4.15. The derivation of the log-linearized equation of motion for capital. Consider the equation of motion for capital, $K_{t+1} = K_t + K_t^{\alpha}(A_t L_t)^{1-\alpha} - C_t - G_t - \delta K_t$.

(*a*) (*i*) Show that $\partial \ln K_{t+1} / \partial \ln K_t$ (holding A_t, L_t, C_t, and G_t fixed) is $(1 + r_{t+1})(K_t/K_{t+1})$.

(*ii*) Show that this implies that $\partial \ln K_{t+1} / \partial \ln K_t$ evaluated at the balanced growth path is $(1 + r^*)/e^{n+g}$.[44]

(*b*) Show that

$$\tilde{K}_{t+1} \simeq \lambda_1 \tilde{K}_t + \lambda_2(\tilde{A}_t + \tilde{L}_t) + \lambda_3 \tilde{G}_t + (1 - \lambda_1 - \lambda_2 - \lambda_3)\tilde{C}_t,$$

where $\lambda_1 \equiv (1 + r^*)/e^{n+g}, \lambda_2 \equiv (1 - \alpha)(r^* + \delta)/(\alpha e^{n+g})$, and $\lambda_3 = -(r^* + \delta)(G/Y)^*/(\alpha e^{n+g})$; and where $(G/Y)^*$ denotes the ratio of G to Y on the balanced growth path without shocks. (Hints: Since the production function is Cobb-Douglas, $Y^* = (r^* + \delta)K^*/\alpha$. On the balanced growth path, $K_{t+1} = e^{n+g}K_t$, which implies that $C^* = Y^* - G^* - \delta K^* - (e^{n+g} - 1)K^*$.)

(*c*) Use the result in (*b*) and equations (4.43)–(4.44) to derive (4.52), where $b_{KK} = \lambda_1 + \lambda_2 a_{LK} + (1 - \lambda_1 - \lambda_2 - \lambda_3)a_{CK}$, $b_{KA} = \lambda_2(1 + a_{LA}) + (1 - \lambda_1 - \lambda_2 - \lambda_3)a_{CA}$, and $b_{KG} = \lambda_2 a_{LG} + \lambda_3 + (1 - \lambda_1 - \lambda_2 - \lambda_3)a_{CG}$.

4.16. A Monte Carlo experiment and the source of bias in OLS estimates of trend reversion. Suppose output growth is described simply by $\Delta \ln y_t = \varepsilon_t$, where the ε's are independent, mean-zero disturbances. Normalize the initial value of $\ln y$, denoted by $\ln y_0$, to 0. This problem asks you to consider what occurs in this situation if one estimates equation (4.56), $\Delta \ln y_t = \alpha' + b \ln y_{t-1} + \varepsilon_t$, by ordinary least squares.

(*a*) Suppose the sample size is 3, and suppose each ε is equal to 1 with probability $\frac{1}{2}$ and -1 with probability $\frac{1}{2}$. For each of the eight possible realizations of $(\varepsilon_1, \varepsilon_2, \varepsilon_3)$ ((1, 1, 1), (1, 1, −1), and so on), what is the OLS estimate of b? What is the average of the estimates? Explain intuitively why the estimates differ systematically from the true value of $b = 0$.

(*b*) Suppose the sample size is 200, and suppose each ε is normally distributed with a mean of 0 and a variance of 1. Using a random-number generator on a computer, generate 200 such ε's; then generate $\ln y$'s using $\Delta \ln y_t = \varepsilon_t$ and $\ln y_0 = 0$; then estimate (4.56) by OLS; finally, record the estimate of b. Repeat this process 500 times. What is the average estimate of b? What fraction of the estimated b's is negative?

Chapter 5
TRADITIONAL KEYNESIAN THEORIES OF FLUCTUATIONS

This chapter and the next develop models of fluctuations based on the assumption that there are barriers to the instantaneous adjustment of nominal prices and wages. As we will see, sluggish nominal adjustment causes changes in the aggregate demand for goods at a given level of prices to affect the amount that firms produce. As a result, it causes purely monetary disturbances (which affect only demand) to change employment and output. In addition, many real shocks, including changes in government purchases, investment demand, and technology, affect aggregate demand at a given price level; thus sluggish price adjustment creates a channel other than the intertemporal-substitution and capital-accumulation mechanisms of basic real-business-cycle models through which these shocks affect employment and output.

This chapter takes nominal stickiness as given. It has two main goals. The first is to investigate aggregate demand. We will examine the determinants of aggregate demand at a given price level and the effects of changes in the price level. The second is to consider alternative assumptions about the form of nominal rigidity. We will investigate different assumptions' implications for firms' willingness to change output in response to changes in aggregate demand and for the behavior of real wages, markups, and inflation. Chapter 6 then turns to the questions of why nominal prices and wages might not adjust immediately to disturbances.

The models of this chapter are based on traditional Keynesian models. Thus both their substance and their modeling strategy are at the other extreme from the pure real-business-cycle models of Chapter 4. The models in this chapter often directly specify relationships among aggregate variables. The relationships are often static, and the models' implications for the behavior of some variables (such as the capital stock) are sometimes omitted from the analysis. In addition, rather than specifying stochastic processes for the exogenous variables, the analysis focuses on the effects of one-time

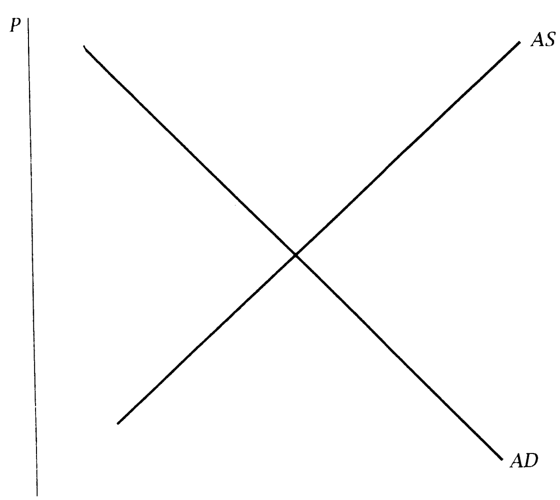
The remainder of the chapter consists of six sections. Sections 5.1 and 5.2 develop the aggregate demand side of the standard Keynesian model. These sections take as given that nominal prices and wages are not completely flexible, and that firms change their output in response to changes in demand. Section 5.1 assumes a closed economy, and Section 5.2 considers the open-economy case.

