9 Nominal Price Rigidities: Empirical Facts and Basic Open-Economy Models

One of the most difficult tasks in international macroeconomics is building a bridge between the real economy and its monetary side. Chapter 8 showed that even when money prices are completely flexible, monetary policy can have a real impact through its effects on seignorage, real money holdings, the consumption-based real interest rate, or risk premiums on currency-denominated assets. But most practical-minded economists would regard these channels as being of second-order importance compared with the short-run aggregate demand shifts that monetary shocks can produce when nominal prices or wages are even somewhat rigid. Indeed, many classic issues at the center of international macroeconomics, including optimum currency areas, choice of an exchange rate regime, the real effects of disinflation, and international monetary policy coordination, would be of relatively little consequence in a flexible-price world.

This chapter begins by illustrating the compelling empirical case for incorporating nominal price rigidities into open-economy macroeconomic analysis. We then review Rudiger Dornbusch's (1976) perfect-foresight extension of the essentially static Keynesian approach to modeling nominal exchange rates due to Fleming (1962) and Mundell (1963, 1964). The best-known facet of Dornbusch's famous model is its demonstration that sticky nominal output prices can induce *overshooting* behavior in exchange rates.

On a theoretical plane, the Dornbusch overshooting model has several methodological drawbacks. The most fundamental is the model's lack of explicit choice-theoretic foundations. In particular, there are no microfoundations of aggregate supply. Thus the model cannot predict how incipient gaps between aggregate demand and output are resolved when prices are set in advance and fail to clear markets. The Dornbusch model also is ill-equipped to capture current account dynamics or the effects of government spending, as it does not account for private or government intertemporal budget constraints. Perhaps most fundamentally, the model's lack of microfoundations deprives it of any natural welfare metric by which to evaluate alternative macroeconomic policies. In Chapter 10 we try to address the problem of reconciling the realistic implications of price stickiness with more satisfactory dynamic foundations.

In an economy where monetary policy surprises can systematically affect output and relative prices, the government could have an incentive to try creating unexpected inflation, either to reduce an inefficiently high unemployment level or simply for political advantage. Such incentives create a *credibility* problem for policymakers. Rational private-sector actors will build their inflationary expectations into price- and wage-setting decisions, thereby putting the government in the position of choosing between accommodative monetary policy and a slump. Since government promises to allow a slump often aren't credible, an upward wage-price-money supply spiral can result.

A number of actual episodes suggest that this type of inflation trap is more than a theoretical possibility. We will model the problem formally, explore its bearing on exchange-rate policy and on the theory of speculative currency crises, and ask whether institutional or other mechanisms can help governments maintain monetary policy credibility.

9.1 Sticky Domestic Goods Prices and Exchange Rates

Domestic macroeconomists have endlessly debated whether actual economies can usefully be characterized by flexible-price models. Much of the debate is over aesthetics: it is difficult to find a single compelling theoretical story that convincingly explains why nominal price adjustment appears sluggish in practice. Indeed, largely because of theoretical difficulties, the fashion for some time among some closed-economy macroeconomists has been to ignore price rigidities altogether. For anyone who looks even casually at international data, however, the idea that nominal price rigidities are irrelevant seems difficult to sustain. Figure 9.1 graphs the log Deutsche mark-dollar exchange rate against the log difference between German and U.S. consumer price indexes. A glance at the diagram, which is extremely typical for countries with floating currencies and open capital markets, shows that exchange rates are an order of magnitude more volatile than CPIs. (Figure 9.2, which graphs first differences in the two series, makes the point even more dramatically.) An immediate corollary of this result is that the short-run volatility of real exchange rates is very similar to that of nominal exchange rates. This striking empirical regularity is totally at odds with the monetary model of Chapter 8 except when most significant shocks buffeting the economy are real.

It is highly implausible, however, that most of the variability in real exchange rates is attributable to real shocks. Contradicting this view most strikingly is the fact that real exchange rates are always much less volatile when nominal exchange rates are fixed than when they are floating. This point has been forcefully documented by Mussa (1986), who compared real exchange-rate volatility under fixed and floating rates across a broad range of industrial-country pairings. Invariably, he found that volatility is dramatically higher under floating rates.[1] Skeptics might argue that the choice of exchange-rate regime is endogenous, and countries experiencing episodes of large real (that is, goods-market) shocks will switch to floating. It is true that the standard literature on choice of exchange-rate regimes prescribes floating rates when real shocks dominate and prescribes fixed rates when monetary and financial shocks dominate (see section 9.4.1). But Mussa found that the phenomenon is universal across numerous episodes of switches between fixed and

1. Mussa's finding has been confirmed in other studies, including Baxter and Stockman (1989) and Flood and Rose (1995).

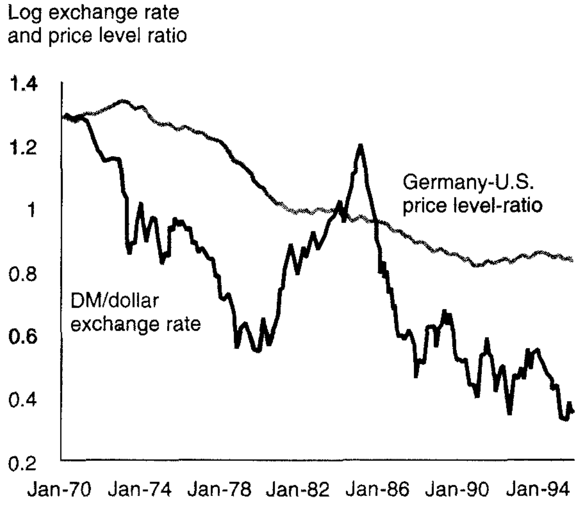

Figure 9.1
Germany and the United States, exchange rate and prices

flexible rates, including some switches that seem clearly exogenous. It is also remarkable that a rise in real exchange-rate volatility tends to occur immediately upon a switch from fixed to floating rates, while a volatility decline occurs immediately upon the reverse switch.

Figure 9.3, which shows the nominal and real lira–French franc exchange rates, is illustrative. During the Bretton Woods period through December 1971 and the realignment-free EMS period from January 1987 until September 1992, the nominal exchange rate was relatively fixed. Over these periods, real exchange rate volatility was fairly low. During periods when the relative value of the two currencies was not effectively fixed (the early 1970s through 1987, and after September 1992), real exchange-rate movements were much more volatile and short-run real changes virtually mirrored short-run nominal exchange-rate changes. When the lira was forced to leave the EMS in September 1992, its real and nominal exchange rates moved sharply upward in tandem. The parallel movement of real and nominal exchange rates also characterizes the three Bretton Woods realignments (two at the end of the 1950s, the last a decade later) that preceded the general Smithsonian realignment at the end of 1971. Plainly the choice of exchange-rate regime can have important effects on at least one real variable.[2]

2. It is not as easy to document the effects of choice of exchange-rate regime on other real variables, such as output, the trade balances, and interest rates. Baxter and Stockman (1989) and Flood and Rose (1995) argue that in fact the choice of exchange-rate regime affects *only* the real exchange rate. Given the relatively small sample periods available, the considerable measurement error in data on variables such as GNP, and econometric problems (such as how to deal with unit roots and detrending), the

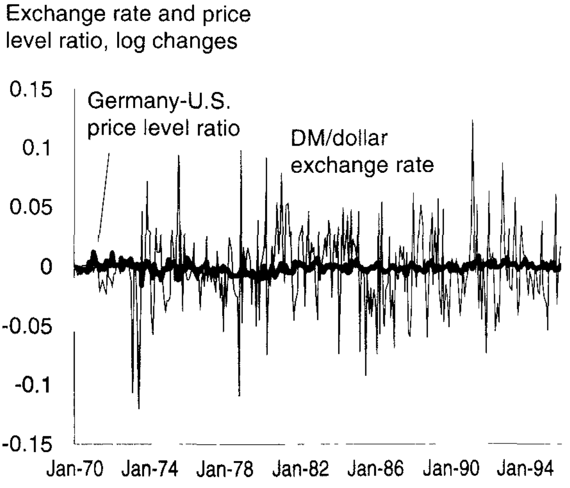

Figure 9.2
Germany and the United States, exchange rate and price changes

At the microeconomic level, an impact of exchange-rate volatility on the inter-country relative prices of similar commodities has been extensively documented. Many studies find that deviations from the law of one price are highly correlated with nominal exchange-rate changes.[3] Engel (1993) compares U.S. with Canadian consumer price data for a large variety of goods including fuel, men's clothing, and apples. In more than 2,000 pairwise comparisons, Engel finds that with only a few exceptions, the relative prices of *similar* goods across the United States and Canada are more volatile than the relative prices of *dissimilar* goods within either country. These findings are reinforced in Engel and Rogers (1995), who extend the comparisons to 23 American and Canadian cities. Even after controlling for distance between two cities, they find an enormous "border effect" on volatility.[4] For example, the volatility of relative prices for very similar consumer goods appears to be much greater between closely neighboring American and Canadian city pairs such as Buffalo and Toronto or Seattle and Vancouver, than between cities such as New York and Los Angeles, which lie on opposite sides of the North American continent but within the same country.

This evidence motivates a look at a classic sticky-price extension of the flexible-price monetary model of Chapter 8.

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issue remains controversial. We will argue in section 9.3.3 that the choice of exchange-rate regime had dramatic consequences for the international transmission of the Great Depression of the 1930s.

3. See, for example, Isard (1977) and Giovannini (1988).

4. For surveys of evidence on deviations from the law of one price, see Froot and Rogoff (1995) and Rogoff (1996).

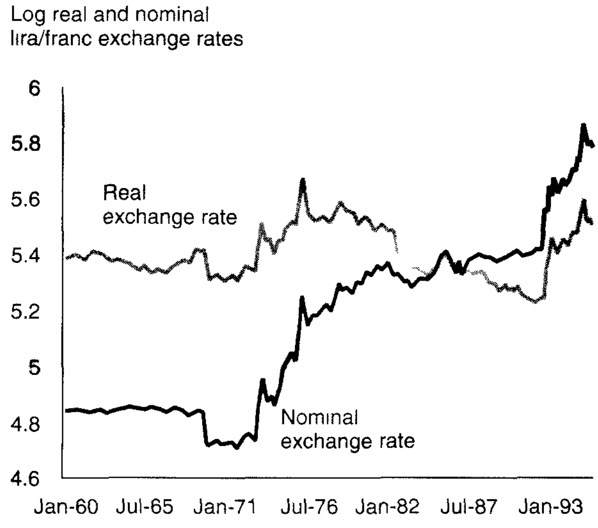

Figure 9.3
France and Italy, exchange rate and prices (liras/franc, natural logarithms)

9.2 The Mundell-Fleming-Dornbusch Model

Since the early 1960s, the dominant policy paradigm for studying open-economy monetary and fiscal policy issues has been the Keynesian framework developed by Mundell (1963, 1964) and Fleming (1962). This section presents a variant of Dornbusch's (1976) famous perfect-foresight extension of the Mundell-Fleming model. As we have already noted, Dornbusch's model has important deficiencies, including its inability to deal adequately with current-account and fiscal-policy dynamics or, more fundamentally, with welfare issues. Nevertheless, the model remains so influential as to warrant discussion in any serious treatment of international monetary theory. Nothing here is essential for understanding the more complete models of Chapter 10. The Dornbusch setup will, however, help the reader frame many of the basic questions in international monetary economics and give perspective on some of the newer developments in the area.

9.2.1 A Small-Open-Economy Model with Sticky Prices and Endogenous Output

The Dornbusch model includes some of the same building blocks as the Cagan-type monetary models we discussed in Chapter 8. A small country faces an exogenous world (foreign-currency) interest rate i^*, which is assumed constant. With open capital markets and perfect foresight, uncovered interest parity must hold:

$$i_{t+1} = i^* + e_{t+1} - e_t. \tag{1}$$

[As in Chapter 8, $\mathsf{i}_{t+1} = \log(1 + i_{t+1})$ is the logarithm of the gross domestic nominal interest rate between periods t and $t + 1$, $\mathsf{i}^* = \log(1 + i^*)$, and e is the logarithm of the exchange rate, defined as the domestic price of foreign currency.][5] As in the basic monetary model of Chapter 8, only domestic residents hold the domestic money, and domestic monetary equilibrium is characterized by the Cagan-type aggregate relationship

$$\mathsf{m}_t - \mathsf{p}_t = -\eta \mathsf{i}_{t+1} + \phi \mathsf{y}_t, \tag{2}$$

where m is the log of the nominal money supply, p is the log of the domestic-currency price level, and y is the log of domestic output.

Let p^* be the (log of the) foreign price level measured in foreign currency. The *model assumes that purchasing power parity (PPP) need not hold, so that the (log)* real exchange rate, $\mathsf{e} + \mathsf{p}^* - \mathsf{p} \equiv \log(\mathcal{E}P^*/P)$, can vary. Here we take the domestic consumption basket as numeraire and define the real exchange rate as the relative price of the foreign consumption basket. (See Chapter 4 for a discussion of real exchange rates. As in that chapter, we refer to a rise in $\mathcal{E}P^*$ relative to P as a home real depreciation or, alternatively, as a real depreciation of the home currency. A fall in $\mathcal{E}P^*$ relative to P is a real appreciation for the home country.)

The Dornbusch model effectively aggregates all domestic output as a single composite commodity and assumes that aggregate demand for home-country output, y^d, is an increasing function of the home real exchange rate $\mathsf{e} + \mathsf{p}^* - \mathsf{p}$:

$$\mathsf{y}_t^d = \bar{\mathsf{y}} + \delta(\mathsf{e}_t + \mathsf{p}^* - \mathsf{p}_t - \bar{\mathsf{q}}), \qquad \delta > 0. \tag{3}$$

(We hold p^* constant throughout.) Interpret the constant $\bar{\mathsf{y}}$ in eq. (3) as the "natural" rate of output. If we denote the real exchange rate by

$$\mathsf{q} \equiv \mathsf{e} + \mathsf{p}^* - \mathsf{p}, \tag{4}$$

then we can interpret $\bar{\mathsf{q}}$ in eq. (3) as the *equilibrium* real exchange rate consistent with full employment. For simplicity, we usually assume both $\bar{\mathsf{y}}$ and $\bar{\mathsf{q}}$ to be constant.

