PROBLEMS AND APPLICATIONS

1. LaunchPad • Country A and country B both have the production function

$$Y = F(K, L) = K^{1/3}L^{2/3}.$$

   a. Does this production function have constant returns to scale? Explain.

   b. What is the per-worker production function, $y = f(k)$?

   c. Assume that neither country experiences population growth or technological progress and that 20 percent of capital depreciates each year. Assume further that country A saves 10 percent of output each year and country B saves 30 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.

   d. Suppose that both countries start off with a capital stock per worker of 1. What are the levels of income per worker and consumption per worker?

   e. Remembering that the change in the capital stock is investment less depreciation, use a calculator (or, better yet, 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?

2. 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.

   a. What is the immediate impact of the war on total output and on output per person?

   b. 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?

3. LaunchPad • Consider an economy described by the production function: $Y = F(K, L) = K^{0.4}L^{0.6}$.

   a. What is the per-worker production function?

   b. 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.

   c. Assume that the depreciation rate is 15 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 might find it easiest to use a computer spreadsheet.) What saving rate maximizes output per worker? What saving rate maximizes consumption per worker?

   d. Use information from Chapter 3 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?

4. "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.

5. 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. A change in consumer preferences increases the saving rate.

   b. A change in weather patterns increases the depreciation rate.

   c. Better birth-control methods reduce the rate of population growth.

d. A one-time, permanent improvement in technology increases the amount of output that can be produced from any given amount of capital and labor.

6. Many demographers predict that the United States will have zero population growth in the coming decades, in contrast to the historical average population growth of about 1 percent per year. 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.

7. 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.)

8. 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.

a. Express output per worker ($y = Y/L$) as a function of capital per worker ($k = K/L$) and the natural rate of unemployment (u).

b. 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.

c. 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.

KEY CONCEPTS

Efficiency of labor
Labor-augmenting technological progress
Endogenous growth theory
Creative destruction

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. Give an example of an institutional difference between countries that might explain the differences in income per person.
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. LaunchPad • An economy has a Cobb–Douglas production function:

$$Y = K^{\alpha}(LE)^{1-\alpha}.$$

   (For a review of the Cobb–Douglas production function, see Chapter 3.) The economy has a capital share of a third, a saving rate of 24 percent, a depreciation rate of 3 percent, a rate of population growth of 2 percent, and a rate of labor-augmenting technological change of 1 percent. It is in steady state.

   a. At what rates do total output, output per worker, and output per effective worker grow?

   b. Solve for capital per effective worker, output per effective worker, and the marginal product of capital.

   c. Does the economy have more or less capital than at the Golden Rule steady state? How do you know? To achieve the Golden Rule steady state, does the saving rate need to increase or decrease?

   d. Suppose the change in the saving rate you described in part (c) occurs. During the transition to the Golden Rule steady state, will the growth rate of output per worker be higher or lower than the rate you derived in part (a)? After the economy reaches its new steady state, will the growth rate of output per worker be higher or lower than the rate you derived in part (a)? Explain your answers.

3. LaunchPad • 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 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 alters 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?

4. 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.)

5. 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.

   a. What is the per-worker production function $f(k)$?

   b. 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.)

   c. 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?

   d. 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?

6. 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?

   a. The rate of growth of total income

   b. The level of income per worker

   c. The real rental price of capital

   d. The real wage

7. This question asks you to analyze in more detail the two-sector endogenous growth model presented in the text.
   a. Rewrite the production function for manufactured goods in terms of output per effective worker and capital per effective worker.
   b. In this economy, what is break-even investment (the amount of investment needed to keep capital per effective worker constant)?
   c. 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.)
   d. 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?
   e. 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.
   f. Based on your analysis, is an increase in u an unambiguously good thing for the economy? Explain.
8. 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, http://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 $z = wx$, 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 9-2.

3. The aggregate demand curve slopes downward. It tells us that the lower the price level, the greater the aggregate quantity of goods and services demanded.
4. In the long run, the aggregate supply curve is vertical because output is determined by the amounts of capital and labor and by the available technology but not by the level of prices. Therefore, shifts in aggregate demand affect the price level but not output or employment.
5. In the short run, the aggregate supply curve is horizontal, because wages and prices are sticky at predetermined levels. Therefore, shifts in aggregate demand affect output and employment.
6. Shocks to aggregate demand and aggregate supply cause economic fluctuations. Because the Fed can shift the aggregate demand curve, it can attempt to offset these shocks to maintain output and employment at their natural levels.

KEY CONCEPTS

Okun's law
Leading indicators
Aggregate demand
Aggregate supply
Shocks
Demand shocks
Supply shocks
Stabilization policy

QUESTIONS FOR REVIEW

1. When real GDP declines during a recession, what typically happens to consumption, investment, and the unemployment rate?
2. Give an example of a price that is sticky in the short run but flexible in the long run.
3. Why does the aggregate demand curve slope downward?
4. Explain the impact of an increase in the money supply in the short run and in the long run.
5. Why is it easier for the Fed to deal with demand shocks than with supply shocks?

PROBLEMS AND APPLICATIONS

1. An economy begins in long-run equilibrium, and then a change in government regulations allows banks to start paying interest on checking accounts. Recall that the money stock is the sum of currency and demand deposits, including checking accounts, so this regulatory change makes holding money more attractive.
   a. How does this change affect the demand for money?
   b. What happens to the velocity of money?
   c. If the Fed keeps the money supply constant, what will happen to output and prices in the short run and in the long run?
   d. If the goal of the Fed is to stabilize the price level, should the Fed keep the money supply constant in response to this regulatory change? If not, what should it do? Why?
   e. If the goal of the Fed is to stabilize output, how would your answer to part (d) change?

