the population you represent?
2. In this chapter we saw that the steady-state rate of unemployment is $U/L = s/(s + f)$. Suppose that the unemployment rate does not begin at this level. Show that unemployment will evolve over time and reach this steady state. (*Hint:* Express the change in the number of unemployed as a function of s , f , and U . Then show that if unemployment is above the natural rate, unemployment falls, and if unemployment is below the natural rate, unemployment rises.)
3. The residents of a certain dormitory have collected the following data: People who live in the dorm can be classified as either involved in a relationship or uninvolved. Among involved people, 10 percent experience a breakup of their relationship every month. Among uninvolved people, 5 percent enter into a relationship every month. What is the steady-state fraction of residents who are uninvolved?
4. Suppose that Congress passes legislation making it more difficult for firms to fire workers. (An example is a law requiring severance pay for fired workers.) If this legislation reduces the rate of job separation without affecting the rate of job finding, how would the natural rate of unemployment change? Do you think it is plausible that the legislation would not affect the rate of job finding? Why or why not?

5. Consider an economy with the following Cobb–Douglas production function:

$$Y = K^{1/3}L^{2/3}.$$

The economy has 1,000 units of capital and a labor force of 1,000 workers.

- a. Derive the equation describing labor demand in this economy as a function of the real wage and the capital stock. (*Hint:* Review Chapter 3.)
 - b. If the real wage can adjust to equilibrate labor supply and labor demand, what is the real wage? In this equilibrium, what are employment, output, and the total amount earned by workers?
 - c. Now suppose that Congress, concerned about the welfare of the working class, passes a law requiring firms to pay workers a real wage of one unit of output. How does this wage compare to the equilibrium wage?
 - d. Congress cannot dictate how many workers firms hire at the mandated wage. Given this fact, what are the effects of this law? Specifically, what happens to employment, output, and the total amount earned by workers?
 - e. Will Congress succeed in its goal of helping the working class? Explain.
 - f. Do you think that this analysis provides a good way of thinking about a minimum-wage law? Why or why not?
6. Suppose that a country experiences a reduction in productivity—that is, an adverse shock to the production function.
 - a. What happens to the labor demand curve?
 - b. How would this change in productivity affect the labor market—that is, employment, unemployment, and real wages—if the labor market is always in equilibrium?
 - c. How would this change in productivity affect the labor market if unions prevent real wages from falling?
 7. When workers' wages rise, their decision about how much time to spend working is affected in two conflicting ways—as you may have learned in courses in microeconomics. The *income effect* is the impulse to work less, because greater incomes mean workers can afford to consume more leisure. The *substitution effect* is the impulse to work more, because the reward for working an additional hour has risen (equivalently, the opportunity cost of leisure has gone up). Apply these concepts to Blanchard's hypothesis about American and European tastes for leisure. On which side of the Atlantic do income effects appear larger than substitution effects? On which side do the two effects approximately cancel? Do you think it is a reasonable hypothesis that tastes for leisure vary by geography? Why or why not?
 8. In any city at any time, some of the stock of usable office space is vacant. This vacant office space is unemployed capital. How would you explain this phenomenon? Is it a social problem?

4. The Solow model shows that an economy's rate of population growth is another long-run determinant of the standard of living. According to the Solow model, the higher the rate of population growth, the lower the steady-state levels of capital per worker and output per worker. Other theories highlight other effects of population growth. Malthus suggested that population growth will strain the natural resources necessary to produce food; Kremer suggested that a large population may promote technological progress.

KEY CONCEPTS

Solow growth model

Steady state

Golden Rule level of capital

QUESTIONS FOR REVIEW

- In the Solow model, how does the saving rate affect the steady-state level of income? How does it affect the steady-state rate of growth?
- Why might an economic policymaker choose the Golden Rule level of capital?
- Might a policymaker choose a steady state with more capital than in the Golden Rule steady state? With less capital than in the Golden Rule steady state? Explain your answers.
- In the Solow model, how does the rate of population growth affect the steady-state level of income? How does it affect the steady-state rate of growth?