The assumption in eq. (3) that a rise in the foreign price level relative to that in the home country (a rise in $\mathsf{e} + \mathsf{p}^*$ relative to p) shifts world demand toward home-produced goods could be justified through several mechanisms. Mundell, Fleming, and Dornbusch assume that the home country has monopoly power over the tradables it produces (despite its smallness in asset markets) and that home-produced tradables have a greater CPI weight at home than abroad. Real depreciation might

5. When Mundell and Fleming wrote, macroeconomists had not yet applied methods for handling rational expectations. In their principal models, Mundell and Fleming basically assumed static exchange rate expectations by requiring that $\mathsf{i}_t = \mathsf{i}^*$ under perfect capital mobility. Equation (1) plays a central role in Dornbusch's (1976) extension of the Mundell-Fleming model.

also increase demand for home goods by shifting domestic spending from foreign tradables to domestic nontradables.

Positing an aggregate demand function such as eq. (3) without deriving it from underlying microfoundations constitutes a sharp methodological departure from the approach we have generally adopted in most other parts of this book. However, like the Cagan and Solow models of earlier chapters, the Dornbusch model yields some important insights that survive more careful derivation. Chapter 10 will model the demand side in more detail.

Although asset markets clear at every moment as in the models of Chapter 8, output markets need not in the Dornbusch model. If goods prices were fully flexible, as in the models of Chapter 8, output would always equal its natural level, so that $y_t^d = y_t = \bar{y}$, and thus q would always equal $\bar{q}$. As we have already seen, the assumption of flexible prices is quite unrealistic. In practice, nominal goods prices adjust much more slowly than exchange rates. In the Dornbusch model, the empirical reality of sticky prices is captured by assuming that p is *predetermined*, and responds only slowly to shocks.

If the price level cannot move immediately to clear markets, however, then unanticipated shocks plainly can lead to excess demand or supply. In the absence of market clearing, one must make some kind of assumption about how the actual level of output is determined. Here we will follow Keynesian tradition and simply assume that output is demand determined, so that $y_t = y_t^d$. For the moment, we are not able to offer any justification for this assumption, and we will leave all details of aggregate supply in the background. Fortunately, it will be possible to give a much more satisfactory treatment once we have introduced microfoundations for aggregate supply in Chapter 10.[6]

Although p_t is predetermined and cannot respond instantly to date t shocks, it does adjust slowly over time in response to excess demand. Specifically, the price level adjusts according to the inflation-expectations-augmented Phillips curve

$$p_{t+1} - p_t = \psi(y_t^d - \bar{y}) + (\tilde{p}_{t+1} - \tilde{p}_t), \tag{5}$$

where

$$\tilde{p}_t \equiv e_t + p_t^* - \bar{q}_t$$

is the price level that would prevail if the output market cleared (*given* e_t, p_t^*, and $\bar{q}_t$). Intuitively, the first term on the right-hand side of eq. (5) embodies the price inflation caused by date t excess demand, while the second term provides for the price-level adjustment needed to keep up with *expected* inflation or productivity

6. A model with implications very similar to those of the Dornbusch model introduces a labor market and assumes that it is the nominal wage, rather than the price level, that is predetermined. (See, for example, Obstfeld, 1985, or Rogoff, 1985a.) Qualitatively similar results also follow from a variant of the model in which some prices are temporarily rigid while others are fully flexible.

growth. That is, the second term captures the movement in prices that would be needed to keep $y = \bar{y}$ if the output market were in equilibrium.[7] Differencing the definition of $\tilde{p}_t$ gives

$$\tilde{p}_{t+1} - \tilde{p}_t = (e_{t+1} + p^*_{t+1} - \bar{q}_{t+1}) - (e_t + p^*_t - \bar{q}_t).$$

Substituting this expression into eq. (5), and recalling that p^* and $\bar{q}$ are assumed constant, we find

$$p_{t+1} - p_t = \psi(y^d_t - \bar{y}) + e_{t+1} - e_t. \tag{6}$$

This completes our description of the Dornbusch model.

9.2.2 Graphical Solution of the Dornbusch Model

To solve the model, we begin by using eqs. (3) and (4) to express eq. (6) as

$$\Delta q_{t+1} = q_{t+1} - q_t = -\psi\delta(q_t - \bar{q}). \tag{7}$$

We will assume $1 > \psi\delta$, which ensures that shocks to the real exchange rate damp out monotonically over time. Next, we substitute eqs. (1), (3), and (4) into eq. (2). Together with the simplifying normalizations $p^* = \bar{y} = i^* = 0$, this step yields

$$m_t - e_t + q_t = -\eta(e_{t+1} - e_t) + \phi\delta(q_t - \bar{q}) \tag{8}$$

or

$$\Delta e_{t+1} = e_{t+1} - e_t = \frac{e_t}{\eta} - \frac{(1-\phi\delta)q_t}{\eta} - \left(\frac{\phi\delta\bar{q} + m_t}{\eta}\right). \tag{9}$$

Equations (7) and (9) constitute a system of two first-order difference equations in q and e. It is not difficult to solve them analytically (see Supplement C to Chapter 2), but it is instructive to consider first the simple phase diagram in Figure 9.4, which is drawn under the assumption that m_t is constant at $\bar{m}$. Under eq. (7), the $\Delta q = 0$ schedule is vertical at $q = \bar{q}$. Thus the speed of anticipated real adjustment is independent of nominal factors. The $\Delta e = 0$ schedule has vertical-axis intercept $\phi\delta\bar{q} + \bar{m}$, and it is upward-sloping as drawn provided $1 > \phi\delta$, a condition we provisionally assume. (Note that the slope must be below 45 degrees.) The steady-state pair $(\bar{q}, \bar{e})$ lies at the intersection of the two curves. It follows from eq. (8) that

$$\bar{e} = \bar{m} + \bar{q}, \tag{10}$$

which, using the definition of q [eq. (4)], implies $\bar{p} = \bar{m}$ (recall that $p^* = 0$).[8]

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7. There are several ways to allow for price-level adjustment in the Dornbusch model, and eq. (5) is based on Mussa (1982). The original Dornbusch (1976) model was designed only to analyze one-time shocks, and is not general enough to allow for anticipated disturbances; see Frankel (1979), Mussa (1982, 1984), Obstfeld and Rogoff (1984), and Obstfeld and Stockman (1985).

8. The solution for $\bar{e}$ follows because in the steady state, $q = \bar{q}$, $m = \bar{m}$, and $e_{t+1} = e_t$.

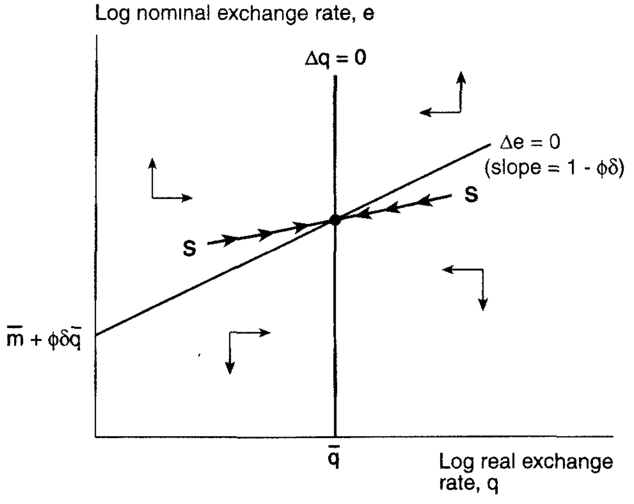

Figure 9.4
The Dornbusch model

Figure 9.4 also describes the system's dynamics away from the steady state. The dynamic arrows show that the Dornbusch model has the saddle-path property familiar from earlier chapters. That is, along all paths beginning anywhere but along the upward-sloping saddle path. SS, the exchange rate will eventually implode or explode. Since we did not derive the money demand function (2) from microfoundations, there is no way to argue rigorously that the economy is constrained to be on SS. One can, however, appeal to the close analogy between this model and the maximizing models of Chapter 8, and to the fact that the no-bubbles path is the only one that tightly links prices to fundamentals.

Now let's consider the time-honored thought experiment of an unanticipated permanent rise in the money supply from $\bar{m}$ to $\bar{m}'$. In the long run, of course, both the exchange rate e and the price level p must increase in proportion to the change in the money supply,

$$\bar{p}' - \bar{p} = \bar{e}' - \bar{e} = \bar{m}' - \bar{m},$$

as is easily shown using eqs. (7) and (9); the long-run interest rate remains i^*. In the short run, however, the price level p is predetermined and cannot respond to the unanticipated money change. Assuming that the economy initially occupies the steady-state equilibrium corresponding to $m_t = \bar{m}$ for all t, then, on initial date 0,

$$p_0 = \bar{m}, \tag{11}$$

which implies that

$$q_0 = e_0 - \bar{m}. \tag{12}$$

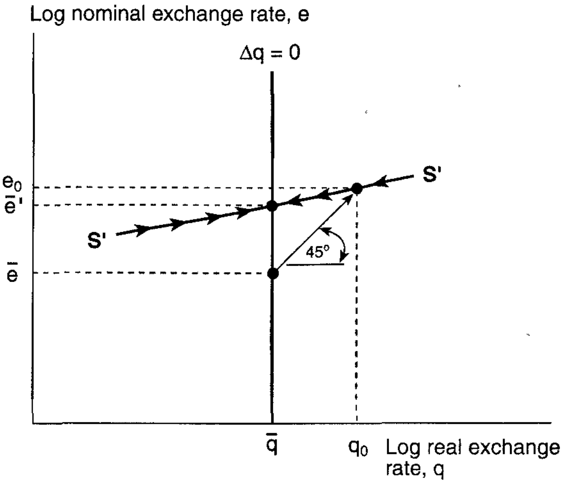

Figure 9.5
Exchange rate overshooting

The economy's immediate response to the unanticipated money shock and its transition to the new steady state are graphed in Figure 9.5. The new saddle path $S'S'$ passes through the new steady state $(\bar{q}, \bar{m}' + \bar{q})$. The 45° arrow in the figure is the initial condition described by eq. (12), which has a slope of unity. (Note that the slope of the saddle path $S'S'$ must be less than unity since it is shallower than the $\Delta e = 0$ schedule, which itself has slope less than one.) Thus, in response to the unanticipated money supply increase, the economy initially jumps to point (q_0, e_0) at the intersection of the new (post-shock) saddle path and the initial condition (12). Note the $e_0 > \bar{e}'$. That is, the exchange rate initially changes *more than proportionately* to the money shock.

This is Dornbusch's celebrated "overshooting" result. One reason it captured the imagination of many international economists and policymakers was its implication that the surprising volatility of floating exchange rates might be consistent with rational expectations. The 1970s were years of monetary instability throughout the industrialized world. If volatile money supplies had amplified effects on exchange rates, Dornbusch reasoned, they might be substantially responsible for the sharp exchange-rate fluctuations observed after the onset of floating in 1973.

The intuition underlying Dornbusch's overshooting result is easily seen by referring to the money demand equation (2), rewritten here:

$$m_t - p_t = -\eta i_{t+1} + \phi y_t.$$

The increase in m causes an increase in real money balances of $\bar{m}' - \bar{m}$, since p is initially fixed. Suppose the exchange rate jumped immediately to its new steady state. Then eq. (3) implies that output would rise (on impact) by $\delta(\bar{m}' - \bar{m})$;

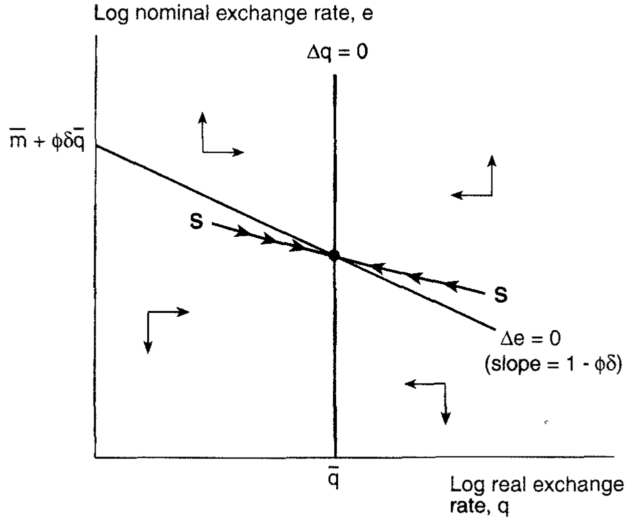

Figure 9.6
Exchange rate undershooting

money demand would thus rise by $\phi\delta(\bar{m}' - \bar{m})$. If, as we assumed in drawing Figures 9.4 and 9.5, $\phi\delta < 1$, then the rise in money demand is less than the rise in money supply. Thus, the home nominal interest rate i must fall below i^* to restore money-market equilibrium. This conclusion contradicts our initial supposition that e jumps immediately to its new steady state, for $i < i^*$ implies an expected *fall* in e, by interest parity equation (1). What does happen? By the preceding logic, the exchange rate cannot rise in the short run by *less* than $\bar{m}' - \bar{m}$. There would again have to be a fall in i, and therefore an expected appreciation—an impossibility, for then the exchange rate would be traveling away from rather than toward its steady state. The only possibility, when $\phi\delta < 1$, is for the currency initially to *overshoot* its long-run level. In the short-run equilibrium i still falls, but future appreciation is a rational expectation if the initial exchange rate e_0 is above its eventual steady state $\bar{e}'$.[9]

The preceding discussion suggests that overshooting will not necessarily occur if output responds sharply to exchange rate depreciation (δ is large) and if the income elasticity of money demand, ϕ, is large. Figure 9.6 graphs the case $\phi\delta > 1$, in which the $\Delta e = 0$ schedule is downward sloping. The saddle path SS now has a negative slope, as the arrows of motion show. An unanticipated permanent rise in the money supply therefore makes the exchange rate e rise less than proportionately to the money-supply increase. (The postshock exchange

9. Uncovered interest parity is an ex ante relationship that need not hold ex post if there are unanticipated shocks. Since we are allowing for an unanticipated shock at time 0, uncovered interest parity places no constraint on the initial movement in e_0.

rate e_0 lies below the new long-run rate $\bar{\mathsf{e}}'$.) Notice that, regardless of whether the exchange rate undershoots or overshoots, the dynamics of the real exchange rate and output are qualitatively the same. The nominal depreciation of domestic currency implies a real depreciation (since prices are sticky). This real depreciation raises aggregate demand, so output rises temporarily above its steady-state value $\bar{\mathsf{y}}$.