Sections 5.3 and 5.4 consider aggregate supply. Section 5.3 shows how different combinations of wage rigidity, price rigidity, and non-Walrasian features of the labor and goods markets yield different implications about the effect of shifts in aggregate demand on output, unemployment, the real wage, and the markup. Section 5.4 discusses short-run and long-run output-inflation tradeoffs.

Finally, Sections 5.5 and 5.6 discuss some empirical evidence about the real effects of monetary changes and the cyclical behavior of the real wage.

5.1 Review of the Textbook Keynesian Model of Aggregate Demand

The textbook Keynesian model is traditionally summarized by two curves in output-price or output-inflation space, an aggregate demand (AD) curve and an aggregate supply (AS) curve. The AD curve slopes down and the AS curve slopes up. These curves are shown in Figure 5.1.



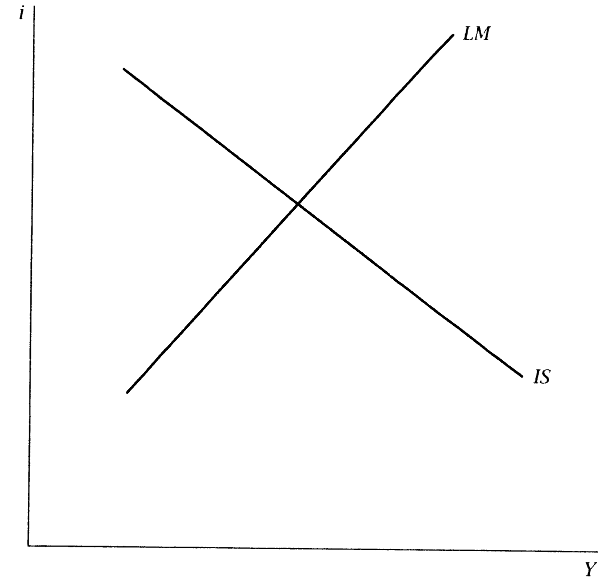


FIGURE 5.2 The *IS-LM* diagram

The fact that the aggregate supply curve is upward-sloping rather than vertical is the critical feature of the model. If the AS curve is vertical, changes on the demand side of the economy affect only prices. But if it is merely upward-sloping, changes in aggregate demand affect both prices and output.

The AD curve summarizes the demand side of the economy. It is derived from two familiar curves in output-interest rate space, the IS and LM curves. These are shown in Figure 5.2. The curves are drawn for a given price level; as we will see shortly, considering different values of the price level allows us to use the IS and LM curves to derive the AD curve. Although there are innumerable variations and extensions of the IS-LM model, here we consider a standard version.

The *IS* Curve

The IS curve shows the combinations of output and the interest rate such that planned and actual expenditures on output are equal.[1] Planned real expenditure depends positively on real income, negatively on the real in-negatively on taxes:

$$E = E(Y, i - \pi^e, G, T), \quad 0 < E_Y < 1,\ E_{i-\pi^e} < 0,\ E_G > 0,\ E_T < 0. \tag{5.1}$$

Here E is planned real expenditure, Y is real output, i is the nominal interest rate, π^e is expected inflation, G is real government purchases, and T is real taxes. E_Y, $E_{i-\pi^e}$, and so on denote the partial derivatives of $E(\bullet)$. G, T, and π^e are all taken as given.[2] The negative effect of the real interest rate on planned expenditure operates through firms' investment decisions and through consumers' purchases, particularly of durable goods. Planned expenditure is assumed to increase less than one-for-one with income; that is, $0 < E_Y < 1$.

In textbook treatments, E is often expressed in terms of its component parts, and strong assumptions are made about how the determinants of planned expenditure enter. A standard formulation is

$$E = C(Y - T) + I(i - \pi^e) + G, \tag{5.2}$$

where $C(\bullet)$ is consumption and $I(\bullet)$ is investment. The restrictions imposed in this specification may be highly unrealistic. For example, there is considerable evidence that the real interest rate affects consumption, and almost overwhelming evidence that income influences investment. To give another example, there is little basis for assuming that income and taxes have equal and opposite effects on spending. Since the general formulation in (5.1) is only slightly more difficult, we will use it in what follows.