PROBLEMS AND APPLICATIONS

- Country A and country B both have the production function

$$Y = F(K, L) = K^{1/2}L^{1/2}.$$
 - Does this production function have constant returns to scale? Explain.
 - What is the per-worker production function, $y = f(k)$?
 - Assume that neither country experiences population growth or technological progress and that 5 percent of capital depreciates each year. Assume further that country A saves 10 percent of output each year and country B saves 20 percent of output each year. Using your answer from part (b) and the steady-state condition that investment equals depreciation, find the steady-state level of capital per worker for each country. Then find the steady-state levels of income per worker and consumption per worker.
 - Suppose that both countries start off with a capital stock per worker of 2. What are the levels of income per worker and consumption per worker? Remembering that the change in the capital stock is investment less depreciation, use a calculator or a computer spreadsheet to show how the capital stock per worker will evolve over time in both countries. For each year, calculate income per worker and consumption per worker. How many years will it be before the consumption in country B is higher than the consumption in country A?
- In the discussion of German and Japanese postwar growth, the text describes what happens when part of the capital stock is destroyed in a war. By contrast, suppose that a war does not directly affect the capital stock, but that casualties reduce the labor force. Assume the economy was in a steady state before the war, the saving rate

- is unchanged, and the rate of population growth after the war is the same as it was before.
- What is the immediate impact of the war on total output and on output per person?
 - What happens subsequently to output per worker in the postwar economy? Is the growth rate of output per worker after the war smaller or greater than it was before the war?
- Consider an economy described by the production function: $Y = F(K, L) = K^{0.3}L^{0.7}$.
 - What is the per-worker production function?
 - Assuming no population growth or technological progress, find the steady-state capital stock per worker, output per worker, and consumption per worker as a function of the saving rate and the depreciation rate.
 - Assume that the depreciation rate is 10 percent per year. Make a table showing steady-state capital per worker, output per worker, and consumption per worker for saving rates of 0 percent, 10 percent, 20 percent, 30 percent, and so on. (You will need a calculator with an exponent key for this.) What saving rate maximizes output per worker? What saving rate maximizes consumption per worker?
 - (Harder) Use calculus to find the marginal product of capital. Add to your table from part (c) the marginal product of capital net of depreciation for each of the saving rates. What does your table show about the relationship between the net marginal product of capital and steady-state consumption?
 - “Devoting a larger share of national output to investment would help restore rapid productivity growth and rising living standards.” Do you agree with this claim? Explain, using the Solow model.
 - Draw a well-labeled graph that illustrates the steady state of the Solow model with population growth. Use the graph to find what happens to steady-state capital per worker and income per worker in response to each of the following exogenous changes.
 - A change in consumer preferences increases the saving rate.
 - A change in weather patterns increases the depreciation rate.
 - Better birth-control methods reduce the rate of population growth.
 - A one-time, permanent improvement in technology increases the amount of output that can be produced from any given amount of capital and labor.
 - Many demographers predict that the United States will have zero population growth in the twenty-first century, in contrast to average population growth of about 1 percent per year in the twentieth century. Use the Solow model to forecast the effect of this slowdown in population growth on the growth of total output and the growth of output per person. Consider the effects both in the steady state and in the transition between steady states.
 - In the Solow model, population growth leads to steady-state growth in total output, but not in output per worker. Do you think this would still be true if the production function exhibited increasing or decreasing returns to scale? Explain. (For the definitions of increasing and decreasing returns to scale, see Chapter 3, “Problems and Applications,” Problem 3.)
 - Consider how unemployment would affect the Solow growth model. Suppose that output is produced according to the production function $Y = K^\alpha[(1 - u)L]^{1 - \alpha}$, where K is capital, L is the labor force, and u is the natural rate of unemployment. The national saving rate is s , the labor force grows at rate n , and capital depreciates at rate δ .
 - Express output per worker ($y = Y/L$) as a function of capital per worker ($k = K/L$) and the natural rate of unemployment (u).
 - Write an equation that describes the steady state of this economy. Illustrate the steady state graphically, as we did in this chapter for the standard Solow model.
 - Suppose that some change in government policy reduces the natural rate of unemployment. Using the graph you drew in part (b), describe how this change affects output both immediately and over time. Is the steady-state effect on output larger or smaller than the immediate effect? Explain.