2. Suppose the Fed reduces the money supply by 5 percent. Assume the velocity of money is constant.
   a. What happens to the aggregate demand curve?
   b. What happens to the level of output and the price level in the short run and in the long run? Give a precise numerical answer.
   c. In light of your answer to part (b), what happens to unemployment in the short run and in the long run according to Okun's law? Again, give a precise numerical answer.
   d. What happens to the real interest rate in the short run and in the long run? (*Hint:* Use the model of the real interest rate in Chapter 3 to see what happens when output changes.) Here, your answer should just give the direction of the changes.
3. Let's examine how the goals of the Fed influence its response to shocks. Suppose that in scenario A the Fed cares only about keeping the price level stable and in scenario B the Fed cares only about keeping output and employment at their natural levels. Explain how in each scenario the Fed would respond to the following.
   a. An exogenous decrease in the velocity of money.
   b. An exogenous increase in the price of oil.
4. The official arbiter of when recessions begin and end is the National Bureau of Economic Research, a nonprofit economics research group. Go to the NBER's Web site (http://www.nber.org) and find the latest turning point in the business cycle. When did it occur? Was this a switch from expansion to contraction or the other way around? List all the recessions (contractions) that have occurred during your lifetime and the dates when they began and ended.

5. The *IS–LM* model combines the elements of the Keynesian cross and the elements of the theory of liquidity preference. The *IS* curve shows the points that satisfy equilibrium in the goods market, and the *LM* curve shows the points that satisfy equilibrium in the money market. The intersection of the *IS* and *LM* curves shows the interest rate and income that satisfy equilibrium in both markets for a given price level.

KEY CONCEPTS

IS–LM model
IS curve
LM curve
Keynesian cross
Government-purchases multiplier
Tax multiplier
Theory of liquidity preference

QUESTIONS FOR REVIEW

1. Use the Keynesian cross to explain why fiscal policy has a multiplied effect on national income.
2. Use the theory of liquidity preference to explain why an increase in the money supply lowers the interest rate. What does this explanation assume about the price level?
3. Why does the *IS* curve slope downward?
4. Why does the *LM* curve slope upward?

PROBLEMS AND APPLICATIONS

1. Use the Keynesian cross model to predict the impact on equilibrium GDP of the following. In each case, state the direction of the change and give a formula for the size of the impact.
   a. An increase in government purchases
   b. An increase in taxes
   c. Equal-sized increases in both government purchases and taxes
2. LaunchPad • In the Keynesian cross model, assume that the consumption function is given by

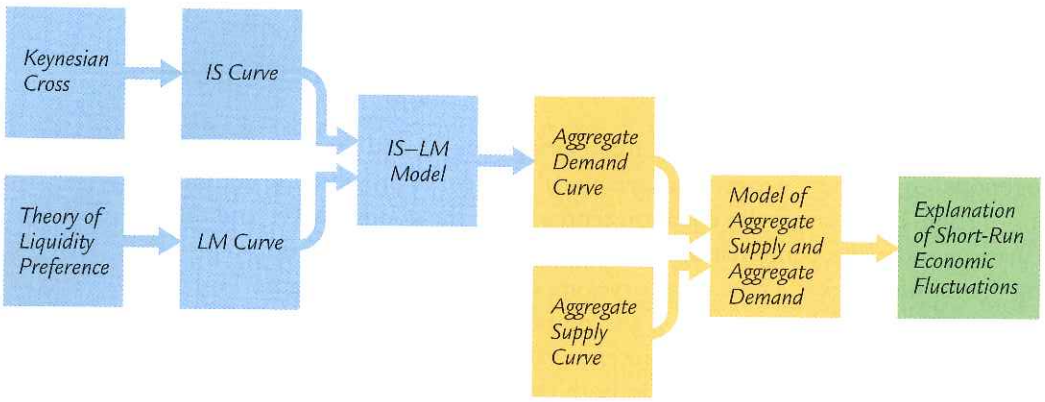
$$C = 120 + 0.8\,(Y - T).$$

   Planned investment is 200; government purchases and taxes are both 400.
   a. Graph planned expenditure as a function of income.
   b. What is the equilibrium level of income?
   c. If government purchases increase to 420, what is the new equilibrium income? What is the multiplier for government purchases?
   d. What level of government purchases is needed to achieve an income of 2,400? (Taxes remain at 400.)
   e. What level of taxes is needed to achieve an income of 2,400? (Government purchases remain at 400.)
3. Although our development of the Keynesian cross in this chapter assumes that taxes are a fixed amount, most countries levy some taxes that rise automatically with national income. (Examples in the United States include the income tax and the payroll tax.) Let's represent the tax system by writing tax revenue as

$$T = \overline{T} + tY,$$

   where T and t are parameters of the tax code. The parameter t is the marginal tax rate: if income rises by \$1, taxes rise by $t \times$ \$1.
   a. How does this tax system change the way consumption responds to changes in GDP?