If one treats goods that a firm produces and then holds as inventories as purchased by the firm, then all output is purchased by someone. Thus actual expenditure equals the economy's output, Y. In equilibrium, planned and actual expenditures must be equal. If planned expenditure falls short of actual expenditure, for example, firms are accumulating unwanted inventories; they will respond by cutting their production. Thus equilibrium requires

$$E = Y. \tag{5.3}$$

Substituting (5.3) into (5.1) yields

$$Y = E(Y, i - \pi^e, G, T). \tag{5.4}$$

Figure 5.3, the *Keynesian cross*, depicts equations (5.1) and (5.3) in (Y, E) space for a given level of the interest rate. Equation (5.3) is just the 45-degree line. Since planned expenditure increases less than one-for-one with Y, the set of points satisfying (5.1) is less steep than the 45-degree line. The point where the planned expenditure curve crosses the 45-degree line (Point A)

[2] Properly speaking, expected inflation should be determined within the model rather

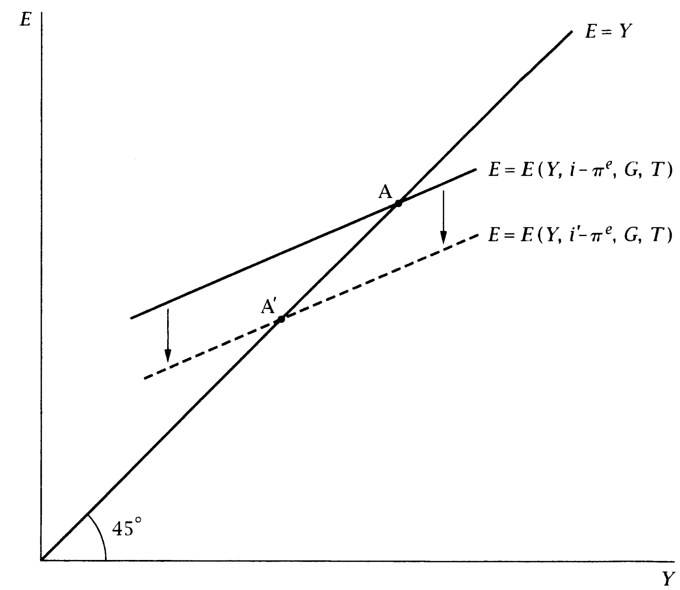


FIGURE 5.3 The Keynesian cross

shows the unique level of income where actual and planned expenditures are equal for the given interest rate.[3]

An increase in the interest rate shifts the planned expenditure line down (since $E(\bullet)$ is decreasing in $i - \pi^e$), and thus reduces the level of income at which actual and planned expenditures are equal; in terms of the diagram, an increase in the interest rate from i to i' shifts the intersection of the two lines from Point A to Point A′. Thus the *IS* curve slopes down.

Differentiating both sides of (5.4) with respect to i yields

$$\left.\frac{dY}{di}\right|_{IS} = E_Y\left(\left.\frac{dY}{di}\right|_{IS}\right) + E_{i-\pi^e}, \tag{5.5}$$

or

$$\left.\frac{dY}{di}\right|_{IS} = \frac{E_{i-\pi^e}}{1 - E_Y}, \tag{5.6}$$

where $\left.\frac{dY}{di}\right|_{IS}$ denotes dY/di along the *IS* curve. Since this is an expression for dY/di (rather than di/dY), it implies that the *IS* curve is flatter when either $E_{i-\pi^e}$ or E_Y is larger. Intuitively, the larger the effect of the interest rate on planned expenditure, the larger the downward shift of the planned expenditure line, and thus the larger the fall in output. Similarly, the steeper the planned expenditure line, the more output must fall in response to a given downward shift of the planned expenditure line to reach a point where planned and actual expenditures are again in balance, and thus the larger the fall in output. This last effect is the famous *multiplier:* because E depends on Y, the fall in Y needed to restore the equality of E and Y is larger than the amount that E falls at a given Y.

The *LM* Curve

The LM curve shows the combinations of output and the interest rate that lead to equilibrium in the money market for a given price level. It is simplest to think of money as high-powered money—currency and reserves—issued by the government. Since high-powered money pays no nominal interest, the opportunity cost of holding it is the nominal interest rate. The demand for real money balances is therefore a decreasing function of the nominal interest rate. In addition, since the volume of transactions is greater when output is higher, the demand for real balances is increasing in output. The nominal money supply is set by the government. Putting all this together, the condition for the supply and demand of real balances to be equal at a given price level is

$$\frac{M}{P} = L(i, Y), \qquad L_i < 0, \qquad L_Y > 0, \tag{5.7}$$

where M is the quantity of money and P is the price level.

Since $L(\bullet)$ is decreasing in i and increasing in Y, the set of combinations of i and Y that satisfy (5.7) is upward-sloping. Formally, differentiating both sides of (5.7) with respect to Y and rearranging yields

$$\left.\frac{di}{dY}\right|_{LM} = -\frac{L_Y}{L_i} > 0. \tag{5.8}$$

Thus increases in the income elasticity of money demand and decreases in the interest elasticity (in absolute value) make the LM curve steeper.[4]

Implicitly, the IS-LM model treats all assets other than money as perfect substitutes. The market for these other assets is then suppressed by Walras's law. Specifically, total wealth in the economy equals the total value of all assets, and the total value of any individual's asset holdings must equal his or her total wealth. Thus if the market for every asset but one clears,

[4] This presentation makes the standard assumption that M is exogenous. Taylor (1998) and D. Romer (2000) have recently proposed replacing this assumption with an assumption [illegible] interest rate an increasing function of

the market for the remaining asset must clear as well. In the IS-LM model there are only two assets (money and everything else), and so only one asset-market equilibrium condition is needed. Many important extensions of the IS-LM model investigate the consequences of relaxing the assumption that all assets other than money are perfect substitutes.[5]

The *AD* Curve

The intersection of the IS and LM curves shows the values of i and Y such that the money market clears and actual and planned expenditures are equal for given levels of M, P, π^e, G, and T. To see how the IS and LM curves imply the existence of a downward-sloping relationship between P and Y, consider the effects of assuming a higher value of P. Since the price level does not enter the planned expenditure function, $E(\bullet)$, the IS curve is unaffected. The rise in the price level reduces the supply of real money balances, however. Thus a higher interest rate is needed to clear the money market for a given level of income, and so the LM curve shifts up. As a result, i rises and Y falls. This is shown in Figure 5.4. Thus the level of output at the