QUESTIONS FOR REVIEW

1. In the Solow model, what determines the steady-state rate of growth of income per worker?
2. In the steady state of the Solow model, at what rate does output per person grow? At what rate does capital per person grow? How does this compare with the U.S. experience?
3. What data would you need to determine whether an economy has more or less capital than in the Golden Rule steady state?
4. How can policymakers influence a nation's saving rate?
5. What has happened to the rate of productivity growth over the past 50 years? How might you explain this phenomenon?
6. How does endogenous growth theory explain persistent growth without the assumption of exogenous technological progress? How does this differ from the Solow model?

PROBLEMS AND APPLICATIONS

1. Suppose an economy described by the Solow model has the following production function:

$$Y = K^{1/2}(LE)^{1/2}.$$

- a. For this economy, what is $f(k)$?
 - b. Use your answer to part (a) to solve for the steady-state value of y as a function of s , n , g , and δ .
 - c. Two neighboring economies have the above production function, but they have different parameter values. Atlantis has a saving rate of 28 percent and a population growth rate of 1 percent per year. Xanadu has a saving rate of 10 percent and a population growth rate of 4 percent per year. In both countries, $g = 0.02$ and $\delta = 0.04$. Find the steady-state value of y for each country.
2. In the United States, the capital share of GDP is about 30 percent, the average growth in output is about 3 percent per year, the depreciation rate is about 4 percent per year, and the capital-output ratio is about 2.5. Suppose that the production function is Cobb–Douglas, so that the capital share in output is constant, and that the United States has been in a steady state. (For a discussion of the Cobb–Douglas production function, see Chapter 3.)
 - a. What must the saving rate be in the initial steady state? [*Hint:* Use the steady-state relationship, $sy = (\delta + n + g)k$.]
 - b. What is the marginal product of capital in the initial steady state?
 - c. Suppose that public policy raises the saving rate so that the economy reaches the Golden Rule level of capital. What will the marginal product of capital be at the Golden Rule steady state? Compare the marginal product at the Golden Rule steady state to the marginal product in the initial steady state. Explain.
 - d. What will the capital–output ratio be at the Golden Rule steady state? [*Hint:* For the Cobb–Douglas production function, the capital–output ratio is related to the marginal product of capital.]
 - e. What must the saving rate be to reach the Golden Rule steady state?
 3. Prove each of the following statements about the steady state of the Solow model with population growth and technological progress.
 - a. The capital–output ratio is constant.
 - b. Capital and labor each earn a constant share of an economy's income. [*Hint:* Recall the definition $MPK = f(k + 1) - f(k)$.]
 - c. Total capital income and total labor income both grow at the rate of population growth plus the rate of technological progress, $n + g$.
 - d. The real rental price of capital is constant, and the real wage grows at the rate of technological progress g . [*Hint:* The real rental price of capital equals total capital income divided by the capital stock, and the real wage equals total labor income divided by the labor force.]