FIGURE 11-14



The Theory of Short-Run Fluctuations This schematic diagram shows how the different pieces of the theory of short-run fluctuations fit together. The Keynesian cross explains the *IS* curve, and the theory of liquidity preference explains the *LM* curve. The *IS* and *LM* curves together yield the *IS–LM* model, which explains the aggregate demand curve. The aggregate demand curve is part of the model of aggregate supply and aggregate demand, which economists use to explain short-run fluctuations in economic activity.

Summary

1. The Keynesian cross is a basic model of income determination. It takes fiscal policy and planned investment as exogenous and then shows that there is one level of national income at which actual expenditure equals planned expenditure. It shows that changes in fiscal policy have a multiplied impact on income.
2. Once we allow planned investment to depend on the interest rate, the Keynesian cross yields a relationship between the interest rate and national income. A higher interest rate lowers planned investment, and this in turn lowers national income. The downward-sloping *IS* curve summarizes this negative relationship between the interest rate and income.
3. The theory of liquidity preference is a basic model of the determination of the interest rate. It takes the money supply and the price level as exogenous and assumes that the interest rate adjusts to equilibrate the supply and demand for real money balances. The theory implies that increases in the money supply lower the interest rate.
4. Once we allow the demand for real money balances to depend on national income, the theory of liquidity preference yields a relationship between income and the interest rate. A higher level of income raises the demand for real money balances, and this in turn raises the interest rate. The upward-sloping *LM* curve summarizes this positive relationship between income and the interest rate.

b. In the Keynesian cross, how does this tax system alter the government-purchases multiplier?

c. In the *IS–LM* model, how does this tax system alter the slope of the *IS* curve?

4. Consider the impact of an increase in thriftiness in the Keynesian cross model. Suppose the consumption function is

$$C = \bar{C} + c(Y - T),$$

where C is a parameter called *autonomous consumption* that represents exogenous influences on consumption and c is the marginal propensity to consume.

a. What happens to equilibrium income when the society becomes more thrifty, as represented by a decline in $\bar{C}$?

b. What happens to equilibrium saving?

c. Why do you suppose this result is called the *paradox of thrift*?

d. Does this paradox arise in the classical model of Chapter 3? Why or why not?

5. LaunchPad • Suppose that the money demand function is

$$(M/P)^d = 800 - 50r,$$

where r is the interest rate in percent. The money supply M is 2,000 and the price level P is fixed at 5.

a. Graph the supply and demand for real money balances.

b. What is the equilibrium interest rate?

c. What happens to the equilibrium interest rate if the supply of money is reduced from 2,000 to 1,500?

d. If the central bank wants the interest rate to be 4 percent, what money supply should it set?

6. LaunchPad • The following equations describe an economy.

$$Y = C + I + G.$$

$$C = 50 + 0.75\,(Y - T).$$

$$I = 150 - 10\,r.$$

$$(M/P)^d = Y - 50r.$$

$$G = 250.$$

$$T = 200.$$

$$M = 3{,}000.$$

$$P = 4.$$

a. Identify each of the variables and briefly explain their meaning.

b. From the above list, use the relevant set of equations to derive the *IS* curve. Graph the *IS* curve on an appropriately labeled graph.

c. From the above list, use the relevant set of equations to derive the *LM* curve. Graph the *LM* curve on the same graph you used in part (b).

d. What are the equilibrium level of income and the equilibrium interest rate?

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equilibrium in the market for goods and services and in the market for real money balances.

3. The aggregate demand curve summarizes the results from the *IS–LM* model by showing equilibrium income at any given price level. The aggregate demand curve slopes downward because a lower price level increases real money balances, lowers the interest rate, stimulates investment spending, and thereby raises equilibrium income.
4. Expansionary fiscal policy—an increase in government purchases or a decrease in taxes—shifts the *IS* curve to the right. This shift in the *IS* curve increases the interest rate and income. The increase in income represents a rightward shift in the aggregate demand curve. Similarly, contractionary fiscal policy shifts the *IS* curve to the left, lowers the interest rate and income, and shifts the aggregate demand curve to the left.
5. Expansionary monetary policy shifts the *LM* curve downward. This shift in the *LM* curve lowers the interest rate and raises income. The increase in income represents a rightward shift of the aggregate demand curve. Similarly, contractionary monetary policy shifts the *LM* curve upward, raises the interest rate, lowers income, and shifts the aggregate demand curve to the left.

KEY CONCEPTS

Monetary transmission mechanism

Pigou effect

Debt-deflation theory

Liquidity trap

QUESTIONS FOR REVIEW

1. Explain why the aggregate demand curve slopes downward.
2. What is the impact of an increase in taxes on the interest rate, income, consumption, and investment?
3. What is the impact of a decrease in the money supply on the interest rate, income, consumption, and investment?
4. Describe the possible effects of falling prices on equilibrium income.

PROBLEMS AND APPLICATIONS

1. According to the *IS–LM* model, what happens in the short run to the interest rate, income, consumption, and investment under the following circumstances? Be sure your answer includes an appropriate graph.
   a. The central bank increases the money supply.
   b. The government increases government purchases.
   c. The government increases taxes.
   d. The government increases government purchases and taxes by equal amounts.
2. Use the *IS–LM* model to predict the short-run effects of each of the following shocks on income, the interest rate, consumption, and investment. In each case, explain what the Fed should do to keep income at its

initial level. Be sure to use a graph in each of your answers.

a. After the invention of a new high-speed computer chip, many firms decide to upgrade their computer systems.

b. A wave of credit card fraud increases the frequency with which people make transactions in cash.

c. A best-seller titled *Retire Rich* convinces the public to increase the percentage of their income devoted to saving.

d. The appointment of a new "dovish" Federal Reserve chair increases expected inflation.