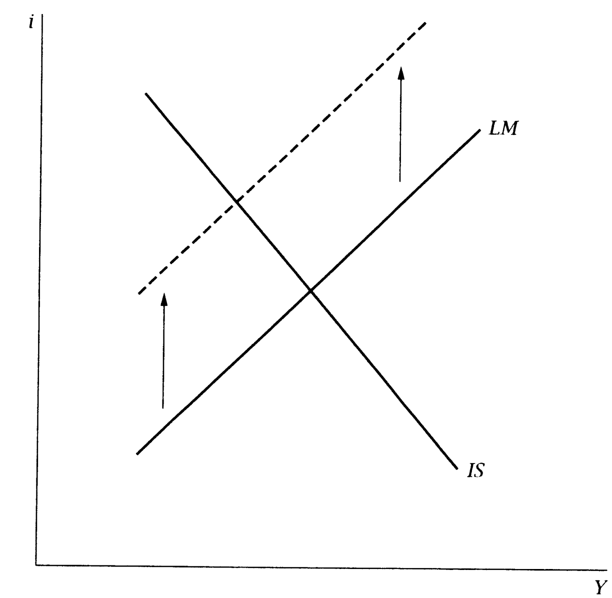


FIGURE 5.4 The effects of an increase in the price level

intersection of the IS and LM curves is a decreasing function of the price level. This is what is shown by the aggregate demand curve.

To find the slope of the AD curve, differentiate (5.4) and (5.7) with respect to P. This yields two equations in two unknowns:

$$\left.\frac{dY}{dP}\right|_{AD} = E_Y \left.\frac{dY}{dP}\right|_{AD} + E_{i-\pi^e} \left.\frac{di}{dP}\right|_{AD}, \tag{5.9}$$

$$-\frac{M}{P^2} = L_i \left.\frac{di}{dP}\right|_{AD} + L_Y \left.\frac{dY}{dP}\right|_{AD}. \tag{5.10}$$

These can be solved to obtain

$$\left.\frac{dY}{dP}\right|_{AD} = \frac{-M/P^2}{[(1-E_Y)L_i/E_{i-\pi^e}] + L_Y}. \tag{5.11}$$

This expression is unambiguously negative, and it shows the determinants of the slope of the aggregate demand curve.

Example: The Effects of an Increase in Government Purchases

The IS and LM curves provide a simple model of aggregate demand that can be used to analyze many issues. Suppose, for example, that government purchases rise. The increase in G raises planned expenditure for a given level of output and the interest rate. The planned expenditure line in Figure 5.3 therefore shifts up, and so the level of Y such that actual and planned expenditures are equal is higher for a given level of the interest rate. Thus the IS curve shifts to the right; this is shown in Panel (a) of Figure 5.5. The shift in the IS curve raises Y (and i) for a given price level, and thus moves the AD curve outward; this is shown in Panel (b) of the figure.[6]

The impact of this change in aggregate demand on output and the price level depends on the aggregate supply curve. If it is vertical, only the price level increases. If it is horizontal, only output increases. And if it is upward-sloping but not vertical, both output and the price level increase.

Thus, incomplete adjustment of nominal prices introduces a new channel through which shocks affect output. For some reason, which we have not yet specified, nominal prices do not adjust fully in the short run. As a result, any change in the demand for goods at a given price level affects output. In contrast, the intertemporal-substitution and wealth effects that drive employment fluctuations in real-business-cycle models would correspond to effects of government purchases on the aggregate supply curve—that is, they would affect not the quantity of output that households and firms want to buy at a given price level, but the quantity that firms want to

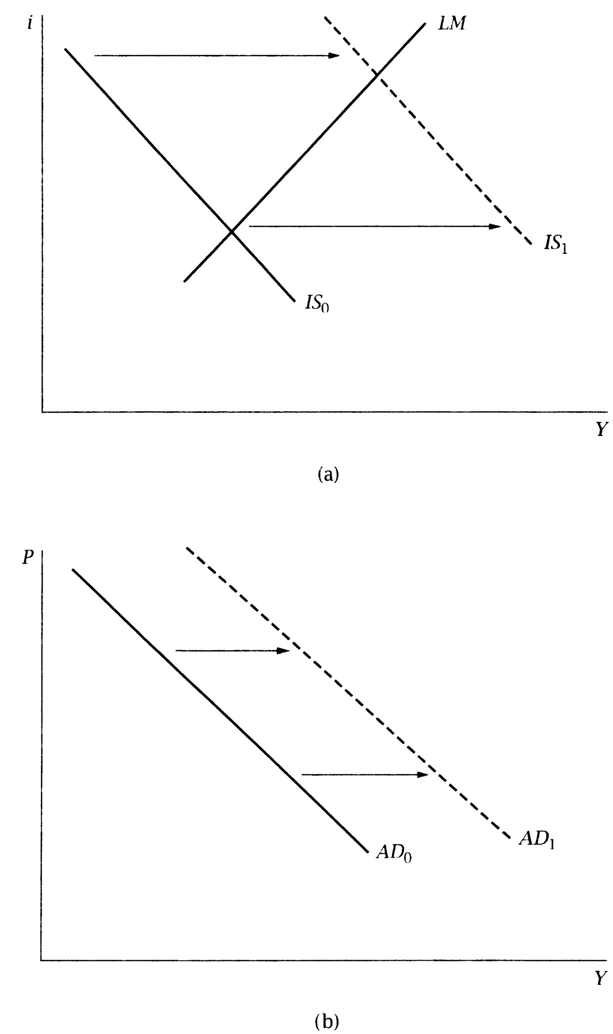


FIGURE 5.5 The effects of an increase in government purchases

5.2 The Open Economy

In most practical applications, the exchange rate and international trade

The Real Exchange Rate and Planned Expenditure

It is simplest to think of the rest of the world as consisting of a single country. Let ε denote the nominal exchange rate—specifically, the price of a unit of foreign currency in terms of domestic currency. With this definition, a rise in the exchange rate means that foreign currency has become more expensive, and therefore corresponds to a weakening, or depreciation, of the domestic currency. Similarly, a fall in ε corresponds to an appreciation of the domestic currency. Let P^* denote the price level abroad (that is, the price of foreign goods in units of foreign currency). These definitions imply that the real exchange rate—the price of foreign goods in units of domestic goods—is $\varepsilon P^*/P$.