9.2.3 Analytical Solution of the Dornbusch Model

We have illustrated the main ideas of the Dornbusch model graphically. For completeness, however, we now show the model's analytical solution. Our approach to solving the model exploits its recursive structure.

Given any date t deviation of the real exchange rate from its long-run value, the solution to eq. (7) [rewritten as $\mathsf{q}_{t+1} - \bar{\mathsf{q}} = (1 - \psi\delta)(\mathsf{q}_t - \bar{\mathsf{q}})$] is

$$\mathsf{q}_s - \bar{\mathsf{q}} = (1 - \psi\delta)^{s-t}(\mathsf{q}_t - \bar{\mathsf{q}}), \qquad s \geq t. \tag{13}$$

(Recall that we have assumed $1 - \psi\delta > 0$.)[10] Having solved for the path of the real exchange rate (as a function of q_t), we can derive the path of the nominal exchange rate e with relative ease. For an exogenously given path of q, eq. (9) can be viewed as a first-order difference equation virtually identical to the Cagan model of Chapter 8, and it is solved similarly. Solving eq. (9) for e_t, and then subtracting $\bar{\mathsf{q}}$ from both sides, yields

$$\mathsf{e}_t - \bar{\mathsf{q}} = \frac{\eta}{1+\eta}(\mathsf{e}_{t+1} - \bar{\mathsf{q}}) + \frac{1-\phi\delta}{1+\eta}(\mathsf{q}_t - \bar{\mathsf{q}}) + \frac{\mathsf{m}_t}{1+\eta}.$$

By iterative forward substitution for $\mathsf{e}_s - \bar{\mathsf{q}}$, one obtains

$$\mathsf{e}_t - \bar{\mathsf{q}} = \frac{1}{1+\eta}\sum_{s=t}^{\infty}\left(\frac{\eta}{1+\eta}\right)^{s-t}\mathsf{m}_s + \frac{1-\phi\delta}{1+\eta}\sum_{s=t}^{\infty}\left(\frac{\eta}{1+\eta}\right)^{s-t}(\mathsf{q}_s - \bar{\mathsf{q}}) \tag{14}$$

after eliminating speculative bubbles by imposing the condition

$$\lim_{T\to\infty}\left(\frac{\eta}{1+\eta}\right)^{T}\mathsf{e}_{t+T} = 0.$$

If the money supply is constant at $\bar{\mathsf{m}}$ as is assumed in the figures, eq. (14) reduces to

$$\mathsf{e}_t - \bar{\mathsf{q}} = \bar{\mathsf{m}} + \frac{1-\phi\delta}{1+\eta}\sum_{s=t}^{\infty}\left(\frac{\eta}{1+\eta}\right)^{s-t}(\mathsf{q}_s - \bar{\mathsf{q}}). \tag{15}$$

To evaluate eq. (15), we substitute for $\mathsf{q}_s - \bar{\mathsf{q}}$ using eq. (13) to get

10. See Supplement C to Chapter 2.

$$\mathsf{e}_t - \bar{\mathsf{q}} = \bar{\mathsf{m}} + \frac{1 - \phi\delta}{1 + \eta}(\mathsf{q}_t - \bar{\mathsf{q}}) \sum_{s=t}^{\infty} (1 - \psi\delta)^{s-t} \left(\frac{\eta}{1 + \eta}\right)^{s-t},$$

which simplifies to the equation for the saddle path **SS**,

$$\mathsf{e}_t = \bar{\mathsf{m}} + \bar{\mathsf{q}} + \frac{1 - \phi\delta}{1 + \psi\delta\eta}(\mathsf{q}_t - \bar{\mathsf{q}}). \tag{16}$$

Notice that we constrained the economy to lie on the saddle path by imposing the no-speculative-bubbles condition following eq. (14). Also note that the slope of the saddle path depends on $1 - \phi\delta$, as demonstrated in the earlier diagrammatic analysis.

We can now solve analytically for the initial jumps in the real and nominal exchange rate that occur if the economy is at a steady state on initial date 0 when an unanticipated permanent increase in the money supply from $\bar{\mathsf{m}}$ to $\bar{\mathsf{m}}'$ occurs. The (postshock) date 0 real exchange rate, q_0, is found by combining the initial condition (12) (which embodies the assumption that $\mathsf{p}_0 = \bar{\mathsf{m}}$ is predetermined) together with saddle-path equation (16) (putting $\bar{\mathsf{m}}'$ in place of $\bar{\mathsf{m}}$, and setting $t = 0$). The second equilibrium condition embodies the assumption that the economy jumps immediately to the new, *postshock*, saddle path. The result is

$$\mathsf{q}_0 = \bar{\mathsf{q}} + \frac{1 + \psi\delta\eta}{\phi\delta + \psi\delta\eta}(\bar{\mathsf{m}}' - \bar{\mathsf{m}}).$$

Since, by eq. (12), $\mathsf{e}_0 = \mathsf{q}_0 + \bar{\mathsf{m}}$,

$$\mathsf{e}_0 = \bar{\mathsf{m}} + \bar{\mathsf{q}} + \frac{1 + \psi\delta\eta}{\phi\delta + \psi\delta\eta}(\bar{\mathsf{m}}' - \bar{\mathsf{m}}). \tag{17}$$

We see that the nominal exchange rate overshoots its new long-run equilibrium if $1 > \phi\delta$. Finally, to obtain the nominal exchange rate's transition path leading to the new long-run equilibrium, we combine the equation preceding eq. (17) with eqs. (13) and (16) to obtain

$$\mathsf{e}_t = \bar{\mathsf{m}}' + \bar{\mathsf{q}} + (1 - \psi\delta)^t \left[\frac{1 - \phi\delta}{\phi\delta + \psi\delta\eta}(\bar{\mathsf{m}}' - \bar{\mathsf{m}})\right].$$

Can *real* shocks also lead to overshooting? Suppose that at time 0, there is an unanticipated fall in $\bar{\mathsf{q}}$ to $\bar{\mathsf{q}}'$. What is the adjustment process? The answer, as one can most easily deduce by comparing the steady-state relationship (10) and the initial condition (12), is that the domestic currency appreciates immediately to its new long-run level, $\bar{\mathsf{m}} + \bar{\mathsf{q}}'$, and the economy immediately goes to the new steady state.[11] The reason is that the required adjustment in the *real* exchange rate can be

11 That is, eqs. (7) and (9) will continue to hold with $\Delta\mathsf{q}_{t+1} = \Delta\mathsf{e}_{t+1} = 0$ if e_{t+1}, e_t, q_t, and $\bar{\mathsf{q}}$ all change by the same amount $\bar{\mathsf{q}}' - \bar{\mathsf{q}}$.

accommodated in equilibrium entirely by a change in the *nominal* rate. It therefore does not necessitate any change in the long-run price level.

9.2.4 More General Money-Supply Processes

Our analysis has focused on one-time permanent increases in the money supply, but it is straightforward to extend the model to allow for temporary money-supply increases. Indeed, we have already done most of the work needed to solve the general case. Using eq. (13) once again to simplify the second summation term in eq. (14) yields

$$\mathsf{e}_t - \bar{\mathsf{q}} = \frac{1}{1+\eta}\sum_{s=t}^{\infty}\left(\frac{\eta}{1+\eta}\right)^{s-t}\mathsf{m}_s + \frac{1-\phi\delta}{1+\psi\delta\eta}(\mathsf{q}_t - \bar{\mathsf{q}})$$

or

$$\mathsf{e}_t - \mathsf{e}_t^{flex} = \frac{1-\phi\delta}{1+\psi\delta\eta}(\mathsf{q}_t - \bar{\mathsf{q}}), \tag{18}$$

where

$$\mathsf{e}_t^{flex} \equiv \bar{\mathsf{q}} + \frac{1}{1+\eta}\sum_{s=t}^{\infty}\left(\frac{\eta}{1+\eta}\right)^{s-t}\mathsf{m}_s = \bar{\mathsf{q}} + \mathsf{p}_t^{flex}. \tag{19}$$

One can interpret e_t^{flex} and p_t^{flex} as the exchange rate and price level that would obtain if output prices were perfectly flexible (in which case q_t would equal $\bar{\mathsf{q}}$).[12]

Instead of thinking of a one-time unanticipated change in the money supply, consider a date 0 change in the (perhaps very general) money supply process that (unexpectedly) changes e_t^{flex} and p_t^{flex} to $(\mathsf{e}_t^{flex})'$ and $(\mathsf{p}_t^{flex})'$ respectively, where $(\mathsf{e}_t^{flex})' - \mathsf{e}_t^{flex} = (\mathsf{p}_t^{flex})' - \mathsf{p}_t^{flex}$, since money shocks don't affect the real exchange rate when prices are flexible. We assume $\mathsf{p}_0 = \mathsf{p}_0^{flex}$. Then it is straightforward to use eq. (18) together with a generalized version of the initial condition (12),

$$\mathsf{q}_0 = \mathsf{e}_0 - \mathsf{p}_0^{flex},$$

and eq. (19) to obtain

$$\mathsf{e}_0 - \mathsf{e}_0^{flex} = \frac{1+\psi\delta\eta}{\phi\delta+\psi\delta\eta}[(\mathsf{e}_0^{flex})' - \mathsf{e}_0^{flex}]. \tag{20}$$

[Compare eq. (20) with eq. (17) for the case of a permanent increase in the money supply, remembering that e_0^{flex} changes one-for-one with $\bar{\mathsf{q}}$.] Finally, eqs. (13), (18), and (20) imply

12. Notice that $\tilde{\mathsf{p}}_t$ defined just after eq. (5), differs from p_t^{flex} in being the hypothetical price level that would clear the output market at the *current* (possibly disequilibrium) nominal exchange rate, not, as in eq. (19), at the flexible-price nominal exchange rate e_t^{flex}. Indeed p_t^{flex} is precisely the equilibrium price level we derived in the flexible-price Cagan model [see eq. (9) in Chapter 8].

$$e_t - (e_t^{flex})' = (1 - \psi\delta)^t [e_0 - (e_0^{flex})']. \tag{21}$$

Assuming that $1 > \phi\delta$, eq. (20) implies that any date 0 disturbance that causes an unanticipated rise in e_0^{flex} will cause an even larger unanticipated rise in e_0. With very general money supply processes, it is no longer meaningful to talk about overshooting with respect to a fixed long-run equilibrium nominal exchange rate. But one can say that the *impact* exchange-rate effect of a monetary shock is greater when prices are sticky than when they are flexible. Thus price stickiness affects the conditional variance of the exchange rate. Equation (21) says the exchange rate converges to its (moving) flexible-price equilibrium value after a shock at a rate given by $\psi\delta$.

So far, our entire analysis has been for the perfect-foresight case, augmented by one-time unanticipated shocks. Because the model is (log) linear, however, it is straightforward to generalize it to the case where the money supply is explicitly stochastic, much along the lines of the log-linear models we considered in earlier chapters.[13] We leave this as an exercise.

9.2.5 Money Shocks, Nominal Interest Rates, and Real Interest Rates

Perhaps the most important insight gained by introducing more general money-supply processes concerns the different patterns of exchange-rate correlation with real and nominal interest rates.[14] In the simplest version of the Dornbusch model, in which there are only permanent unanticipated changes in the level of the money supply, lower nominal interest rates on a currency are associated with depreciation. In the flexible-price models of Chapter 8, however, we found that shocks to the *growth rate* of the money supply lead to the opposite correlation: increases in the nominal interest rate are associated with currency depreciation. When there is a money-supply growth-rate shock, which effect dominates?

Unlike money-supply-level shocks, growth-rate shocks lead to a positive correlation between nominal interest rates and exchange rates in the Dornbusch model. Suppose that the money supply is initially governed by the process

$$m_t = \bar{m} + \mu t$$

and that the economy is in a steady state (i.e., has converged to the long-run flexible-price equilibrium). The nominal interest rate in this steady state must be $i^* + \mu$. Then, at time 0, there is an unanticipated rise in the expected *future* money growth rate from μ to μ' so that

13. See, for example, Mussa (1982, 1984).

14. Frankel (1979), in a classic paper, stressed the importance of distinguishing between real and nominal interest rates in empirical exchange-rate modeling. Frankel's paper was the first serious effort to implement the Dornbusch model empirically.

$$\mathrm{m}_t = \bar{\mathrm{m}} + \mu' t, \quad \forall t \geq 0.$$

It is easy to confirm that the flex-price exchange rate depreciates immediately by

$$(\mathrm{e}_0^{flex})' - \mathrm{e}_0^{flex} = \eta(\mu' - \mu), \tag{22}$$

because the expected future rate of depreciation under flexible prices rises from μ to μ'. Assuming there is overshooting, the actual exchange rate e_0 rises even more than e_0^{flex}, as we saw in eq. (20).

Solving for the impact effect on the nominal interest rate is trickier. We calculate the new path of the nominal interest rate (for all $t \geq 0$) to be

$$\mathrm{i}_{t+1} = \mathrm{i}^* + \mathrm{e}_{t+1} - \mathrm{e}_t = \mathrm{i}^* + (\mathrm{e}_{t+1}^{flex})' - (\mathrm{e}_t^{flex})' - \psi\delta(1 - \psi\delta)^t[\mathrm{e}_0 - (\mathrm{e}_0^{flex})']$$

using eqs. (1) and (21).[15] Since $(\mathrm{e}_{t+1}^{flex})' - (\mathrm{e}_t^{flex})' = \mu'$, the change in the nominal interest rate's path is

$$\mathrm{i}_{t+1} - (\mathrm{i}^* + \mu) = (\mu' - \mu) - \psi\delta(1 - \psi\delta)^t[\mathrm{e}_0 - (\mathrm{e}_0^{flex})']. \tag{23}$$

There are two countervailing effects in eq. (23). A permanent rise in the money growth rate from μ to μ' implies an equal rise in the trend rate of depreciation. But the remaining term on the right-hand side of eq. (23) is negative in the overshooting case. In the long run, the rise in trend depreciation clearly dominates, but is this necessarily the case in the short run? The answer is yes. Solve eq. (20) for $e_0 - (\mathrm{e}_0^{flex})'$ and combine the result with eqs. (22) and (23) (for $t = 0$) to derive the impact change in the nominal interest rate, $\mathrm{i}_1 - (\mathrm{i}^* + \mu)$:

$$(\mu' - \mu) - \psi\delta\eta\left(\frac{1 - \phi\delta}{\phi\delta + \psi\delta\eta}\right)(\mu' - \mu) = \phi\delta\left(\frac{1 + \psi\delta\eta}{\phi\delta + \psi\delta\eta}\right)(\mu' - \mu).$$

Since $\mu' - \mu > 0$, the correlation between i and e induced by one-shot money-supply growth-rate shocks is unambiguously positive. This result stands in contrast to the correlation induced by one-shot changes in money-supply levels.