3. LaunchPad • Consider the economy of Hicksonia.

a. The consumption function is given by

$$C = 300 + 0.6(Y - T).$$

The investment function is

$$I = 700 - 80r.$$

Government purchases and taxes are both 500. For this economy, graph the *IS* curve for r ranging from 0 to 8.

b. The money demand function in Hicksonia is

$$(M/P)^d = Y - 200r.$$

The money supply M is 3,000 and the price level P is 3. Graph the *LM* curve for r ranging from 0 to 8.

c. Find the equilibrium interest rate r and the equilibrium level of income Y.

d. Suppose that government purchases are increased from 500 to 700. How does the *IS* curve shift? What are the new equilibrium interest rate and level of income?

e. Suppose instead that the money supply is increased from 3,000 to 4,500. How does the *LM* curve shift? What are the new equilibrium interest rate and level of income?

f. With the initial values for monetary and fiscal policy, suppose that the price level rises from 3 to 5. What happens? What are the new equilibrium interest rate and level of income?

g. For the initial value of monetary and fiscal policy, derive and graph an equation for the aggregate demand curve. What happens to this aggregate demand curve if fiscal or monetary policy changes, as in parts (d) and (e)?

4. LaunchPad • An economy is initially described by the following equations:

$$C = 500 + 0.75(Y - T)$$

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

$$M/P = Y - 200r$$

$$G = 1000$$

$$T = 1000$$

$$M = 6{,}000$$

$$P = 2$$

a. Derive and graph the *IS* curve and the *LM* curve. Calculate the equilibrium interest rate and level of income. Label that point A on your graph.

b. Suppose that a newly elected president cuts taxes by 20 percent. Assuming the money supply is held constant, what are the new equilibrium interest rate and level of income? What is the tax multiplier?

c. Now assume that the central bank adjusts the money supply to hold the interest rate constant. What is the new level of income? What must the new money supply be? What is the tax multiplier?

d. Now assume that the central bank adjusts the money supply to hold the level of income constant. What is the new equilibrium interest rate? What must the money supply be? What is the tax multiplier?

e. Show the equilibria you calculated in parts (b), (c), and (d) on the graph you drew in part (a). Label them points B, C, and D.

5. Determine whether each of the following statements is true or false, and explain why. For each true statement, discuss whether there is anything unusual about the impact of monetary and fiscal policy in that special case.

a. If investment does not depend on the interest rate, the *LM* curve is horizontal.

b. If investment does not depend on the interest rate, the *IS* curve is vertical.

c. If money demand does not depend on the interest rate, the *IS* curve is horizontal.

d. If money demand does not depend on the interest rate, the *LM* curve is vertical.

e. If money demand does not depend on income, the *LM* curve is horizontal.

f. If money demand is extremely sensitive to the interest rate, the *LM* curve is horizontal.

6. Monetary policy and fiscal policy often change at the same time.

a. Suppose that the government wants to raise investment but keep output constant. In the *IS–LM* model, what mix of monetary and fiscal policy will achieve this goal?

b. In the early 1980s, the U.S. government cut taxes and ran a budget deficit while the Fed pursued a tight monetary policy. What effect should this policy mix have?

7. Use the *IS–LM* diagram to describe both the short-run effects and the long-run effects of the following changes on national income, the interest rate, the price level, consumption, investment, and real money balances.

a. An increase in the money supply

b. An increase in government purchases

c. An increase in taxes

8. The Fed is considering two alternative monetary policies:

- holding the money supply constant and letting the interest rate adjust, or
- adjusting the money supply to hold the interest rate constant.

In the *IS–LM* model, which policy will better stabilize output under the following conditions? Explain your answer.

a. All shocks to the economy arise from exogenous changes in the demand for goods and services.

b. All shocks to the economy arise from exogenous changes in the demand for money.

9. Suppose that the demand for real money balances depends on disposable income. That is, the money demand function is

$$M/P = L(r, Y - T).$$

Using the *IS–LM* model, discuss whether this change in the money demand function alters the following.

a. The analysis of changes in government purchases

b. The analysis of changes in taxes

10. This problem asks you to analyze the *IS–LM* model algebraically. Suppose consumption is a linear function of disposable income:

$$C(Y - T) = a + b(Y - T),$$

where $a > 0$ and $0 < b < 1$. The parameter b is the marginal propensity to consume, and the parameter a is a constant sometimes called autonomous consumption. Suppose also that investment is a linear function of the interest rate:

$$I(r) = c - dr,$$

where $c > 0$ and $d > 0$. The parameter d measures the sensitivity of investment to the interest rate, and the parameter c is a constant sometimes called autonomous investment.

a. Solve for Y as a function of r, the exogenous variables G and T, and the model's parameters a, b, c, and d.

b. How does the slope of the *IS* curve depend on the parameter d, the interest sensitivity of investment? Refer to your answer to part (a), and explain the intuition.

c. Which will cause a bigger horizontal shift in the *IS* curve, a \$100 tax cut or a \$100 increase in government spending? Refer to your answer to part (a), and explain the intuition.