A higher real exchange rate implies that foreign goods have become more expensive relative to domestic goods. Both domestic residents and foreigners are therefore likely to increase their purchases of domestic goods relative to foreign ones. Thus planned expenditure rises. Mathematically, equation (5.4) becomes

$$Y = E\left(Y, i - \pi^e, G, T, \frac{\varepsilon P^*}{P}\right), \tag{5.12}$$

with $E(\bullet)$ increasing in $\varepsilon P^*/P$.[8] Money demand is likely to be largely unaffected by the exchange rate; thus the LM curve is the same as before.

Since any individual country is small relative to the entire rest of the world, it is reasonable to take the foreign price level as given. But it is not reasonable to take the exchange rate as given. Equations (5.7) and (5.12), together with the AS curve, are thus not a complete model.

At this point one can make different assumptions about the exchange-rate regime (floating or fixed), capital mobility (perfect or imperfect), and exchange-rate expectations (static or rational). What set of assumptions is appropriate depends on the economy being studied and the questions being asked. Here we discuss some of the most important possibilities.

The Mundell–Fleming Model

The simplest assumptions about capital movements are that there are no barriers to capital mobility and that investors are risk-neutral; we will refer to this case as *perfect capital mobility*. Barriers to foreign investment in most industrialized countries are small, and many investors appear willing to make large changes in their portfolios in response to small rate-of-return differences. As a result, perfect capital mobility is likely to be a good approximation for many purposes.

justified both on the grounds of ease and on the grounds that it is difficult to find evidence of predictable exchange-rate movements (Meese and Rogoff, 1983). These assumptions about capital mobility and exchange-rate expectations lead to the famous Mundell-Fleming model (Mundell, 1968; Fleming, 1962).

Perfect capital mobility implies that if there were any difference in the expected rate of return between domestic and foreign assets, investors would put all their wealth into the asset with the higher yield. Since both types of assets must be held by someone, it follows that the expected rates of return on the two assets must be equal. The expected rate of return on foreign assets in terms of domestic currency is the foreign interest rate plus any expected increase in the price of foreign currency. With static exchange-rate expectations, the expected change in the price of foreign currency is zero. Thus the requirement that the expected rates of return are equal is simply

$$i = i^*, \tag{5.13}$$

where i^* is the foreign interest rate; i^* is taken as given.

At this point it is necessary to distinguish between floating and fixed exchange rates. With a floating exchange rate, aggregate demand is described by the three equations (5.7), (5.12), and (5.13) in the three unknowns i, Y, and ε. Since i is determined trivially by the requirement that it equals i^*, the system immediately reduces to two equations in Y and ε:

$$\frac{M}{P} = L(i^*, Y), \tag{5.14}$$

$$Y = E\left(Y, i^* - \pi^e, G, T, \frac{\varepsilon P^*}{P}\right). \tag{5.15}$$

Figure 5.6 plots the sets of points satisfying (5.14) and (5.15) in output-exchange rate space. Since an increase in $\varepsilon P^*/P$ raises planned expenditure, the set of solutions to (5.15) is upward-sloping; this is shown as the IS^* curve in the figure. And since the exchange rate does not affect money demand, the set of solutions to (5.14) is vertical; this is shown as the LM^* curve.

The fact that the LM^* curve is vertical means that output for a given price level—that is, the position of the AD curve—is determined entirely in the money market. To take the same example as in the previous section, suppose that government purchases rise. This change shifts the IS^* curve to the right. As shown in Figure 5.7, however, at a given price level this leads only to appreciation of the exchange rate and has no effect on output. Thus the aggregate demand curve is unaffected.

Assuming a fixed rather than a floating exchange rate requires two

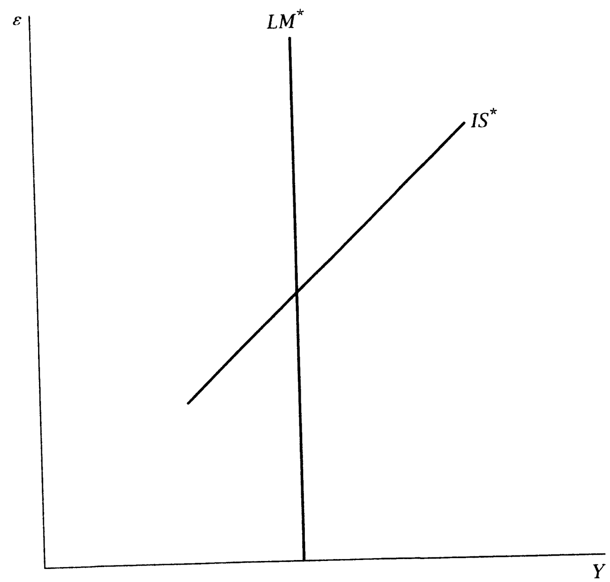
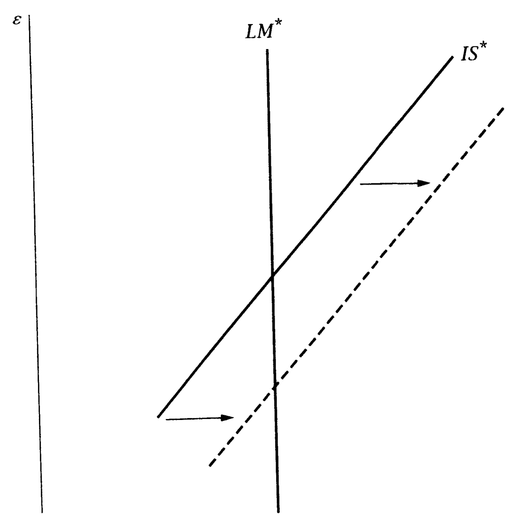