Although the correlation between nominal exchange rates and interest rates is ambiguous when money shocks are dominant, the Dornbusch model does offer a strong and clear prediction about the correlation between *real* exchange rates and *real* interest rates when the long-run real exchange rate, $\bar{\mathrm{q}}$, is constant. Indeed, in our formulation that correlation is embodied in the price level adjustment mechanism, eq. (6). Defining the real interest rate as $\mathrm{i}_{t+1} - (\mathrm{p}_{t+1} - \mathrm{p}_t)$, we normalize $\mathrm{i}^* = 0$ and use eqs. (1), (3), and (6) to express it as

$$\mathrm{i}_{t+1} - (\mathrm{p}_{t+1} - \mathrm{p}_t) = (\mathrm{e}_{t+1} - \mathrm{e}_t) - (\mathrm{p}_{t+1} - \mathrm{p}_t) = -\psi\delta(\mathrm{e}_t + \mathrm{p}^* - \mathrm{p}_t - \bar{\mathrm{q}}). \tag{24}$$

15. To derive the second equality, forward eq. (21) by one period and subtract eq. (21) itself from the resulting expression.

Higher real interest rates thus are associated with a currency that has appreciated in real terms.[16] In a more general setting where foreign interest rates and prices can vary, this relationship is easily generalized to

$$[i_{t+1} - (p_{t+1} - p_t)] - [i^*_{t+1} - (p^*_{t+1} - p^*_t)] = -\psi\delta(e_t - p_t + p^*_t - \bar{q}). \tag{25}$$

According to this generalized formulation, it is the *difference* between the home and foreign real interest rates that is inversely related to the degree of home-currency real depreciation.[17]

9.3 Empirical Evidence on Sticky-Price Exchange-Rate Models

The Mundell-Fleming-Dornbusch model is widely regarded as offering realistic predictions on the exchange rate, interest rate, and output effects of major changes in monetary policy. Countries that adopt dramatic monetary tightening almost invariably appear to experience real currency appreciation and higher real interest rates; examples include the Volcker deflation of the 1980s in the United States, Britain's monetary tightening under Prime Minister Margaret Thatcher starting in 1979 (see Buiter and Miller, 1983), and the attempts by European countries such as Italy and France to deflate by pegging to the Deutsche mark within the European Monetary System. In the 1990s, several Latin American countries drastically tightened monetary policy after the severe inflations of the 1980s, with similar effects on real interest rates and real exchange rates.

16. Our derivation of the real-interest-rate–real-exchange-rate relationship is much simpler than in Frankel (1979) because we adopted the Mussa (1982) price adjustment mechanism. But the intuition is the same. Expected trend movements in the equilibrium real exchange rate would add a trend adjustment term to the right-hand side of eq. (24).

17. To derive the last relationship, use interest parity, condition (1), to write

$$i_{t+1} - (p_{t+1} - p_t) = i^*_{t+1} + (e_{t+1} - e_t) - (p_{t+1} - p_t)$$

or, adding $p^*_{t+1} - p^*_t$ to both sides,

$$[i_{t+1} - (p_{t+1} - p_t)] - [i^*_{t+1} - (p^*_{t+1} - p^*_t)] = (e_{t+1} - e_t) + (p^*_{t+1} - p^*_t) - (p_{t+1} - p_t).$$

Notice next that eq. (6) becomes

$$p_{t+1} - p_t = \psi(y^d_t - \bar{y}) + e_{t+1} + p^*_{t+1} - e_t - p^*_t$$

with a variable foreign price level (but still assuming a constant long-run real exchange rate). Using eq. (3) to eliminate $y^d_t - \bar{y}$ as before, we therefore can write

$$\begin{aligned}(e_{t+1} - e_t) + (p^*_{t+1} - p^*_t) - (p_{t+1} - p_t) &= -\psi(y^d_t - \bar{y})\\ &= -\psi\delta(e_t + p^* - p_t - \bar{q}).\end{aligned}$$

Combining this result with the preceding expression for the international real interest-rate differential, we reach eq. (25).

While conventional wisdom holds the Mundell-Fleming-Dornbusch model to be useful in predicting the effects of major shifts in policy, its ability to predict systematically interest-rate and exchange-rate movements is more debatable. In this section, we look at some of the evidence, beginning with the model's predictive power for interest rates and exchange rates, and then turning to output, where the model arguably is more successful. More detailed surveys can be found in Frankel and Rose (1995) and Isard (1995).

9.3.1 The Real-Interest-Differential–Real-Exchange-Rate Relationship

Many studies have attempted to detect the relationship (25) between the real interest rate and the real exchange rate predicted by the Dornbusch model, generally with little success. Meese and Rogoff (1988) could not reject the null hypothesis of no cointegration between the real exchange rate and the real interest rate differential for various cross rates among the dollar, yen, and Deutsche mark. Campbell and Clarida (1987) find that movements in expected interest differentials have not been large enough, or persistent enough, to account for variability in the real dollar exchange rate. Edison and Pauls (1993) have applied cointegration tests and error-correction mechanisms in equations that control for third variables (such as cumulated current accounts), but again with generally negative results.

A casual look at the evidence on the trade-weighted United States dollar may leave you surprised that researchers have had such difficulty detecting the negative real-exchange-rate–real-interest-rate correlation predicted by eq. (25). Figure 9.7 graphs quarterly data on the real value of the dollar against a trade-weighted average of other OECD countries' currencies. The real interest rate differential is measured by using interest rates on long-term bonds less one-year CPI changes. (Other standard expected inflation measures yield similar results.) For ease of visual interpretation, the real exchange rate in the figure is defined as $p - p^* - e$, *making a real appreciation an upward movement in the exchange rate index.* [Note well that under this convention, eq. (25) predicts a *positive* association between the two series.][18] As Figure 9.7 illustrates, the dollar's sharp upward appreciation during the mid-1980s occurred during a period when real interest rates in the United States were extremely high compared to those in its trading partners. Even apart from this episode, the figure seems loosely to suggest that long-term movements in the real-interest-rate differential do indeed have some correlation with long-term dollar exchange rate swings, even if the two variables do not move in lockstep.

18. The real exchange rate and interest rate data are taken from *International Financial Statistics* (the source for all the data in Figures 9.7–9.9). The countries included in multilateral averages are: Australia, Austria, Belgium-Luxembourg, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. One limitation of the real exchange rate measure used in Figure 9.7 is that it does not account for trade with developing countries.

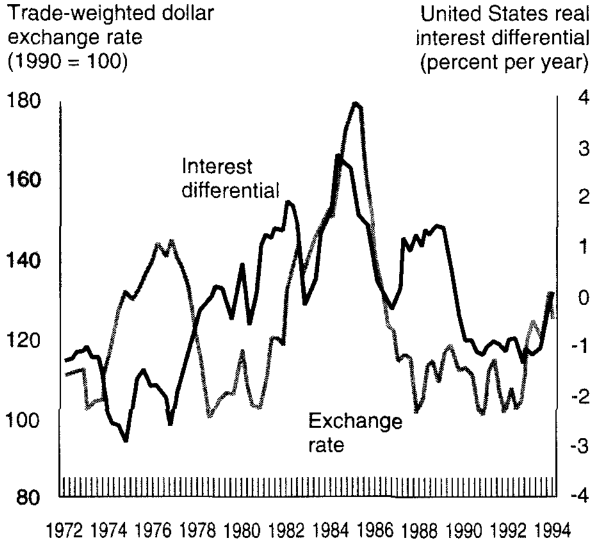

Figure 9.7
The dollar and relative U.S. real interest rates

Why doesn't the visual impression come through in regression analysis? Baxter (1994) suggests that most tests have focused too much on high-frequency (short-term) correlations and not enough on low-frequency movements. She uses methods better suited to detecting low-frequency movements and finds some correlation. She attributes its relatively small size to the preponderant role of high-frequency exchange-rate movements in explaining the total variance of exchange-rate movements.

Figures 9.8 and 9.9 show similar graphs for the trade-weighted yen and Deutsche mark. For these currencies, correlations between real interest differentials and real trade-weighted exchange rates seem, if anything, to go in the wrong direction (a relatively high real interest rate associated with a real currency depreciation). Overall, then, the empirical evidence on the real-interest-rate–real-exchange-rate correlation hardly provides overwhelming support for the Mundell-Fleming-Dornbusch model with a fixed long-run real exchange rate. Perhaps this outcome should not be surprising given the large literature on the speed of convergence to purchasing power parity. As Froot and Rogoff (1995) show, consensus estimates for the rate at which PPP shocks damp out are very slow. Consider a regression of the form

$$\mathsf{q}_t = a_0 + \rho \mathsf{q}_{t-1} + \epsilon_t,$$

where q is the real exchange rate and ϵ is a random disturbance. On annual panel data for industrialized countries, a typical estimate of ρ is 0.85. This implies an average half-life of deviations from PPP of roughly 4.2 years [where the half-life X

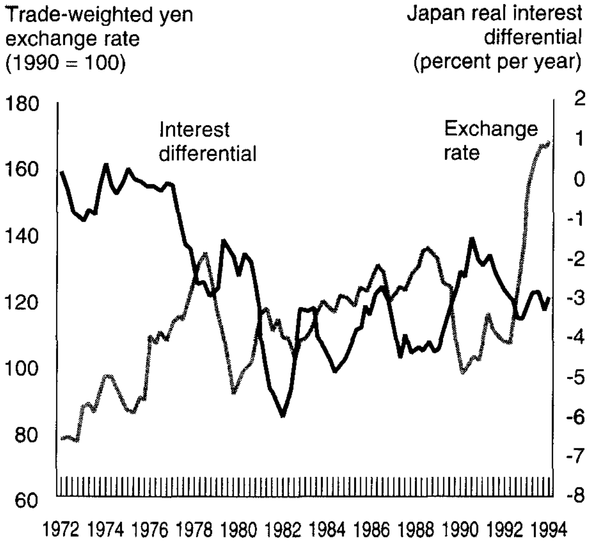

Figure 9.8
The yen and relative Japanese real interest rates

solves the equation $(0.85)^X = 1/2$]. Such slow convergence might make any systematic relationship between real exchange rates and the real interest rate difficult to detect except over fairly long horizons. The long half-life of PPP deviations remains something of a puzzle (see Rogoff, 1992, 1996).

9.3.2 Explaining the Nominal Exchange Rate

However badly the Mundell-Fleming-Dornbusch model fares in predicting the correlation between real exchange rates and real interest rates, its performance in predicting nominal exchange rates can only be described as worse (though it is not clear that a better model exists). Meese and Rogoff (1983a) analyzed the forecasting performance of a variety of monetary models of exchange rate determination, including the Dornbusch model and the flexible-price monetary model of Chapter 8. They showed that for major nominal exchange rates against the dollar, a random-walk model outperforms any of the structural models at one- to twelve-month forecast horizons. Remarkably, the random-walk model performs better *even if the structural-model forecasts are based on actual realized values of their explanatory variables*. In other words, the models fit very poorly out of sample, so that exchange rate movements are hard to rationalize on the basis of standard models even with the benefit of hindsight. As Frankel and Rose (1995) note, this awkwardly negative result has withstood numerous attempts to overturn it. The reasons behind the models' poor performances are not yet fully understood. Meese

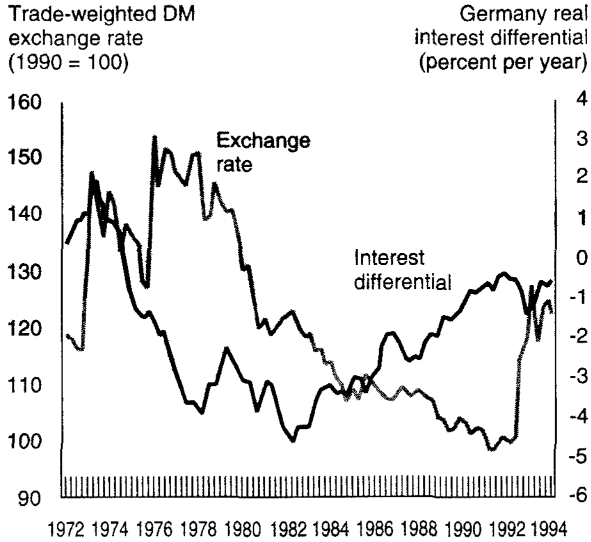

Figure 9.9
The Deutsche mark and relative German real interest rates

and Rogoff (1983b) consider a variety of explanations, including the breakdown of money demand functions and prolonged deviations from long-run purchasing power parity, without reaching a decisive answer. They do, however, find that the structural models may outperform the random walk at two- to three-year horizons. More conclusive evidence is presented by Chinn and Meese (1995) and Mark (1995), who show that the superior performance of various monetary models at very long horizons is statistically significant.[19]

The undeniable difficulties that international economists encounter in empirically explaining nominal exchange rate movements are an embarrassment, but one shared with virtually any other field that attempts to explain asset price data. Prescott (1986) has expressed the view that the difficulties of explaining asset price fluctuations are such that macroeconomic models should be judged mainly on their

19. In an interesting paper, Eichenbaum and Evans (1995) try using some alternative measures of money innovations for the United States, including statistical innovations in nonborrowed reserves and the federal funds rate. Their reasoning is that such measures better capture the exogenous component of monetary policy. (Foreign monetary policy is measured using the foreign interest rate.) Eichenbaum and Evans also try Romer and Romer's (1989) dates marking deliberate monetary contractions; these are based on minutes of the Federal Reserve's Open Market Committee. With all three measures, they find that monetary contractions lead to dollar appreciations as in the Dornbusch model. Somewhat surprisingly, however, they find roughly a two-year lag before the effect of the monetary contraction peaks. To date the Eichenbaum-Evans analysis has not been subjected to out-of-sample testing. Clarida and Gali (1994) find a similar delayed effect of money on exchange rates.

Table 9.1
Comparing Exchange-Rate and Stock-Price-Index Volatility, January 1981–August 1994
(standard deviation of month-to-month log changes)

Dollar/DM	Dollar/yen	S&P 500	Commerzbank	Nikkei
2.9	2.8	3.4	5.7	5.9

ability to explain fluctuations in output, consumption, investment, and other real quantity variables.