Now suppose demand for real money balances is a linear function of income and the interest rate:

$$L(r, Y) = eY - fr,$$

where $e > 0$ and $f > 0$. The parameter e measures the sensitivity of money demand to income, while the parameter f measures the sensitivity of money demand to the interest rate.

d. Solve for r as a function of Y, M, and P and the parameters e and f.

e. Using your answer to part (d), determine whether the LM curve is steeper for large or small values of f, and explain the intuition.

f. How does the size of the shift in the LM curve resulting from a \$100 increase in M depend on

i. the value of the parameter e, the income sensitivity of money demand?

ii. the value of the parameter f, the interest sensitivity of money demand?

g. Use your answers to parts (a) and (d) to derive an expression for the aggregate demand curve. Your expression should show Y as a function of P; of exogenous policy variables M, G, and T; and of the model's parameters. This expression should not contain r.

h. Use your answer to part (g) to prove that the aggregate demand curve has a negative slope.

i. Use your answer to part (g) to prove that increases in G and M, and decreases in T, shift the aggregate demand curve to the right. How does this result change if the parameter f, the interest sensitivity of money demand, equals zero? Explain the intuition for your result.

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PROBLEMS AND APPLICATIONS

1. Use the Mundell–Fleming model to predict what would happen to aggregate income, the exchange rate, and the trade balance under both floating and fixed exchange rates in response to each of the following shocks. Be sure to include an appropriate graph in your answer.
   a. A fall in consumer confidence about the future induces consumers to spend less and save more.
   b. The introduction of a stylish line of Toyotas makes some consumers prefer foreign cars over domestic cars.
   c. The introduction of automatic teller machines reduces the demand for money.
2. LaunchPad • A small open economy is described by the following equations:

$$C = 50 + .75(Y - T)$$

$$I = 200 - 20r$$

$$NX = 200 - 50\epsilon$$

$$M/P = Y - 40r$$

$$G = 200$$

$$T = 200$$

$$M = 3000$$

$$P = 3$$

$$r^* = 5$$

   a. Derive and graph the IS^* and LM^* curves.
   b. Calculate the equilibrium exchange rate, level of income, and net exports.
   c. Assume a floating exchange rate. Calculate what happens to the exchange rate, the level of income, net exports, and the money supply if the government increases its spending by 50. Use a graph to explain what you find.
   d. Now assume a fixed exchange rate. Calculate what happens to the exchange rate, the level of income, net exports, and the money supply if the government increases its spending by 50. Use a graph to explain what you find.
3. A small open economy with a floating exchange rate is in recession with balanced trade. If policymakers want to reach full employment while maintaining balanced trade, what combination of monetary and fiscal policy should they choose? Use a graph, and be sure to identify the effects of each policy.
4. The Mundell–Fleming model takes the world interest rate r^* as an exogenous variable. Let's consider what happens when this variable changes.
   a. What might cause the world interest rate to rise? (*Hint*: The world is a closed economy.)
   b. If the economy has a floating exchange rate, what happens to aggregate income, the exchange rate, and the trade balance when the world interest rate rises?
   c. If the economy has a fixed exchange rate, what happens to aggregate income, the exchange rate, and the trade balance when the world interest rate rises?
5. Business executives and policymakers are often concerned about the competitiveness of American industry (the ability of U.S. industries to sell their goods profitably in world markets).
   a. How would a change in the nominal exchange rate affect competitiveness in the short run when prices are sticky?
   b. Suppose you wanted to make domestic industries more competitive but did not want to alter aggregate income. According to the Mundell–Fleming model, what combination of monetary and fiscal policies should you pursue? Use a graph, and be sure to identify the effects of each policy.
6. Suppose that higher income implies higher imports and thus lower net exports. That is, the net-exports function is

$$NX = NX(e, Y).$$

   Examine the effects in a small open economy of a fiscal expansion on income and the trade balance under the following exchange-rate regimes.
   a. A floating exchange rate
   b. A fixed exchange rate

   How does your answer compare to the results in Table 13-1?

7. Suppose that money demand depends on disposable income, so that the equation for the money market becomes

$$M/P = L(r, Y - T).$$

Analyze the short-run impact of a tax cut in a small open economy on the exchange rate and income under both floating and fixed exchange rates.

8. Suppose that the price level relevant for money demand includes the price of imported goods and that the price of imported goods depends on the exchange rate. That is, the money market is described by

$$M/P = L(r, Y),$$

where

$$P = \lambda P_d + (1 - \lambda)P_f/e.$$

Here, P_d is the price of domestic goods, P_f is the price of foreign goods measured in the foreign currency, and e is the exchange rate. Thus, P_f/e is the price of foreign goods measured in the domestic currency. The parameter λ is the share of domestic goods in the price index P. Assume that the price of domestic goods P_d and the price of foreign goods measured in foreign currency P_f are sticky in the short run.

   a. Suppose that we graph the LM^* curve for given values of P_d and P_f (instead of the usual P). Is this LM^* curve still vertical? Explain.

   b. What is the effect of expansionary fiscal policy under floating exchange rates in this model? Explain. Contrast with the standard Mundell–Fleming model.

   c. Suppose that political instability increases the country risk premium and, thereby, the interest rate. What is the effect on the exchange rate, the price level, and aggregate income in this model? Contrast with the standard Mundell–Fleming model.