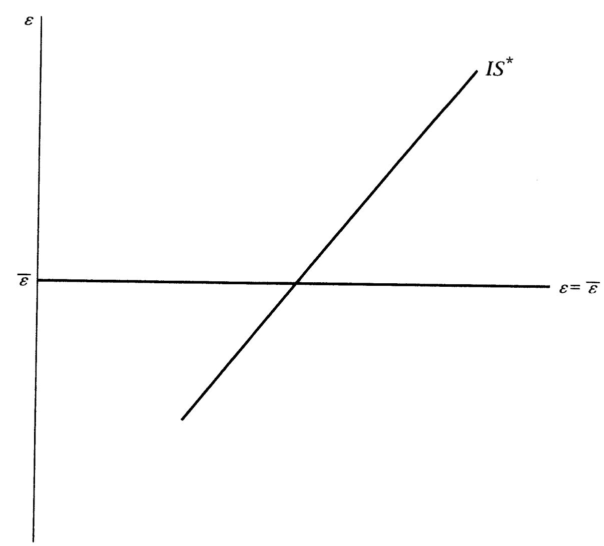
FIGURE 5.6 The Mundell–Fleming model with a floating exchange rate



Second, the money supply becomes endogenous rather than exogenous. For the government to fix the exchange rate, it must stand ready to buy or sell domestic currency in exchange for foreign currency at the rate $\overline{\varepsilon}$. The government therefore cannot independently set M, but must let it adjust to ensure that the exchange rate remains at $\overline{\varepsilon}$.

The aggregate demand side of the model with a fixed exchange rate therefore consists of the LM equation, (5.7); the IS equation, (5.12); the interest-rate equation, (5.13); and the exchange-rate equation, (5.16). Once again, we can substitute the $i = i^*$ condition into the IS and LM equations to simplify the system. This gives us the LM^* equation, (5.14); the IS^* equation, (5.15); and the exchange-rate equation, (5.16). In addition, the LM^* equation, $M/P = L(i^*, Y)$, serves only to determine M and can therefore be neglected. Thus we are left with the IS^* equation and the exchange-rate equation. The IS^* curve is upward-sloping as before, and the exchange-rate equation is simply a horizontal line at $\overline{\varepsilon}$. Figure 5.8 depicts the solutions to these equations in output-exchange rate space.

The results for this case are the opposite of those for a floating exchange rate. Changes in planned expenditure now affect aggregate demand. A rise in government purchases, for example, shifts the IS^* curve to the right and thus raises output for a given price level. Disturbances in the money market, in contrast, have no effect on Y for a given P. A rise in the demand for money, for example, leads only to an increase in the money supply.



Finally, with a fixed exchange rate, the exchange rate itself is a policy instrument. For example, a devaluation—an increase in the fixed exchange rate, $\bar{\varepsilon}$—stimulates net exports and thus increases aggregate demand.

Rational Exchange-Rate Expectations and Overshooting

The Mundell–Fleming model assumes that exchange-rate expectations are static. But with a floating exchange rate, it turns out that when plausible assumptions about the dynamics of prices and output are added to the model, there are predictable changes in exchange rates. Thus static expectations are not rational: an investor with static expectations is making systematic errors in his or her exchange-rate forecasts. Such an investor can therefore earn a higher average rate of return by using information that helps to forecast exchange-rate movements. Thus it is natural to ask what happens if investors form their expectations concerning movements in the exchange rate using all the available information—that is, if they have rational expectations. Since static expectations *are* rational when the exchange rate is fixed and likely to remain so, we focus on a floating exchange rate.[9]

When expectations are not static, perfect capital mobility no longer necessarily implies that domestic and foreign interest rates are equal. Consider an investor at some time t deciding where to hold his or her wealth. If the investor puts a dollar into a domestic asset that earns a continuously compounded rate of return of i, at time $t + \Delta t$ he or she will have $e^{i\Delta t}$ dollars. Suppose the investor instead invests in foreign assets. At t, the investor's dollar can be used to purchase foreign assets that are worth $1/\varepsilon(t)$ units of foreign currency; after Δt these assets are worth $e^{i^*\Delta t}/\varepsilon(t)$ units of foreign currency; and this foreign currency can be used to buy $\varepsilon(t + \Delta t)e^{i^*\Delta t}/\varepsilon(t)$ dollars.

Under perfect capital mobility, these two ways of investing the dollar must have the same expected payoff. $\varepsilon(t)$, i, and i^* are known, but $\varepsilon(t+\Delta t)$ may be uncertain. Thus we have

$$e^{i\Delta t} = \frac{E[\varepsilon(t + \Delta t)]}{\varepsilon(t)} e^{i^*\Delta t}. \tag{5.17}$$

Equation (5.17) holds for all values of Δt. The derivatives of both sides with respect to Δt are therefore equal:

$$e^{i\Delta t} i = \frac{E[\varepsilon(t + \Delta t)]}{\varepsilon(t)} e^{i^*\Delta t} i^* + e^{i^*\Delta t} \frac{E[\dot{\varepsilon}(t + \Delta t)]}{\varepsilon(t)}. \tag{5.18}$$

[9] Rational expectations may differ from static expectations under a fixed exchange rate ... probability of a change in the exchange rate. In addition, there are cases that ...