In trying to understand the difficulties in empirically modeling exchange rates, it is probably wrong to look for a special explanation of exchange-rate volatility. Instead, one should seek a unifying explanation for the volatility that all major asset prices display, including those of stocks and bonds as well as currencies. Indeed, nominal exchange rates typically are *less* volatile than, say, national stock-price indexes. Table 9.1 compares standard deviations of month-to-month changes in the log of the dollar/DM and dollar/yen exchange rates with those of the Standard and Poor's 500 stock index for the United States, the Commerzbank index for Germany, and the Nikkei 300 index for Japan.[20]

The standard deviation of month-to-month exchange rate changes is just under 3 percent, but the volatility of stock prices is even higher. One loose rationale for the higher volatility of stock prices is that currency values depend on GNP, which is more diversified than even a broad national stock market index.

9.3.3 Monetary Contraction and the International Transmission of the Great Depression

A central prediction of the Mundell-Fleming-Dornbusch model, and indeed of most Keynesian models, is that unanticipated monetary contractions lead to temporary declines in output. This assertion is perhaps the model's most controversial. For example, the real business cycle approach discussed in Chapter 7 argues that one can explain a substantial part of business cycle regularities by a model in which money has no real effects. In contrast, Friedman and Schwartz (1963) assign monetary shocks a dominant role. Resolving this debate empirically by estimating the effects of monetary shocks is not easy. First, it can be difficult to separate anticipated from unanticipated money shocks. (In theory unanticipated shocks should be much more important.) Second, if the monetary authorities follow any sort of money feedback rule (for example, a rule making money depend on exchange rates or interest rates), the money supply becomes endogenous. In this case, it can be difficult to distinguish the effects of money on output from the effects of third factors

20. Controlling for time trends does not qualitatively affect the results.

that simultaneously influence both.[21] Finally, the constant evolution of transactions technologies is making it increasingly difficult to find a measure of monetary policy that has a stable relationship with prices and output.

Partly as a result of these difficulties, economists recently have refocused their attention on the Great Depression of the 1930s. The Great Depression stands out for its severity and length. In the United States, unemployment rates exceeded 25 percent, the stock market dropped by 90 percent, and almost 50 percent of all banks failed. To varying degrees, countries in Europe, Latin America, and Asia experienced similarly precipitous declines. To paraphrase Bernanke (1983), a theory of business cycles that has nothing to say about the Great Depression is like a theory of earthquakes that explains only small tremors.

9.3.3.1 New International Evidence on the Great Depression

Until the 1980s most research on the Great Depression concentrated on the U.S. experience. In their classic book, Friedman and Schwartz (1963) placed the Depression at the doorstep of the U.S. Federal Reserve. According to Friedman and Schwartz, the young Fed (it was less than 20 years old at the outset of the Depression), whether by accident or design, initiated a sharp contraction in the U.S. money supply toward the end of the 1920s. This contraction was exacerbated by the banking crises of the early 1930s. A leader among skeptics of the monetary view was Temin (1976), who argued that money contractions were a response to the decline in output rather than vice versa, and that the main cause of the Depression in the United States was a large autonomous drop in consumption demand (a shift in the Keynesian *IS* curve, rather than the *LM* curve) that occurred in 1930.

More recently, economists have taken account of the worldwide scope of the Great Depression, drawing on evidence from twenty to thirty countries instead of just the United States. Leading examples of this research are Choudhri and Kochin (1980), Díaz-Alejandro (1983), Eichengreen and Sachs (1985), Hamilton (1988), Eichengreen (1992), and Bernanke and Carey (1995).

The new view is that the Depression was indeed caused by an exogenous worldwide monetary contraction, originating mainly in the United States and transmitted abroad by a combination of policy errors and technical flaws in the interwar gold standard. These problems forced any country pegging its currency to gold to contract its money supply sharply to maintain exchange parity. Countries outside the gold bloc—"floaters"—were free to devalue their currencies as necessary to avoid deflation. In an insightful paper, Choudhri and Kochin (1980) first noticed the clear divergence in economic performance between countries that abandoned the gold standard early in the Depression and others that stubbornly clung to gold.

21. As noted above, Romer and Romer (1989) try to overcome this endogeneity problem by using minutes of Federal Reserve Open Market Committee meetings to identify conscious monetary tightening. They find that their measure of monetary tightness helps predict downturns in GNP.

Comparing four countries outside the gold bloc (three Scandinavian countries and Spain) with four countries that stayed on gold (Belgium, Italy, the Netherlands, and Poland), Choudhri and Kochin found that the gold peggers suffered significantly sharper declines in output and employment. In a more comprehensive study, Eichengreen and Sachs (1985) showed that by 1935, countries that abandoned gold had substantially recovered from the Great Depression, while the gold bloc countries remained immersed in it.

Figure 9.10, based on data from Bernanke and Carey (1995), illustrates the finding. The vertical axis measures the ratio of real industrial production in 1935 to real industrial production in 1929, and the horizontal axis gives the corresponding ratio for the wholesale price level. The figure shows a striking positive correlation between cumulative inflation and the speed at which a country recovered from the Depression. A simple cross-section least squares regression of the cumulative industrial production change $\log(IP_{1935}/IP_{1929})$ on cumulative inflation $\log(WPI_{1935}/WPI_{1929})$ yields

$$\log(IP_{1935}/IP_{1929}) = \underset{(0.21)}{2.45} + \underset{(0.23)}{0.49}\log(WPI_{1935}/WPI_{1929}), \qquad R^2 = 0.17.$$

Thus a 1 percent increase in cumulative 1929–35 inflation is correlated with a 0.5 percent cumulative increase in industrial production. Countries that left the gold standard earliest in the period had the greatest latitude to inflate (though not all countries exercised this option with equal vigor), and monetary expansion seems systematically positively correlated with output growth.

9.3.3.2 Was the Global Monetary Contraction Simply an Endogenous Response to Output Decline? Flaws in the Interwar Gold Standard

If regressions such as the one in the preceding subsection were the only evidence linking adherence to the gold standard with the local severity of the Great Depression, one might still be able to argue that somehow output contraction induced countries to stay on the gold standard, rather than vice versa. This view—basically an international extension of Temin's (1976) hypothesis that monetary contraction was endogenous—is no longer sustainable in the face of a massive body of evidence assembled by Eichengreen (1992). Eichengreen considers in detail the political and technical underpinnings of the monetary contraction. He forcefully argues that the deflation experienced under the interwar gold standard was not the result of passive responses to declining output, but rather the unintended consequence of flawed central bank institutions, poor policy decisions, and difficult economic conditions that remained in the wake of World War I.

We touched on the history of the gold standard in our discussion of alternative monetary regimes in Chapter 8. Between 1870 and World War I the gold standard supported vigorous world trade and enjoyed a high degree of credibility. During that period, of course, central banks did not confront the political mandate to main-

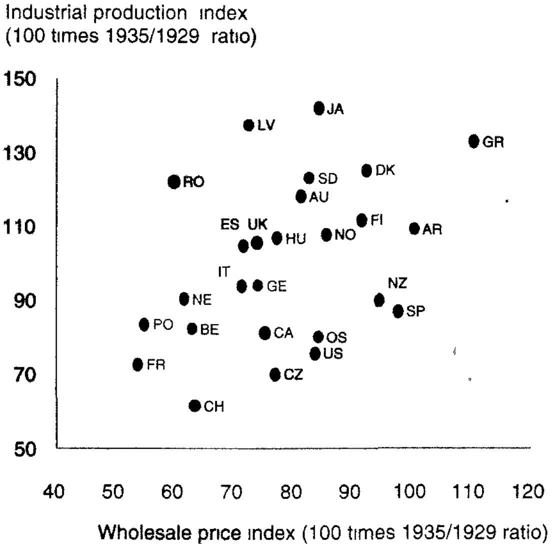

Figure 9.10
Industrial production and price levels in the Great Depression (1935; 1929 = 100)

tain full employment that emerged in the interwar years. In addition, the period was punctuated only by smallish, local wars.

The international gold standard was suspended when World War I broke out, but with a great deal of effort it was rebuilt after peace had been made. By 1929 virtually all market economies had returned to gold.

As Eichengreen (1992) and Bernanke (1995) argue, however, the reconstituted gold standard was built on much shakier ground than its prewar predecessor. First and perhaps foremost, having demonstrated their willingness to abandon the gold standard as a result of World War I (without necessarily returning to prewar exchange parities afterward), many countries were more vulnerable to speculators who might doubt the credibility of their commitment to gold. Second, in the interwar period, most countries maintained only fractional gold backing of their currencies, and most central banks held major currencies such as the dollar or pound in lieu of gold. This practice effectively increased the leverage of the world monetary gold stock, implying a heightened multiplier effect on the world money supply whenever hoarders pulled gold out of the system. Third, as with any fixed-exchange-rate regime, there was an asymmetry between deficit and surplus countries. Deficit countries were ultimately forced to deflate to maintain their currencies' exchange values while surplus countries faced no comparable pressure to inflate. Under the supposed gold standard "rules of the game," surplus countries were supposed to inflate as they gained gold through balance of payments surpluses, but instead the surplus countries, especially the United States and France, simply stockpiled the world's gold.

All these weaknesses in the interwar gold standard system helped propagate a deflationary monetary contraction that appears to have originated in the United States.

9.3.3.3 Summary

There is now overwhelming evidence suggesting that countries that abandoned gold early in the Great Depression and inflated did much better than countries that tried to stay linked to gold. A careful reading of the historical record also suggests that the monetary contraction initiating the Depression was exogenous, rather than a passive response to output, and that the international gold standard was a powerful transmission mechanism for the exogenous deflationary impulse. In sum, evidence from the interwar years provides some of the strongest support for a systematic effect of monetary policy on output.

From a welfare perspective, it is interesting to contrast the modern view of devaluation in the Great Depression with the older view of Nurkse (1944), who viewed devaluation as a "beggar-thy-neighbor" policy that raises the devaluer's income mainly at trading partners' expense. In Chapter 10, we will look at a model that suggests a different interpretation: countries that devalued their currencies (in order to inflate) may have actually helped their neighbors by expanding global aggregate demand. Under plausible assumptions, this positive effect can outweigh any trade-balance effects that occur because of shifts in competitiveness.

An important question that remains largely unresolved is why the Great Depression lasted so long, ending decisively only shortly before World War II. Bernanke (1983) argues that Depression had a devastating impact on financial intermediation, especially in the United States. It took many years for the country to rebuild its banking and financial industry. One piece of evidence he offers is that small firms without access to equity markets took more of a beating than large firms. (Looking at modern data, Gertler and Gilchrist, 1994, also find that monetary contractions tend to hit small firms harder than large firms.) Skeptics argue that a sector that accounts for only a very small fraction of GNP cannot account for such prolonged and severe dislocations. A different hypothesis is advanced by Eichengreen and Sachs (1985) and Bernanke and Carey (1995). These studies present cross-country evidence that nominal wage rigidities may have been sustained far beyond the one or two years most macroeconomists think of as an upper bound for delay in nominal wage adjustment. The studies do not, however, offer a detailed theory to explain their findings. Thus there still is no fully satisfactory explanation of the Great Depression's remarkable duration.

9.4 Choice of the Exchange-Rate Regime

Despite limited predictive and explanatory power, the Mundell-Fleming-Dornbusch model has deeply influenced thinking on a broad range of policy issues. One of the most important applications of the model is to the choice of exchange-rate regime.

9.4.1 Fixed versus Flexible Exchange Rates

A central result of the Mundell-Fleming-Dornbusch framework is that with sticky prices and flexible exchange rates, purely monetary shocks can spill over into the real economy, leading to large changes in prices and output and prolonged periods of adjustment. This prediction lies at the heart of a literature that argues that fixed exchange rates are superior to floating rates when money-demand shocks are the dominant source of disturbance buffeting the economy.[22] To understand the logic of the case for fixed rates, we need to extend our model to incorporate money-demand shocks. Suppose we modify the money-demand equation (2) to include a money-demand shock, so that now

$$\mathsf{m}_t - \mathsf{p}_t = -\eta \mathsf{i}_{t+1} + \phi \mathsf{y}_t + \epsilon_t,$$

where ϵ_t is an unpredictable shift in money demand. One might think of money-demand shocks as arising from changes in the transaction technology or the money multiplier, or from portfolio shifts. Clearly, it changes nothing essential to modify all formulas for a stochastic version of the log-linear Dornbusch model by replacing m_t with $\mathsf{m}_t - \epsilon_t$. Money-demand shocks simply have effects equal but opposite to those of money-supply shocks.

A fixed exchange rate fully and automatically eliminates any real effects of money-demand shocks. Why? Because, as our analysis in section 8.4.1 showed, fixing the exchange rate implies setting the money supply so as to keep $\mathsf{m}_t - \epsilon_t$ fixed, other things being equal. Thus fixing the exchange rate requires the monetary authority instantly to satisfy all money-demand shifts through (nonsterilized) foreign exchange intervention. Though there are some subtleties involving the timing of money-supply infusions, using the current money supply to peg the home nominal interest rate to the foreign nominal interest rate is an essentially equivalent policy. Again, if money-demand disturbances are the only shock buffeting the economy and the authorities fix i, they automatically fix $\mathsf{m}_t - \epsilon_t$.

When shocks are real (that is, originate in the goods market), a policy of holding the money supply constant will often dominate a policy of trying to fix the

22. See, for example, the discussion in Garber and Svensson (1995). For a discussion of exchange-rate policy focusing on developing countries, see Edwards (1989).

exchange rate. We saw an example of this in our analysis of a fall in the long-run equilibrium exchange rate $\bar{q}$ (a domestic real appreciation) in the Dornbusch model. (Recall the last paragraph of section 9.2.3.) In the example, adjustment to a new full-employment equilibrium was immediate under a floating exchange rate. Significantly, the shift to the new equilibrium required only an appreciation of the nominal exchange rate, which eliminated the need for a change in the nominal price level. Had the authorities been pursuing a fixed exchange-rate policy, however, domestic goods' money prices would have borne the entire burden of downward adjustment. Because these are sticky, the economy would have reached its new long-run equilibrium only gradually, after a period of unemployment.