9. Use the Mundell–Fleming model to answer the following questions about the state of California (a small open economy).

   a. What kind of exchange-rate system does California have with its major trading partners (Alabama, Alaska, Arizona, . . .)?

   b. If California suffers from a recession, should the state government use monetary or fiscal policy to stimulate employment? Explain. (*Note*: For this question, assume that the state government can print dollar bills.)

   c. If California prohibited the import of wines from the state of Washington, what would happen to income, the exchange rate, and the trade balance? Consider both the short-run and the long-run impacts.

   d. Can you think of any important features of the Californian economy that are different from, say, the Canadian economy and that might make the Mundell–Fleming model less useful when applied to California than to Canada?

exchange. The exchange rate falls, as in panel (c). As domestic goods become cheaper relative to foreign goods, net exports rise.

We can now see that the monetary transmission mechanism works through two channels in a large open economy. As in a closed economy, a monetary expansion lowers the interest rate, which stimulates investment. As in a small open economy, a monetary expansion causes the currency to depreciate in the market for foreign exchange, which stimulates net exports. Both effects result in a higher level of aggregate income. Indeed, because the *IS* curve is flatter here than it is in a closed economy, any given shift in the *LM* curve will have a larger impact on income.

A Rule of Thumb

This model of the large open economy describes well the U.S. economy today. Yet it is somewhat more complicated and cumbersome than the model of the closed economy we studied in Chapters 11 and 12 and the model of the small open economy we developed in this chapter. Fortunately, there is a useful rule of thumb to help you determine how policies influence a large open economy without remembering all the details of the model: *The large open economy is an average of the closed economy and the small open economy. To find how any policy will affect any variable, find the answer in the two extreme cases and take an average.*

For example, how does a monetary contraction affect the interest rate and investment in the short run? In a closed economy, the interest rate rises, and investment falls. In a small open economy, neither the interest rate nor investment changes. The effect in the large open economy is an average of these two cases: a monetary contraction raises the interest rate and reduces investment, but only somewhat. The fall in the net capital outflow mitigates the rise in the interest rate and the fall in investment that would occur in a closed economy. But unlike in a small open economy, the international flow of capital is not so strong as to fully negate these effects.

This rule of thumb makes the simple models all the more valuable. Although they do not describe perfectly the world in which we live, they do provide a useful guide to the effects of economic policy.

MORE PROBLEMS AND APPLICATIONS

1. Imagine that you run the central bank in a large open economy with a floating exchange rate. Your goal is to stabilize income, and you adjust the money supply accordingly. Under your policy, what happens to the money supply, the interest rate, the exchange rate, and the trade balance in response to each of the following shocks?

a. The government raises taxes to reduce the budget deficit.

b. The government restricts the import of foreign cars.

2. Over the past several decades, the economies of the world have become more financially integrated. That is, investors in all nations have become more willing and able to take advantage of financial opportunities abroad. Consider how this development affects the ability of monetary policy to influence the economy.
   a. If investors become more willing and able to substitute foreign and domestic assets, what happens to the slope of the *CF* function?
   b. If the *CF* function changes in this way, what happens to the slope of the *IS* curve?
   c. How does this change in the *IS* curve affect the Fed's ability to control the interest rate?
   d. How does this change in the *IS* curve affect the Fed's ability to control national income?
3. Suppose that policymakers in a large open economy want to raise the level of investment without changing aggregate income or the exchange rate.
   a. Is there any combination of domestic monetary and fiscal policies that would achieve this goal?
   b. Is there any combination of domestic monetary, fiscal, and trade policies that would achieve this goal?
   c. Is there any combination of monetary and fiscal policies at home and abroad that would achieve this goal?
4. This appendix considers the case of a large open economy with a floating exchange rate. Now suppose instead that a large open economy has a fixed exchange rate. That is, the central bank announces a target for the exchange rate and commits itself to adjusting the money supply to ensure that the equilibrium exchange rate equals the target.
   a. Describe what happens to income, the interest rate, and the trade balance in response to a fiscal expansion, such as an increase in government purchases. Compare your answer to the case of a small open economy with a fixed exchange rate.
   b. Describe what happens to income, the interest rate, and the trade balance if the central bank expands the money supply by buying bonds from the public. Compare your answer to the case of a small open economy with a fixed exchange rate.

KEY CONCEPTS

Sticky-price model
Imperfect-information model
Phillips curve
Adaptive expectations
Demand-pull inflation
Cost-push inflation
Sacrifice ratio
Rational expectations
Natural-rate hypothesis
Hysteresis

QUESTIONS FOR REVIEW

1. Explain the two theories of aggregate supply. On what market imperfection does each theory rely? What do the theories have in common?
2. How is the Phillips curve related to aggregate supply?
3. Why might inflation be inertial?
4. Explain the differences between demand-pull inflation and cost-push inflation.
5. Under what circumstances might it be possible to reduce inflation without causing a recession?
6. Explain two ways in which a recession might raise the natural rate of unemployment.