When this expression is evaluated at $\Delta t = 0$, it simplifies to

$$i = i^* + \frac{E[\dot{\varepsilon}(t)]}{\varepsilon(t)}. \tag{5.19}$$

Equation (5.19) states that under perfect capital mobility, interest-rate differences must be offset by expectations of exchange-rate movements. The domestic interest rate can exceed the foreign interest rate, for example, only if the domestic currency is expected to depreciate at a rate equal to the interest-rate differential. Equation (5.19) is known as *uncovered interest-rate parity*.[10]

The possibility of expected exchange-rate movements associated with interest-rate differences gives rise to the possibility of *exchange-rate overshooting* (Dornbusch, 1976). "Overshooting" refers to a situation where the initial reaction of a variable to a shock is greater than its long-run response. To see how the exchange rate can overshoot, suppose that initially $i = i^*$ and the exchange rate is not expected to change, and that there is then an increase in the money supply. As stressed later in the chapter, Keynesian models generally imply that monetary disturbances have no real effects in the long run. Thus the long-run effect of the shock will be to cause both the price level and the exchange rate to rise proportionally with the increase in money.

Now consider the short-run effect of the shock. If the monetary expansion reduces the interest rate, then (5.19) implies that $E[\dot{\varepsilon}]$ must be negative: if i is less than i^*, investors will hold domestic assets only if they expect the domestic currency to appreciate. But this means that the domestic currency is worth less now than it will be in the long run; that is, it must have depreciated by so much at the time of the shock that it has overshot its expected long-run value.

This leaves the question of whether the monetary expansion reduces the domestic interest rate. A particularly simple case occurs in a variant of the model where producers cannot change output in the very short run, so that the *IS* equation, (5.12), need not be satisfied at every moment. With both prices and output fixed, the only variable that can adjust to ensure that the *LM* equation, (5.7), is satisfied is the interest rate. Thus i must fall in response to an increase in M, and so there must be exchange-rate overshooting.

The intuition for this result is straightforward. If at the time of the shock the exchange rate merely depreciates to its new long-run equilibrium level, the interest-rate differential causes all investors to want to purchase

[10] The parity is "uncovered" because although positive expected profits can be made by purchasing one country's assets and selling the other's when (5.19) fails, these profits are not riskless. The alternative is *covered interest-rate parity*, which refers to the relationship in (5.18) with the expected future exchange rate replaced by the price in futures markets of

foreign currency to obtain the higher-yielding foreign assets. This cannot be an equilibrium. Instead, the price of domestic currency is bid down until it is sufficiently below its expected long-run level that the expected appreciation just balances the lower interest rate on domestic assets.

When the IS equation is assumed to hold continuously, an increase in M no longer necessarily reduces i. Thus in this case there can be either undershooting or overshooting. Which occurs turns out to be a complicated function of the parameters of the model (see Dornbusch, 1976, and Problem 5.10).

Imperfect Capital Mobility

The assumptions that there are no barriers to capital movements between countries and that investors are risk-neutral are surely too strong. Transaction costs and the desire to diversify, for example, cause investors not to put all their wealth into a single country's assets in response to a small difference in expected returns. It is therefore natural to consider the effects of imperfect capital mobility. We focus on the case of a floating exchange rate, and for simplicity we revert to the assumption of static exchange-rate expectations.

A simple way to model imperfect capital mobility is to assume that capital flows depend on the difference between domestic and foreign interest rates. Specifically, define the capital flow, CF, as foreigners' purchases of domestic assets minus domestic residents' purchases of foreign assets. Our assumption is

$$CF = CF(i - i^*), \qquad CF'(\bullet) > 0. \tag{5.20}$$

The capital flow, CF, and net exports, NX, must sum to 0. If net exports are negative, for example, this means that the country's sales of goods and services to foreigners are not sufficient to pay for its imports. The country must therefore be paying for the excess by selling assets to foreigners—that is, CF must be equal and opposite to NX. Thus equilibrium requires[11]

$$CF(i - i^*) + NX\left(Y, i - \pi^e, G, T, \frac{\varepsilon P^*}{P}\right) = 0. \tag{5.21}$$

The aggregate demand side of the model now consists of the IS equation, (5.12); the LM equation, (5.7); and the balance-of-payments equation, (5.21). If net exports are the only component of planned expenditure that is affected by the exchange rate, the model can be analyzed graphically. With this assumption, we can write planned expenditure as the sum of domestic

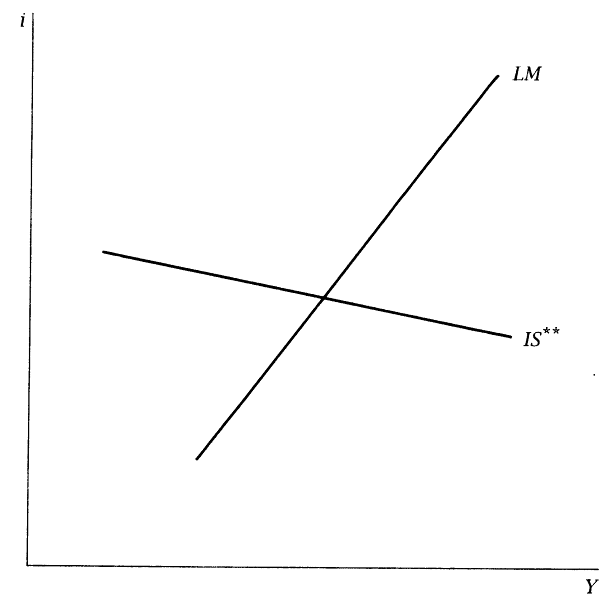
residents' planned expenditure (on both domestic and foreign goods) and net exports:

$$Y = E^D(Y, i - \pi^e, G, T) + NX\left(Y, i - \pi^e, G, T, \frac{\varepsilon P^*}{P}\right), \tag{5.22}$$

where $E^D(\bullet)$ is domestic residents' planned expenditure. $E^D(\bullet)$ is assumed to satisfy $0 < E^D_Y < 1$, $E^D_{i-\pi^e} < 0$, $E^D_G > 0$, and $E^D_T < 0$. We can then use (5.21) to substitute for net exports, and thereby eliminate the exchange rate from the model:

$$Y = E^D(Y, i - \pi^e, G, T) - CF(i - i^*). \tag{5.23}$$

Since $CF(i - i^*)$ is increasing in i, the set of points satisfying (5.23) is downward-sloping in (Y, i) space. This locus is shown in Figure 5.9 as the IS^{**} curve. Note that the exchange rate is implicitly changing as we move along the curve. Since the interest rate affects Y in (5.23) both through its direct effect on domestic demand and through its effect on the exchange rate and net exports, the IS^{**} curve is flatter than a conventional IS curve. In the extreme case of perfect capital mobility, the IS^{**} curve is flat at i^*. The LM curve is the same as before.



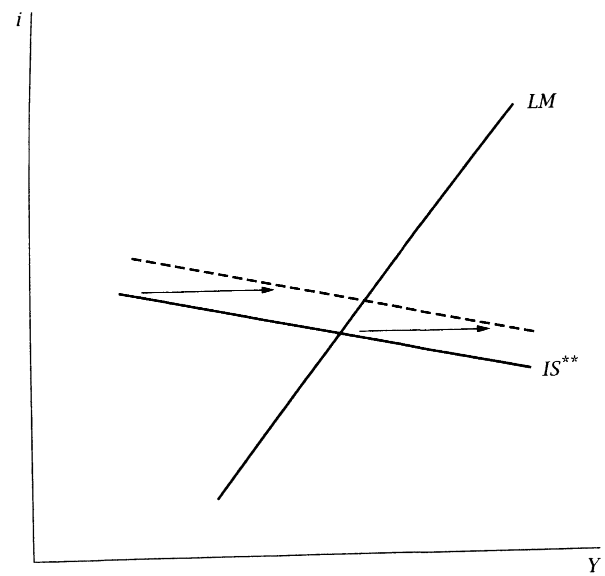


FIGURE 5.10 **The effects of an increase in government purchases with imperfect capital mobility and a floating exchange rate**

The results for this case typically fall between those for a closed economy and those for perfect capital mobility. Consider again the effects of an increase in government purchases. Since this increase raises expenditure for a given interest rate, the IS^{**} curve shifts to the right, as shown in Figure 5.10. Thus, in contrast to what happens with perfect capital mobility, i and Y rise for a given price level. Since the IS^{**} curve is flatter than the closed-economy IS curve, however, the effects are weaker than they are in a closed economy. The effects of other shocks can be analyzed in similar ways.

5.3 Alternative Assumptions about Wage and Price Rigidity

We now turn to the aggregate supply side of the model. This section describes various ways that a nonvertical AS curve might arise. In all of them, incomplete nominal adjustment is assumed rather than derived. Thus this section's purpose is not to discuss possible microeconomic foundations of nominal stickiness; that is the job of Chapter 6. Instead, the goal is to explore some combinations of nominal wage and price rigidity and charac-

teristics of the labor and goods markets that give rise to a nonvertical AS curve. The different sets of assumptions have different implications for unemployment, for the behavior of the real wage and the markup in response to aggregate demand fluctuations, and for firms' pricing behavior.

We consider four sets of assumptions. The first two are valuable baselines. Both, however, appear to fail as even remotely approximate descriptions of actual economies. The other two are more complicated and potentially more accurate. Together, the four cases illustrate the wide range of possibilities.

Case 1: Keynes's Model

The aggregate supply portion of the model in Keynes's *General Theory* (1936) begins with the assumption that the nominal wage is rigid (at least over some range):

$$W = \overline{W}. \tag{5.24}$$

Output is produced by competitive firms. Labor, L, is the only factor of production that is variable in the short run, and is subject to decreasing returns:

$$Y = F(L), \qquad F'(\bullet) > 0, \qquad F''(\bullet) < 0. \tag{5.25}$$

Since firms are competitive, they hire labor up to the point where the marginal product of labor equals the real wage:

$$F'(L) = \frac{W}{P}. \tag{5.26}$$

Equations (5.24)–(5.26) imply an upward-sloping AS curve. Since the wage is fixed, a higher price level implies a lower real wage. Firms respond by raising employment, which increases output. Thus there is a positive relationship between P and Y.

The reason that incomplete nominal adjustment causes shifts in aggregate demand to change output in this case is straightforward. With rigid nominal wages, increases in the price level reduce the real wage and therefore increase the amount that firms want to sell. As a result, increases in aggregate demand lead not just to increases in prices, but to increases in both prices and output.

Figure 5.11 shows the situation in the labor market for a given price level. Employment and the real wage are determined by labor demand at the real wage that is implied by the fixed nominal wage and the price level (Point E in the diagram). Thus there is involuntary unemployment: some workers would like to work at the prevailing wage but cannot. The amount of unemployment is the difference between supply and demand at the prevailing real wage (distance EA in the diagram).