Thus far, we have really discussed only pure fixed rates and pure floating rates (exogenous money). If Keynesian stabilization issues are the only problem, then, in general, the optimal exchange-rate policy does not call for fixing either the exchange rate or the money supply. Instead, the optimal policy takes the form of a feedback rule such as

$$m_t - \bar{m} = \Phi(e_t - \bar{e}),$$

where the optimal choice of Φ depends on the parameters of the model and the relative variance of the two types of economic shock. As the ratio of the variance of real shocks to the variance of monetary shocks goes to zero, the optimal regime will approach a fixed rate, implying $\Phi \to \infty$. (See Marston, 1985, and exercise 3. In a model where sterilized intervention is effective, the feedback rule can be generalized to incorporate shifts in portfolio preferences; see Branson and Henderson, 1985.)

We will not explore the literature on fixed versus flexible exchange rates in any great detail. One reason is that most of the literature is based on models that lack the microfoundations needed for meaningful welfare analysis. (Nevertheless, the key result that fixed exchange rates are optimal when financial disturbances dominate is likely to hold in more complete models.) Another reason for not dwelling too much on stabilization comparisons across exchange-rate regimes is that *credibly* fixed rates may not be a viable long-run option for most countries, given the pervasive possibility of speculative attacks on fixed exchange rates. Finally, many countries that adopt fixed exchange rates are more concerned with the effect on anti-inflation credibility than on short-term stabilization. We will discuss links among monetary-policy credibility, inflation, and exchange rates at the end of this chapter.

9.4.2 Optimum Currency Areas

A further step beyond fixed exchange rates is for two countries to share a common currency, as do, for example, the various states in the United States. Compared to a fixed exchange rate, a currency union is much harder to break, but it also requires a higher degree of policy coordination among members. The theory of optimal currency areas is one of the classic issues in international finance, dating back to the work of Mundell (1961), McKinnon (1963), and Kenen (1969). In recent years, with Europe's attempt to institute a common currency and the monetary problems facing the formerly communist bloc, the question of currency unions has again come to the forefront of international economic policy. Whereas a detailed analysis of optimum currency areas is well beyond the scope of this book, we will try in this section to give the reader at least a brief overview of the basic issues.

The main *benefits* two countries reap from having a common currency are generally thought to include the following:

1. Reduced transaction costs from currency conversion. Though the fees on large currency transactions are quite small, currency turnover is extremely high, so cumulative costs can be higher than one might imagine. Using bank data collected by the Bank for International Settlements, economists at the Commission of the European Communities (1990) estimated these costs to be between 0.25 and 0.4 percent of gross community product. (The bulk of the implied savings, about 70 percent, would come from eliminating margin and transaction fees paid to banks.)
2. Reduced accounting costs and greater predictability of relative prices for firms doing business in both countries.
3. Insulation from monetary disturbances and speculative bubbles that might otherwise lead to temporary unnecessary fluctuations in real exchange rates (given sticky domestic prices).
4. Less political pressure for trade protection because of sharp shifts in real exchange rates.

The main *costs* of having a common currency include these:

1. Individual regions in a currency union forgo the ability to use monetary policy to respond to region-specific macroeconomic disturbances. When labor mobility is high across regions, it is less necessary for each area to stabilize regional employment with its own independent monetary policy. Labor mobility is relatively high within the United States, but it is low within many European countries. Some authors, including Stockman (1988b), have argued that for Europe nation-specific productivity shocks play a substantial role in explaining aggregate national output fluctuations. This and similar findings suggest that asymmetric shocks should be an important consideration in deciding upon an exchange-rate regime.
2. Regions in a currency union give up the option to use inflation to reduce the real burden of public debt. (See Calvo and Leiderman, 1992, for a formal welfare analysis.) This budgetary inflexibility might be particularly important in extreme circumstances such as wars, for example. Also, as Sachs and Sala-i-Martin (1992) emphasize, currency unions such as the United States that share a national income

tax and transfer system have less need for region-specific monetary policy. Income taxes, for example, automatically transfer resources from boom regions to those in slump, thereby providing some measure of automatic stabilization.

3. Related to the last point, political and strategic problems arise in determining how member countries split seignorage revenues. (Regions that do not otherwise share a common fiscal policy must determine how to share seignorage revenues from printing the joint currency.) See, for example, Casella (1992) and Sibert (1994). Comparable problems arise in determining the currency union's joint monetary policy; see Alesina and Grilli (1992) and Canzoneri and Rogers (1990).

4. Avoiding speculative attacks in the transition from individual currencies to a common currency can be a major problem; witness the currency crises in Europe during the early 1990s. For a model of this problem, see Froot and Rogoff (1991), who argue that accelerating the speed of transition will not necessarily help temper speculative attacks and might simply hasten their occurrence.

An issue closely related to optimal currency areas is the choice of fixed or flexible exchange rates for two countries with different currencies. Of course, if exchange rates could be credibly fixed *forever*, then the differences between having a fixed exchange rate and a common currency would be fairly minor, and would mainly have to do with how leadership in monetary policy is determined. In practice, however, fixed exchange rate regimes never can be 100 percent credible. "Fixed" exchange rates are, in fact, more realistically thought of as "fixed but adjustable." As a practical matter, fixing the exchange rate for any length of time is not simple in a world of highly liquid and highly integrated world capital markets. Given the right conditions, speculative attacks can swiftly and ruthlessly undermine a country's commitment to a fixed exchange rate.[23]

Because it is difficult to separate stabilization from credibility issues in the choice of exchange-rate regime, we next turn to a formal exploration of credibility in monetary policy.

9.5 Models of Credibility in Monetary Policy

Our discussion of the choice of fixed versus flexible rates assumed that the monetary authorities can commit to a policy reaction function, and that this commitment will be perceived as fully credible by the public. In reality, credibility is a central problem in monetary design. If monetary expansions can raise output, won't monetary authorities be tempted to try routinely to raise employment above its natural

23. Garber and Svensson (1995) argue that the problem of speculative attacks is so severe that it dominates any practical analysis of the choice of exchange rate regime. See also the overviews of the international monetary system by Eichengreen (1994) and Goldstein (1995).

rate? Since the late 1970s, the recognition that strategic considerations are central to macroeconomic policy has led to a revolution in the theory of policy design, both at the domestic and at the international levels. We have alluded to credibility issues at several points in this book, but apart from our discussion of dynamic inconsistency in international borrowing in Chapter 6, we have not explored the subject systematically. This section provides a very basic introduction to the credibility problems that arise in making monetary policy. The macroeconomic model underlying our analysis is deliberately stylized, because we wish to highlight the gaming aspects of monetary policy rather than the technicalities of the transmission mechanism. Many of the results of the overly simple framework that follows can, however, be reinterpreted in terms of the more sophisticated models of Chapter 10.

9.5.1 The Kydland-Prescott, Barro-Gordon Model

In this section we present a simplified but very useful and influential model of monetary policy credibility. The basic ideas were first described by Kydland and Prescott (1977), though Barro and Gordon (1983b) showed the model's potential for explaining the stagflation that many industrialized countries experienced during the 1970s.[24] Barro and Gordon viewed their model as a positive account of inflation, but the subsequent literature, beginning with Rogoff (1985b) and more recently including Walsh (1995), Persson and Tabellini (1993), and Svensson (1995), has shown that the approach has important normative implications for the design of monetary institutions.

9.5.1.1 The Model

Consider a world in which private agents commit to nominal contracts one period before the contracts come into effect. For concreteness, let's think of nominal wage contracts, though the example here readily extends to other nominal rigidities. Of course, wage setters care about the real wage, not the nominal wage, so they must form forecasts of next period's inflation to know what nominal wage to commit to today. If these forecasts turn out to be wrong, real wages will deviate from their market-clearing level. Following standard Keynesian convention, we assume firms are always on their demand curves for labor, so that (all else equal) when inflation is higher than expected, employment rises, and when inflation is unexpectedly low, employment falls. Thus output is determined entirely by firms' demand for labor.

To capture these assumptions algebraically, we assume that the log of date t output, y_t, differs from its natural or flexible-price equilibrium level, $\bar{y}$, by an amount inversely proportional to the (log) real wage $w - p$. Thus,

24. Working roughly at the same time as Kydland and Prescott, Calvo (1978) developed a somewhat different model based on government seignorage needs. A broad survey is included in Persson and Tabellini (1990). See also Fischer (1990).

$$\mathsf{y}_t = \bar{\mathsf{y}} - (\mathsf{w}_t - \mathsf{p}_t) - z_t, \tag{26}$$

where we have assumed a proportionality constant of 1 to simplify the notation, and z_t is a conditional mean-zero, i.i.d. output supply shock. If workers always commit to a wage that sets expected output at its natural level, then the nominal wage for date t set in period $t-1$ satisfies

$$\mathsf{w}_t = \mathrm{E}_{t-1}\mathsf{p}_t. \tag{27}$$

The monetary authorities set period t policy *after* wage setters form inflation expectations on date $t-1$ and after observing any date t shocks. For simplicity we will assume that they directly set inflation, defined by

$$\pi_t \equiv \mathsf{p}_t - \mathsf{p}_{t-1}. \tag{28}$$

The loss function that the monetary authorities *minimize* is a weighted sum of squared deviations from an output target of $\tilde{\mathsf{y}}$ and an inflation target of 0:

$$\mathfrak{L}_t = (\mathsf{y}_t - \tilde{\mathsf{y}})^2 + \chi\pi_t^2. \tag{29}$$

The quantity

$$\tilde{\mathsf{y}} - \bar{\mathsf{y}} = k > 0 \tag{30}$$

represents a positive wedge between the output level targeted by the authorities and the natural level of output. Such a wedge could arise even if the monetary authorities maximize social welfare. For example, if insider labor negotiators do not take into account the welfare of outsider workers, employment will be inefficiently low even if nominal wages are fully flexible. Alternatively, the socially optimal level of unemployment might be below the natural rate because income taxes separate the social and private returns to labor, or because of hard-to-repeal minimum-wage laws. (The model of Chapter 10 will yield another interpretation, that the market-determined output level is too low because of monopolistic producers or labor unions.) The constant χ in the authorities' loss function (29) weights the cost of inflation relative to that of suboptimal output. It may also reflect the private sector's preferences (though the choices of wage setters at a single atomistic firm have only an infinitesimal effect on economy-wide inflation). Inflation has several social costs. Higher *anticipated* inflation reduces the demand for money, which costs (virtually) nothing to produce but yields liquidity services at the margin (Bailey, 1956). Even *unanticipated* inflation is costly in the model, however. Higher unexpected inflation sharpens random income redistributions, degrades the allocation signals in relative prices, and raises the distortions a nonindexed tax system inflicts. In practice, the latter costs probably dwarf the liquidity cost of expected inflation. Driffill, Mizon, and Ulph (1990) survey the evidence.

Successively substituting eqs. (26), (27), and (30) into eq. (29), we obtain $\mathfrak{L}_t = (\mathsf{p}_t - \mathrm{E}_{t-1}\mathsf{p}_t - z_t - k)^2 + \chi\pi_t^2$ or, using the definition of inflation in eq. (28),

$$\mathfrak{L}_t = (\pi_t - \pi_t^{\mathrm{e}} - z_t - k)^2 + \chi \pi_t^2, \tag{31}$$

where $\pi_t^{\mathrm{e}} \equiv \mathrm{E}_{t-1}\pi_t = \mathrm{E}_{t-1}\mathrm{p}_t - \mathrm{p}_{t-1}$.

Clearly, the model is ad hoc compared with the models considered in other chapters of this book. It nonetheless provides a useful (if rough) depiction of the typical tensions between monetary authorities and wage setters in many countries. The authorities would like output to be above its market-clearing level, whereas each individual wage setter, while perhaps agreeing with the general social goals of high aggregate employment and low inflation, wishes to avoid being among those who work at unexpectedly low real wages.[25]

We have assumed that the monetary authorities set actual inflation π_t *after* the private sector sets nominal contracts (which embody π_t^{e}), but does this fact mean that the authorities will always choose to set inflation high enough to force unemployment below the natural rate? Perhaps surprisingly, the answer is no. To see why, we need to consider how equilibrium is determined.

9.5.1.2 Equilibrium in the One-Shot Game

The presence of the wedge k between the target and natural output levels creates a *dynamic consistency* problem for the monetary authorities (in the sense we used that term in Chapter 6). The authorities would like to be able credibly to announce a zero-mean distribution of future inflation. But if such an announcement were believed by wage setters, the monetary authorities would be in a position to raise output above its natural level through an inflationary surprise at very little cost. Absent a mechanism for enforcing a promise of zero average inflation, a monetary authority whose promises are believed will never find $\pi = 0$ optimal ex post.

Though they move first, the atomistic wage setters understand the loss function (31) that the monetary authorities will minimize in the following period. They realize that for given values of π_t^{e} and z_t, the first-order condition for the authorities [found by differentiating eq. (31) with respect to π_t] will be

$$\frac{\mathrm{d}\mathfrak{L}_t}{\mathrm{d}\pi_t} = \underbrace{2(\pi_t - \pi_t^{\mathrm{e}} - z_t - k)}_{\substack{\text{(minus) marginal benefit of} \\ \text{higher inflation}}} + \underbrace{2\chi\pi_t}_{\substack{\text{marginal cost of} \\ \text{higher inflation}}} = 0, \tag{32}$$

which implies

$$\pi_t = \frac{k + \pi_t^{\mathrm{e}} + z_t}{1+\chi}. \tag{33}$$

25. Each worker will wish to avoid a cut in his own real wages even if the government redistributes the higher national output ex post to make everyone in the economy better off. The reason is that an atomistic worker regards the redistributive tax and transfer payments as exogenous to his own employment situation.

Thus the inflation level chosen by the monetary authorities is a function of inflationary expectations.