PROBLEMS AND APPLICATIONS

1. In the sticky-price model, describe the aggregate supply curve in the following special cases. How do these cases compare to the short-run aggregate supply curve we discussed in Chapter 10?
   a. All firms have sticky prices ($s = 1$).
   b. The desired price does not depend on aggregate output ($a = 0$).
2. Suppose that an economy has the Phillips curve

$$\pi = \pi_{-1} - 0.5(u - 5).$$

   a. What is the natural rate of unemployment?
   b. Graph the short-run and long-run relationships between inflation and unemployment.
   c. How much cyclical unemployment is necessary to reduce inflation by 4 percentage points? Using Okun's law, compute the sacrifice ratio.
   d. Inflation is running at 6 percent. The central bank wants to reduce it to 2 percent. Give two scenarios that will achieve that goal.
3. LaunchPad • An economy has the following equation for the Phillips curve:

$$\pi = E\pi - .5(u - 6)$$

People form expectations of inflation by taking a weighted average of the previous two years of inflation:

$$E\pi = 0.7\ \pi_{-1} + 0.3\ \pi_{-2}$$

Okun's law for this economy is:

$$(Y - Y_{-1})/Y_{-1} = 3.0 - 2.0\ (u - u_{-1})$$

The economy begins at its natural rate of unemployment with a stable inflation rate of 5 percent.

   a. What is the natural rate of unemployment for this economy?
   b. Graph the short-run tradeoff between inflation and unemployment that this economy faces. Label the point where the economy begins as point A. (Be sure to give numerical values for point A.)
   c. A fall in aggregate demand leads to a recession, causing the unemployment rate to rise 4 percentage points above its natural rate. On your graph in part (a), label the point the economy experiences that year as point B. (Once again, be sure to give numerical values.)

d. Unemployment remains at this high level for two years (the initial year described in part (c) and one more), after which it returns to its natural rate. Create a table showing unemployment, inflation, expected inflation, and output growth for 10 years beginning two years before the recession. (These calculations are best done on a computer spreadsheet.)

e. On the same graph you used in part (b), graph the short-run tradeoff the economy faces at the end of this 10-year period. Label the point where the economy finds itself as point C. (Again, use numerical values.)

f. Compare the equilibrium before the recession with the new long-run (period ten) equilibrium. How much does inflation change? How many percentage points of output are lost during the transition? What is this economy's sacrifice ratio?

4. According to the rational-expectations approach, if everyone believes that policymakers are committed to reducing inflation, the cost of reducing inflation—the sacrifice ratio—will be lower than if the public is skeptical about the policymakers' intentions. Why might this be true? How might credibility be achieved?

5. Suppose that the economy is initially at a long-run equilibrium. Then the Fed increases the money supply.

a. Assuming any resulting inflation to be unexpected, describe any changes in GDP, unemployment, and inflation that are caused by the monetary expansion. Explain your conclusions using three diagrams: one for the *IS–LM* model, one for the *AD–AS* model, and one for the Phillips curve.

b. Assuming instead that any resulting inflation is expected, describe any changes in GDP, unemployment, and inflation that are caused by the monetary expansion. Once again, explain your conclusions using three diagrams: one for the *IS–LM* model, one for the *AD–AS* model, and one for the Phillips curve.

6. Assume that people have rational expectations and that the economy is described by the sticky-price model. Explain why each of the following propositions is true.

a. Only unanticipated changes in the money supply affect real GDP. Changes in the money supply that were anticipated when prices were set do not have any real effects.

b. If the Fed sets the money supply at the same time as people are setting prices, so that everyone has the same information about the state of the economy, then monetary policy cannot be used systematically to stabilize output. Hence, a policy of keeping the money supply constant will have the same real effects as a policy of adjusting the money supply in response to the state of the economy. (This is called the *policy irrelevance proposition*.)

c. If the Fed sets the money supply well after people have set prices, so that the Fed has collected more information about the state of the economy, then monetary policy can be used systematically to stabilize output.

7. Suppose that an economy has the Phillips curve

$$\pi = \pi_{-1} - 0.5(u - u^n)$$

and that the natural rate of unemployment is given by an average of the past two years' unemployment:

$$u^n = 0.5(u_{-1} + u_{-2}).$$

a. Why might the natural rate of unemployment depend on recent unemployment (as is assumed in the preceding equation)?

b. Suppose that the Fed follows a policy to permanently reduce the inflation rate by 1 percentage point. What effect will that policy have on the unemployment rate over time?

c. What is the sacrifice ratio in this economy? Explain.

d. What do these equations imply about the short-run and long-run tradeoffs between inflation and unemployment?

8. Some economists believe that taxes have an important effect on the labor supply. They argue that higher taxes cause people to want to work less and that lower taxes cause them to want to work more. Consider how this effect alters the macroeconomic analysis of tax changes.
   a. If this view is correct, how does a tax cut affect the natural level of output?
   b. How does a tax cut affect the aggregate demand curve? The long-run aggregate supply curve? The short-run aggregate supply curve?
   c. What is the short-run impact of a tax cut on output and the price level? How does your answer differ from the case without the labor-supply effect?
   d. What is the long-run impact of a tax cut on output and the price level? How does your answer differ from the case without the labor-supply effect?
9. Go to the Web site of the Bureau of Labor Statistics (http://www.bls.gov). For each of the past five years, find the inflation rate as measured by the consumer price index for all items (sometimes called *headline inflation*) and as measured by the CPI excluding food and energy (sometimes called *core inflation*). Compare these two measures of inflation. Why might they be different? What might the difference tell you about shifts in the aggregate supply curve and in the short-run Phillips curve?