4. Two countries, Richland and Poorland, are described by the Solow growth model. They have the same Cobb–Douglas production function, $F(K, L) = A K^\alpha L^{1-\alpha}$, but with different quantities of capital and labor. Richland saves 32 percent of its income, while Poorland saves 10 percent. Richland has population growth of 1 percent per year, while Poorland has population growth of 3 percent. (The numbers in this problem are chosen to be approximately realistic descriptions of rich and poor nations.) Both nations have technological progress at a rate of 2 percent per year and depreciation at a rate of 5 percent per year.
- What is the per-worker production function $f(k)$?
 - Solve for the ratio of Richland's steady-state income per worker to Poorland's. (*Hint:* The parameter α will play a role in your answer.)
 - If the Cobb–Douglas parameter α takes the conventional value of about $1/3$, how much higher should income per worker be in Richland compared to Poorland?
 - Income per worker in Richland is actually 16 times income per worker in Poorland. Can you explain this fact by changing the value of the parameter α ? What must it be? Can you think of any way of justifying such a value for this parameter? How else might you explain the large difference in income between Richland and Poorland?
5. The amount of education the typical person receives varies substantially among countries. Suppose you were to compare a country with a highly educated labor force and a country with a less educated labor force. Assume that education affects only the level of the efficiency of labor. Also assume that the countries are otherwise the same: they have the same saving rate, the same depreciation rate, the same population growth rate, and the same rate of technological progress. Both countries are described by the Solow model and are in their steady states. What would you predict for the following variables?
- The rate of growth of total income
 - The level of income per worker
 - The real rental price of capital
 - The real wage
6. This question asks you to analyze in more detail the two-sector endogenous growth model presented in the text.
- Rewrite the production function for manufactured goods in terms of output per effective worker and capital per effective worker.
 - In this economy, what is break-even investment (the amount of investment needed to keep capital per effective worker constant)?
 - Write down the equation of motion for k , which shows Δk as saving minus break-even investment. Use this equation to draw a graph showing the determination of steady-state k . (*Hint:* This graph will look much like those we used to analyze the Solow model.)
 - In this economy, what is the steady-state growth rate of output per worker Y/L ? How do the saving rate s and the fraction of the labor force in universities u affect this steady-state growth rate?
 - Using your graph, show the impact of an increase in u . (*Hint:* This change affects both curves.) Describe both the immediate and the steady-state effects.
 - Based on your analysis, is an increase in u an unambiguously good thing for the economy? Explain.
7. Choose two countries that interest you—one rich and one poor. What is the income per person in each country? Find some data on country characteristics that might help explain the difference in income: investment rates, population growth rates, educational attainment, and so on. (*Hint:* The Web site of the World Bank, www.worldbank.org, is one place to find such data.) How might you figure out which of these factors is most responsible for the observed income difference? In your judgment, how useful is the Solow model as an analytic tool for understanding the difference between the two countries you chose?

MORE PROBLEMS AND APPLICATIONS

1. In the economy of Solovia, the owners of capital get two-thirds of national income, and the workers receive one-third.
 - a. The men of Solovia stay at home performing household chores, while the women work in factories. If some of the men started working outside the home so that the labor force increased by 5 percent, what would happen to the measured output of the economy? Does labor productivity—defined as output per worker—increase, decrease, or stay the same? Does total factor productivity increase, decrease, or stay the same?
 - b. In year 1, the capital stock was 6, the labor input was 3, and output was 12. In year 2, the capital stock was 7, the labor input was 4, and output was 14. What happened to total factor productivity between the two years?
2. Labor productivity is defined as Y/L , the amount of output divided by the amount of labor input. Start with the growth-accounting equation and show that the growth in labor productivity depends on growth in total factor

productivity and growth in the capital–labor ratio. In particular, show that

$$\frac{\Delta(Y/L)}{Y/L} = \frac{\Delta A}{A} + \alpha \frac{\Delta(K/L)}{K/L}.$$

Hint: You may find the following mathematical trick helpful. If $z = ux$, then the growth rate of z is approximately the growth rate of w plus the growth rate of x . That is,

$$\Delta z/z \approx \Delta w/w + \Delta x/x.$$

3. Suppose an economy described by the Solow model is in a steady state with population growth n of 1.8 percent per year and technological progress g of 1.8 percent per year. Total output and total capital grow at 3.6 percent per year. Suppose further that the capital share of output is $1/3$. If you used the growth-accounting equation to divide output growth into three sources—capital, labor, and total factor productivity—how much would you attribute to each source? Compare your results to the figures we found for the United States in Table 9-3.