Because expectations are rational and wage setters understand that inflation will be set ex post according to eq. (33), the *equilibrium* inflation expectation π_t^e on date $t-1$ satisfies

$$\pi_t^e = \mathrm{E}_{t-1}\pi_t = \mathrm{E}_{t-1}\left\{\frac{k+\pi_t^e+z_t}{1+\chi}\right\},$$

or, since $\mathrm{E}_{t-1}z_t = 0$,

$$\pi_t^e = \frac{k}{\chi}. \tag{34}$$

Observe that expected inflation is higher, the greater is the wedge k between the authorities' target output level and the natural rate. Expected inflation is lower, the greater is χ, the relative weight the authorities place on inflation stabilization versus employment stabilization. Finally, substituting eq. (34) into eq. (33) yields ex post inflation,

$$\pi_t = \frac{k}{\chi} + \frac{z_t}{1+\chi}. \tag{35}$$

Comparing the last two equations, we find that in equilibrium, the monetary authorities do *not* succeed in systematically surprising wage setters, for realized and expected inflation differ only by the unpredictable exogenous shock z_t. How is this possible if the monetary authorities move after wages are set and can always set inflation above the level anticipated in wage contracts? The intuition is seen most easily by referring to first-order condition eq. (32) and, temporarily, abstracting from the z shocks. Suppose that private agents were to set $\pi_t^e = 0$. Then, if the monetary authorities chose $\pi_t = 0$, they would perceive the marginal cost of higher inflation, $2\chi\pi_t$, as zero. But the marginal benefit from slightly higher inflation [that is, the reduction in the first (output) component of the monetary authorities' loss function], $-2(\pi_t - \pi_t^e - k)$, would be a positive number (a positive reduction in the loss function). Thus zero inflation cannot be an equilibrium. In the "time-consistent" equilibrium (Kydland and Prescott's perhaps unfortunate terminology), the marginal benefit to higher inflation exactly offsets the marginal cost at $\pi_t = \pi_t^e$. The monetary authorities *could* inflate above and beyond the private sectors' expectations, *but it is not in their interest to do so.* (We are ignoring second-order conditions, but it is easy to check that they are met here.) Reintroducing the supply shock z does not change the basic intuition of the equilibrium. The monetary authorities partially counteract the output effects of the z shocks, but private sector expectations are still correct on average.[26]

26. While it may appear that wage setters must explicitily coordinate in order to reach the equilibrium characterized by eq. (34), this is not the case. We have derived the equilibrium under the assumption that each wage-setting unit acts independently.

9.5.1.3 Equilibrium with a Commitment Technology

Clearly, the equilibrium is not optimal from anyone's perspective. It entails a costly inflationary bias to monetary policy with no mean gain in output. One possible solution would be for the country to adopt a constitutional amendment to have zero inflation so that $\pi_t = 0$, in which case $\pi_t^e = 0$ as well. But this situation is not optimal because it prevents the authorities from using monetary policy to stabilize the economy in response to the supply shocks z. (If you don't like that story, think of the monetary authorities as needing flexibility to deal with financial crises.) Ideally, the monetary authorities would like to convince wage setters that they will only use monetary policy to offset shocks. Rather than commit to zero inflation, they would like to commit ex ante to the optimal policy rule

$$\pi_t = \frac{z_t}{1+\chi}, \tag{36}$$

which, as you can show, minimizes $\mathrm{E}_{t-1}\mathfrak{L}_t$ [derived from eq. (31)] subject to $\pi_t^e = \mathrm{E}_{t-1}\pi_t$.[27]

The question is whether there is any practical way to make such a binding commitment, especially when one takes into account that in reality an optimal ex ante rule such as eq. (36) must be able to deal with a wide array of possible disturbances.

9.5.1.4 Reputational Equilibria

An optimistic view of the credibility problem in monetary policy is that it largely disappears in a more realistic long-horizon setting. Suppose, for example, that instead of minimizing the static loss function (31), the monetary authorities seek to minimize the present-value loss function

$$\mathrm{E}_t\left\{\sum_{s=t}^{\infty}\beta^{s-t}\mathfrak{L}_s\right\}, \tag{37}$$

where $\mathfrak{L}_s = (\pi_s - \pi_s^e - z_s - k)^2 + \chi\pi_s^2$. Then trigger-strategy equilibria in which expected inflation is lower than the "one-shot-game" level k/χ in eq. (34) may exist (in analogy to those we studied in Chapter 6).

Again, the idea is easiest to illustrate by assuming that the z shocks are absent. Suppose that private sector expectations are given by

$$\pi_t^e = \begin{cases} 0 & \text{if } \pi_{t-s} = \pi_{t-s}^e, \ \forall s > 0 \\ k/\chi & \text{otherwise.} \end{cases} \tag{38}$$

27. This is really only a second-best policy, of course, since it does not eliminate the underlying distortion causing the wedge k between the target and natural output levels. If that wedge could be eliminated, for example, through tax or labor-market reform, there would be no need for the monetary authorities to bind themselves in advance.

Thus expected inflation is zero in period t provided the monetary authorities set $\pi = \pi^e$ in all earlier periods. Otherwise, inflation expectations revert permanently to those of the one-shot game (there is an infinite period of "punishment"). To see whether these expectations are consistent with a zero-inflation equilibrium, we need to compare the cost and benefit to the monetary authorities of cheating by setting inflation greater than zero. Assuming that $\pi_t^e = 0$, the discounted cost of *not* setting $\pi_t = 0$ is simply $[\beta/(1-\beta)]\chi(k/\chi)^2 = [\beta/(1-\beta)]k^2/\chi$, the present value of the future costs from having equilibrium inflation at its one-shot-game level instead of zero from date $t+1$ on.[28] The maximum date t benefit from cheating when $\pi_t^e = 0$ is found by minimizing

$$\mathfrak{L}_t = (\pi_t - k)^2 + \chi\pi_t^2,$$

which yields $\pi_t = k/(1+\chi)$. If the monetary authorities cheat, their minimized date t loss function therefore is

$$\left(\frac{k}{1+\chi} - k\right)^2 + \chi\left(\frac{k}{1+\chi}\right)^2 = \frac{\chi}{1+\chi}k^2,$$

which is less than the date t loss k^2 that would obtain if instead π_t were set at $\pi_t^e = 0$. The short-term "gain" from cheating is thus $k^2(1 - \frac{\chi}{1+\chi}) = k^2/(1+\chi)$. We see that if the government does not discount the future too much (β is near 1), then the cost of cheating, which we calculated as $[\beta/(1-\beta)]k^2/\chi$, can easily outweigh the short-term benefit, $k^2/(1+\chi)$. If $\beta < \chi/(1+2\chi)$, however, zero inflation isn't an equilibrium. Even if β is too low to support the zero-expected inflation equilibrium under the trigger-strategy expectations in eq. (38), it will still generally be possible for eq. (38) to support a positive equilibrium inflation rate below the one-shot-game level.[29]

It is straightforward to reintroduce the z shocks. The analysis is much the same except that trigger strategy expectations are given by

$$\pi_t^e = \begin{cases} 0 & \text{if } \pi_{t-s} = \pi_{t-s}^e + z_{t-s}/(1+\chi), \ \forall s > 0 \\ k/\chi & \text{otherwise.} \end{cases} \tag{39}$$

Notice that in this case, the monetary authorities are allowed to stabilize in response to observable supply shocks without compromising their "reputation."

As in Chapter 6, the trigger-strategy equilibrium that we have discussed would unravel backward if the monetary authorities had a finite rather than an infinite horizon. (There would be no incentive to adopt anything but the one-shot-game

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28. Note that, given the expectations in eq. (38), the monetary authorities will always set inflation at its one-shot-game level k/χ once they have already cheated and are suffering punishment anyway.

29. Even with a one-period (rather than infinite) punishment interval, it is always possible to support an expected inflation rate lower than that of the one-shot game (again in analogy with Chapter 6). For details and discussion of more complex punishment strategies, see Rogoff (1987). The trigger strategy type of equilibrium was proposed by Barro and Gordon (1983a).

inflation rate in the last period T, but then there can be no incentive to maintain a reputation in $T-1$, etc.) One should not take this apparent fragility of the trigger-strategy equilibrium too literally though, since there are ways to resurrect "reputational" equilibria when policymakers' horizons are finite (e.g., if there is some degree of imperfect information about the policymakers' costs of breaking commitments; see Rogoff, 1987). The fairly robust point is that if monetary policy is a repeated game (and it certainly is), then the authorities' incentives to engage in surprise inflation in the current period may be tempered by concern for future reputation. It is sometimes even possible to support the optimal (with commitment) policy.

Unfortunately, there are good reasons for not relying too heavily on reputational considerations as a solution to the government's credibility problems in conducting monetary policy. First and foremost, reputational models generally admit a multiplicity of equilibria. In the preceding trigger-strategy model, even when zero expected inflation is sustainable as an equilibrium, the one-shot-game expected inflation rate $\pi^{e}=k/\chi$ remains an equilibrium, as does any inflation rate between 0 and k/χ. (Indeed, even negative expected inflation rates are sustainable.) As a result, there is a substantial coordination problem in achieving the most favorable reputational equilibrium. This coordination problem is likely to be quite severe in a macroeconomic setting with a very large number of agents. Even in setups where the equilibrium is unique, it typically turns out to be quite sensitive to the parameterization of the model.

9.5.2 Institutional Resolutions of the Dynamic Consistency Problem

If credibility is a problem in monetary policy, are there institutional reforms a country can adopt to lower inflationary expectations without sacrificing all flexibility in monetary policy?

9.5.2.1 The Conservative Central Banker

One possible way societies might confront the problem of monetary-policy credibility is to create an independent central bank that places a high weight on inflation stabilization. Suppose, for example, that the government delegates monetary policy to an independent "conservative" central banker with known preferences

$$\mathfrak{L}_{t}^{\mathrm{CB}}=(\pi_{t}-\pi_{t}^{\mathrm{e}}-z_{t}-k)^{2}+\chi^{\mathrm{CB}}\pi_{t}^{2},$$

where $\chi^{\mathrm{CB}}>\chi$. That is, the central banker is conservative in the sense of placing a higher relative weight on inflation stabilization than does society as a whole. This scenario is not unrealistic: central bankers are often chosen from among conservative elements in the financial community. Following the same steps as in deriving eqs. (34) and (35), one can show that the (one-shot-game) equilibrium is now characterized by

$$\pi_t^e = \frac{k}{\chi^{CB}}, \tag{40}$$

$$\pi_t = \frac{k}{\chi^{CB}} + \frac{z_t}{1+\chi^{CB}}. \tag{41}$$

Equations (40) and (41) reveal the pros and cons of having a conservative central banker. On the plus side, expected inflation in eq. (40) is lower than in eq. (34) since $\chi^{CB} > \chi$. However, comparing eqs. (41) and (35), we see that the conservative central banker reacts less to supply shocks than would a central banker who shared society's preferences. A conservative central banker is too concerned with stabilizing inflation relative to stabilizing employment. Clearly, if $k = 0$, so there are no distortions and no inflation bias, it makes no sense to have a conservative central banker. On the other hand, if $k > 0$ and there are no supply shocks, it is optimal to have a central banker who cares only about inflation ($\chi^{CB} = \infty$). Rogoff (1985b) shows that, in general, the optimal central banker has $\chi < \chi^{CB} < \infty$, and thus is conservative but not "too" conservative. The proof involves an envelope theorem argument. When χ^{CB} is very large, π^e is very small, and therefore the marginal cost of allowing slightly higher expected inflation is small. Thus the stabilization benefits of lowering χ^{CB} toward χ are first-order whereas the inflation cost is second-order. On the other hand, when $\chi^{CB} = \chi$, the monetary authorities are stabilizing optimally, and the inflation benefits to raising χ^{CB} are first-order while the stabilization costs are second-order.[30] There is thus a trade-off between flexibility and commitment. Lohmann (1992) shows that this trade-off may be mitigated by setting up the central bank so that the head may be fired at some large fixed cost. In this case, society will fire the conservative central banker in the face of very large supply shocks.[31]

9.5.2.2 Optimal Contracts for Central Bankers

One alternative to appointing a conservative central banker is to impose intermediate monetary targets on the central bank, perhaps through clauses in the central bank governor's employment contract.[32] Walsh (1995) has shown that the optimal contract in this class my eliminate the inflation bias of monetary policy without any sacrifice in stabilization efficacy.[33]

30. Effinger, Hoeberichts, and Schaling (1995) develop a closed-form solution to the model.

31. See also Flood and Isard's (1989) "escape clause" model of fixed exchange rates. Obstfeld (1991), however, shows that escape clauses such as Lohmann's and Flood and Isard's can lead to multiple equilibria and therefore be destabilizing. We will see such an example later on when we revisit models of speculative attacks on fixed exchange rates.

32. See Rogoff (1985b), who considers the credibility implications of a variety of intermediate targets, including inflation and nominal GNP. Using interest rate targets—nominal or real—to anchor inflation actually turns out to be counterproductive.

33. Persson and Tabellini (1993) expand Walsh's idea to look at various alternative monetary institutions. See also Persson and Tabellini (1995).

Suppose again that society creates an independent central bank, this time choosing a central banker who places the same relative preference weight on inflation stabilization as society [as reflected in eq. (31)]. In addition to society's welfare, however, the central banker also responds to monetary incentives. Suppose that these incentives are set so that the central banker's loss function is given by

$$\mathcal{L}_t^{\mathrm{CB}} = (\pi_t - \pi_t^{\mathrm{e}} - z_t - k)^2 + \chi \pi_t^2 + 2\omega \pi_t. \tag{42}$$

This objective function is the same as the social welfare function (31) except for the additional linear term in inflation tacked on the end. Imagine that the central banker receives a bonus that is reduced as inflation rises.

In place of first-order condition (32), the first-order condition for the central bank in setting inflation now becomes

$$\frac{\mathrm{d}\mathcal{L}_t^{\mathrm{CB}}}{\mathrm{d}\pi_t} = 2(\pi_t - \pi_t^{\mathrm{e}} - z_t - k + \chi \pi_t + \omega) = 0.$$

Taking $t-1$ expectations of the above equation and setting $\pi_t^{\mathrm{e}} = \mathrm{E}_{t-1}\pi_t$, we see that the equilibrium is now described by

$$\pi_t^{\mathrm{e}} = \frac{k-\omega}{\chi}, \tag{43}$$

$$\pi_t = \frac{k-\omega}{\chi} + \frac{z_t}{1+\chi}, \tag{44}$$

so that if $k-\omega$ is set equal to zero, the central bank will be induced to adopt the same monetary policy [eq. (36)] that it would in the presence of a commitment technology! The trick is that the added incentive term is linear, so that it mitigates the average inflation bias without affecting the central bank's marginal incentives for responding to z shocks. One of the most impressive features of the optimal linear incentive contract is that it turns out to be robust to incorporation of some types of private information (e.g., if the central bank has private information about its inflation forecasts, as in Canzoneri, 1985).[34]

What are some drawbacks to optimal incentive contracts? The most troubling question is whether a government that cannot itself be trusted to resist the temptation to inflate can be trusted to properly monitor the central bank's anti-inflationary incentives. Walsh (1995) and Persson and Tabellini (1993) argue that the contract may be encoded legally, but this justification is not sufficient. Even a government bound to make the payments specified in the contract may be hard to deter from offering a self-interested central banker extra-contract incentives that outweigh those specified in the original agreement. For example, the ex ante contract may give the central banker \$1 million minus \$100, 000 for every point of inflation. However, ex

34. Svensson (1995) shows that a system of intermediate inflation targets shares many of the desirable features of the optimal-contracting approach.

post, the government can offer the banker other incentives, explicitly or under the table, that more than offset his pecuniary loss from inflating. Any cost to bribing the central banker is likely to be small relative to the potential gains as perceived by the government. Government officials often find creative *sub-rosa* ways to pay themselves, so there is no reason to assume they could be prevented from tempting a central banker if the stakes were high enough.