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2. *Closed or Open?* You decide whether you want a closed economy (which occurs when the capital flow CF always equals zero) or an open economy (which allows CF to differ from zero).
3. *Small or Large?* If you want an open economy, you decide whether you want a small one (in which CF is infinitely elastic at the world interest rate r^*) or a large one (in which the domestic interest rate is not pinned down by the world rate).
4. *Floating or Fixed?* If you are examining a small open economy, you decide whether the exchange rate is floating (in which case the central bank sets the money supply) or fixed (in which case the central bank allows the money supply to adjust).
5. *Fixed Velocity?* If you are considering a closed economy with the Keynesian assumption of fixed prices, you decide whether you want to focus on the special case in which velocity is exogenously fixed.

By making this series of modeling decisions, you move from the more complete and complex model to a simpler, more narrowly focused special case that is easier to understand and use.

When you are thinking about the real world, it is important to keep in mind all the models and their simplifying assumptions. Each of these models provides insight into some facet of the economy.

MORE PROBLEMS AND APPLICATIONS

1. Let's consider some more special cases of the mother of all models. Starting with this comprehensive model, what extra assumptions would you need to yield each of the following specialized models?
   a. The model of the classical large open economy in the appendix to Chapter 6.
   b. The Keynesian cross in the first half of Chapter 11.
   c. The *IS–LM* model for the large open economy in the appendix to Chapter 13.

PROBLEMS AND APPLICATIONS

1. Derive the long-run equilibrium for the dynamic *AD–AS* model. Assume there are no shocks to demand or supply ($\epsilon_t = v_t = 0$) and inflation has stabilized ($\pi_t = \pi_{t-1}$), and then use the five equations in Table 15-1 to derive the value of each variable in the model. Be sure to show each step you follow.

2. Suppose the monetary-policy rule has the wrong natural rate of interest. That is, the central bank follows this rule:

$$i_t = \pi_t + \rho' + \theta_\pi(\pi_t - \pi_t^*) + \theta_Y(Y_t - \bar{Y}_t)$$

   where ρ' does not equal ρ, the natural rate of interest in the goods demand equation. The rest of the dynamic *AD–AS* model is the same as in the chapter. Solve for the long-run equilibrium under this policy rule. Explain in words the intuition behind your solution.

3. "If a central bank wants to achieve lower nominal interest rates, it has to raise the nominal interest rate." Explain in what way this statement makes sense.

4. The *sacrifice ratio* is the accumulated loss in output that results when the central bank lowers its target for inflation by 1 percentage point. For the parameters used in the text simulation (see the FYI box), what is the implied sacrifice ratio? Explain.

5. The text analyzes the case of a temporary shock to the demand for goods and services. Suppose, however, that ϵ_t were to increase permanently. What would happen to the economy over time? In particular, would the inflation rate return to its target in the long run? Why or why not? (*Hint*: It might be helpful to solve for the long-run equilibrium without the assumption that ϵ_t equals zero.) How might the central bank alter its policy rule to deal with this issue?

6. Suppose a central bank does not satisfy the Taylor principle; in particular, assume that θ_π is slightly less than zero, so the nominal interest rate rises less than one-for-one with inflation. Use a graph similar to figure 15-13 to analyze the impact of a supply shock. Does this analysis contradict or reinforce the Taylor principle as a guideline for the design of monetary policy?

7. The text assumes that the natural rate of interest ρ is a constant parameter. Suppose instead that it varies over time, so now it has to be written as ρ_t.

   a. How would this change affect the equations for dynamic aggregate demand and dynamic aggregate supply?

   b. How would a shock to ρ_t affect output, inflation, the nominal interest rate, and the real interest rate?

   c. Can you see any practical difficulties that a central bank might face if ρ_t varied over time?

8. Suppose that people's expectations of inflation are subject to random shocks. That is, instead of being merely adaptive, expected inflation in period t, as seen in period $t - 1$, is $E_{t-1}\pi_t = \pi_{t-1} + \eta_{t-1}$, where η_{t-1} is a random shock. This shock is normally zero, but it deviates from zero when some event beyond past inflation causes expected inflation to change. Similarly, $E_t\pi_{t+1} = \pi_t + \eta_t$.

   a. Derive both the dynamic aggregate demand (*DAD*) equation and the dynamic aggregate supply (*DAS*) equation in this slightly more general model.

   b. Suppose that the economy experiences an *inflation scare*. That is, in period t, for some reason people come to believe that inflation in period $t + 1$ is going to be higher, so η_t is greater than zero (for this period only). What happens to the *DAD* and *DAS* curves in period t? What happens to output, inflation, and nominal and real interest rates in that period? Explain.

   c. What happens to the *DAD* and *DAS* curves in period $t + 1$? What happens to output, inflation, and nominal and real interest rates in that period? Explain.

   d. What happens to the economy in subsequent periods?

   e. In what sense are inflation scares self-fulfilling?

9. Use the dynamic *AD–AS* model to solve for inflation as a function of only lagged inflation and supply and demand shocks. (Assume target inflation is constant.)
   a. According to the equation you have derived, does inflation return to its target after a shock? Explain. (*Hint*: Look at the coefficient on lagged inflation.)
   b. Suppose the central bank does not respond to changes in output but only to changes in inflation, so that $\theta_Y = 0$. How, if at all, would this fact change your answer to part (a)?
   c. Suppose the central bank does not respond to changes in inflation but only to changes in output, so that $\theta_\pi = 0$. How, if at all, would this fact change your answer to part (a)?
   d. Suppose the central bank does not follow the Taylor principle but instead raises the nominal interest rate only 0.8 percentage point for each percentage-point increase in inflation. In this case, what is θ_π? How does a shock to demand or supply influence the path of inflation?