Another problem with the optimal contract scheme is that there may be uncertainty about the relative weight the banker places on public welfare versus personal financial remuneration. If so, uncertainty about, say, the central banker's financial needs (e.g., private information about a costly impending divorce) may lead to uncertainty over inflation and introduce extraneous noise into inflation policy. Such uncertainty is above and beyond any uncertainty that might exist over the central banker's value of χ^{CB} (relative weight on inflation stabilization).[35] Finally, as Herrendorf and Lockwood (1996) point out, the efficiency of the contract approach may be reduced when the private sector resets its wage contracts at more frequent intervals than the government is able to reset the terms of the central banker's contract. (Given political constraints, this assumption seems highly plausible.) In this case, an appropriately structured contract can still reduce the mean inflation rate to zero but the response to supply shocks is no longer optimal. Herrendorf and Lockwood derive conditions under which the conservative central banker approach is more robust to this problem. While these criticisms are important, the optimal contract approach remains valuable in providing a concrete framework for designing optimal institutions.

9.5.3 Political Business Cycles

One interesting theoretical and empirical application of models of monetary policy credibility is to the study of political business cycles. During much of the postwar period, many Western democracies could be characterized as having had a conservative political party that placed a relatively high weight on keeping inflation in check and a liberal party more concerned about unemployment. Hibbs (1977) showed that these differences have led empirically to a type of political business cycle in which inflation and output growth tend to be high when liberals are in office, and low when conservative regimes are in power. His model, however, assumes a very crude static Phillips curve framework in which the monetary authorities can systematically raise output growth by raising inflation. Alesina (1987) presents a clever refinement of the Hibbs model that allows the private sector to form expectations in a more rational manner.

Suppose that the preferences of the monetary authority are determined by the party in power (we drop any consideration of whether these preferences coincide

35. See exercise 4 at the end of the chapter.

with society's preferences or a utilitarian social welfare function). When liberals are in power, the monetary authorities' objective function is

$$\mathfrak{L}_t^{\mathrm{L}} = -(\pi_t - \pi_t^{\mathrm{e}} - k) + \frac{\chi^{\mathrm{L}}}{2}\pi_t^2, \tag{45}$$

where L superscripts pertain to the "liberal" party. (We abstract from supply shocks z, which are not important here.) Notice also that we have chosen a functional form in which the term $\pi_t - \pi_t^{\mathrm{e}} - k$ enters linearly. This change turns out to simplify the analysis and also corresponds to the notion that liberal parties always prefer more output to less. The conservative party places no weight on employment stabilization, so that its objective function is simply

$$\mathfrak{L}_t^{\mathrm{C}} = \pi_t^2. \tag{46}$$

Thus the conservative party always sets inflation at $\pi = 0$.

When the public knows in advance that the liberal party is going to be in power, equilibrium inflation is

$$\pi_t^{\mathrm{e}} = \pi_t = \frac{1}{\chi^{\mathrm{L}}}. \tag{47}$$

[Differentiate eq. (45) with respect to π_t holding π_t^{e} constant, then solve the resulting equation for π_t and observe that $\pi_t^{\mathrm{e}} = \pi_t$ in equilibrium.] When the preferences of the policymaker in office are known in advance by wage setters, there is no difference in real wages and employment under the two regimes, since monetary policy is fully anticipated. The only difference is that equilibrium inflation is higher under the liberal party (it is zero under the conservatives).

Suppose, however, that there is an election in period t, and that when setting wages in $t-1$, the public does not know which party is going to win. For simplicity, assume that the probability of either party winning is exogenous and equal to $\frac{1}{2}$. In this case, expected inflation is given by

$$\pi_t^{\mathrm{e}} = \frac{1}{2}\cdot 0 + \frac{1}{2}\cdot\frac{1}{\chi^{\mathrm{L}}} = \frac{1}{2\chi^{\mathrm{L}}}. \tag{48}$$

[The problem is simplified by the fact that with the functional form (46), the liberal party's choice of inflation is independent of π_t^{e}.] If the conservative party actually wins the election, inflation will be lower than anticipated, real wages will be high and output growth low. If the liberal party wins, inflation will be higher than anticipated and output growth high.

Alesina's analysis suggests the following prediction. Throughout a liberal government's term inflation will be high, and throughout a conservative government's term inflation will be low. But output growth will be different for the two types of government only during the first part of a term in office, when contracts have not fully adjusted to the new government's preferences. During the second part of a government's term in office, output growth will be the same regardless of which party holds power. This is an interesting and strong refinement of the Hibbs model. Remarkably, Alesina (1987) finds that "rational partisan" political business cycles are evident across a broad range of Western democracies. Growth tends to be higher under liberal parties but only during the first year or two after an election, while inflation tends to be higher under liberal parties throughout their term in office.

One can criticize the Alesina model on a number of grounds. If elections are such a major source of inflation uncertainty, why aren't contracts timed to expire just before predictable elections so that new contracts can take into account the preferences of the winner? Won't the cycle be sharply mitigated in a lopsided election where there is little uncertainty about the ultimate victor? Nevertheless, the simple crisp empirical predictions of the model, together with its apparent empirical power, make this one of the most interesting pieces of evidence in favor of the general Kydland-Prescott and Barro-Gordon approach.

We note that this type of political business cycle is strikingly different from the classic Nordhaus (1975) cycle in which incumbents attempt to expand output prior to elections to try to convince voters to reelect them. For rational expectations refinements of the Nordhaus model based on cycles in budget policy, see Rogoff and Sibert (1988) and Rogoff (1990).

Application: Central Bank Independence and Inflation

The preceding discussion suggests that the inflation bias in monetary policy may be reduced by making the central bank independent of political pressures. In reality the degree of central bank independence is measured on a continuum. Variables such as the length of directors' terms, the process through which directors are appointed, and even the budgetary resources over which the bank has control may all have a bearing on its true independence in formulating monetary policy. Alesina and Summers (1993), Cukierman, Webb, and Neyapti (1992), and Grilli, Masciandaro, and Tabellini (1991), among many others, have noted a negative correlation between long-run industrial-country inflation rates and various indicators of central bank independence.

Figure 9.11 plots the Cukierman, Webb, and Neyapti (1992) measure of central bank independence (CBI) against average 1973–94 CPI inflation rates for 17 industrial countries. The least squares regression line for the cross section is

$$\pi_{1973-94} = \underset{(1.57)}{8.30} - \underset{(2.35)}{6.02}CBI, \qquad R^2 = 0.30$$

(with standard errors in parentheses). The slope coefficient is of the hypothesized sign, and significant.

A number of authors have questioned whether results such as these really imply a strong causal link from CBI to low inflation. For one thing, this empirical cor-

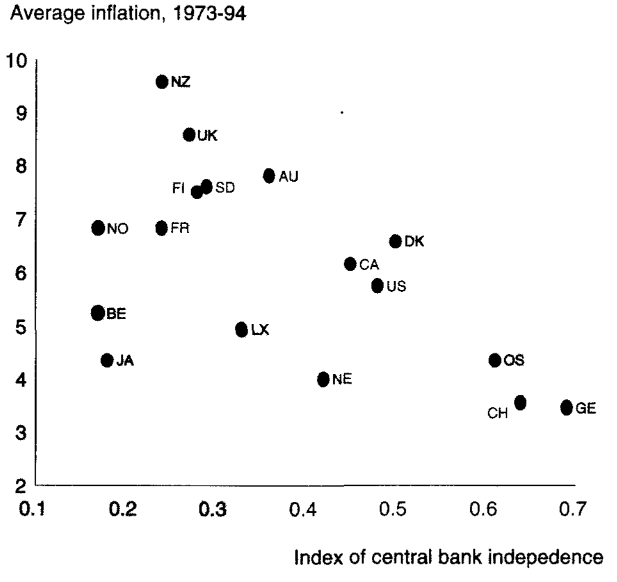

Figure 9.11
Central bank independence versus inflation

relation does not extend easily beyond the set of industrialized countries. It may also be that CBI and low inflation arise from a common source. Posen (1995) argues that the political influence of a country's financial industry is instrumental in explaining both the independence of its central bank and its inflation record. In his framework, CBI in itself has no favorable inflation effect unless the central bank's directorate is more "hawkish" on inflation than the rest of government, and an influential financial community can best ensure this outcome. In addition, there are countries evident in Figure 9.11, notably Japan, with relatively dependent central banks yet low average inflation. (However, the main outside influence over the Bank of Japan is the Ministry of Finance, which is itself both conservative and very independent.) Milesi-Ferretti (1995) suggests that countries dominated by conservative politicians may avoid setting up institutions conducive to low inflation. The conservatives in power are themselves averse to inflation, but they wish to keep voters fearful of what the liberal opposition might do if elected. Campillo and Miron (in press) find little evidence that CBI affects long-run inflation even in high-income countries once other determinants of inflation, such as the size of the public debt, are included in cross-section regressions.

Because institutions are endogenous in the long run, the critics who view inflation and CBI as jointly determined have a point. At this stage, the evidence linking central bank independence to low inflation may be regarded as highly suggestive but not decisive. ■

9.5.4 Pegging the Exchange Rate to Gain Anti-Inflation Credibility

The basic lessons of the preceding closed-economy analyses readily extend to the open economy. The same institutional resolutions of the credibility problem available in the closed economy (an independent central bank, inflation targeting) are available in the open economy. In the open economy, however, another instrument for trying to commit to low inflation is available, the exchange rate. Indeed, pegging the exchange rate against the currency of a low-inflation country has been an extremely popular approach to developing or maintaining anti-inflation credibility. Giavazzi and Pagano (1988) argue that during the 1980s, many EMS countries effectively designated Germany's Bundesbank as their "conservative central banker" by pegging their nominal exchange rates to the Deutsche mark. Most developing countries have made exchange-rate stability the centerpiece of their inflation stabilization attempts.

In Chapter 8, however, we showed that fixed exchange rates can be susceptible to speculative crises. There we treated the government's behavior as mechanical. Here we show how speculative attacks can arise in a setting where the government's objectives are spelled out explicitly. An important implication of our discussion is that fixed exchange-rate commitments, like reliance on reputational mechanisms, may do little to buttress the credibility of governments with otherwise strong incentives to inflate. Indeed, they may give rise to multiple equilibria and the possibility of currency crises with a self-fulfilling element.[36]

9.5.4.1 The Model

Let's return to this section's basic model of monetary policy credibility. Reinterpret the model as applying to an open economy in which PPP holds, so that $P = \mathcal{E}P^*$, or, in log notation with P^* normalized to 1, $\mathsf{e} = \mathsf{p}$. Suppose the government minimizes the loss function

$$\mathcal{L}_t = (\mathsf{y}_t - \tilde{\mathsf{y}})^2 + \chi\pi_t^2 + C(\pi_t), \tag{49}$$

where, because of the PPP assumption, π_t corresponds to $\mathsf{e}_t - \mathsf{e}_{t-1}$, the realized rate of currency depreciation, as well as to the inflation rate. Under a fixed exchange rate, $\pi_t = 0$.

The loss function in eq. (49) is of the same general category as eq. (42), but with a different supplementary inflation-cost term $C(\pi_t)$. In an attempt to temper its credibility problems, the government here has adopted a "fixed but adjustable" exchange rate. It has placed itself in a position such that any upward change in e (a devaluation, implying $\pi_t > 0$) leads to an extra cost to the government of $C(\pi_t) = \bar{c}$, whereas any downward change in e (a revaluation, implying $\pi_t < 0$) leads to a

36. This section's analysis is based on Obstfeld (1996b).

cost of $C(\pi_t) = \underline{c}$. The fixed cost of a parity change could be viewed as the political cost of reneging on a promise to fix the exchange rate (for example, an EMS exchange-rate mechanism commitment).[37] If there is no change in parity, $C(0) = 0$. As we shall see, the fixed cost to breaking the exchange rate commitment may help reduce expected inflation but also may leave the economy open to speculative attacks.

Wages are again determined by eq. (27) and aggregate supply as in eq. (26). Output therefore is described by an expectations-augmented Phillips curve

$$\mathrm{y} = \bar{\mathrm{y}} + (\pi - \pi^{\mathrm{e}}) - z; \tag{50}$$

that is, output net of the natural rate depends on unexpected currency depreciation (equals inflation) and a random supply shock, as before. Again, $\tilde{\mathrm{y}} - \bar{\mathrm{y}} = k > 0$. We have dropped time subscripts under the assumption that the equilibrium is time invariant, which will turn out to be consistent with our assumptions.

9.5.4.2 Equilibria

We will focus here only on equilibria of the one-shot game. We remind you that the private sector chooses depreciation expectations π^{e} before observing either z or π. In contrast, the government chooses π after observing both z and π^{e}.

Let us initially ignore the fixed cost term $C(\pi)$. If there were no fixed cost, the government would choose

$$\pi = \frac{k + \pi^{\mathrm{e}} + z}{1 + \chi} \tag{51}$$

just as in eq. (33). Substituting this solution back into eqs. (50) and (49), we see that the resulting output level is

$$\mathrm{y} = \bar{\mathrm{y}} + \frac{k - \chi\pi^{\mathrm{e}} - \chi z}{1 + \chi}, \tag{52}$$

and that the government's ex post policy loss is

$$\mathcal{L}^{\mathrm{FLEX}} = \frac{\chi}{1 + \chi}(k + \pi^{\mathrm{e}} + z)^2. \tag{53}$$

Without *any* option of altering the exchange rate, the government's ex post loss would instead be

$$\mathcal{L}^{\mathrm{FIX}} = (k + z + \pi^{\mathrm{e}})^2 > \mathcal{L}^{\mathrm{FLEX}}. \tag{54}$$

Now take into account the fixed costs of currency realignment, $C(\pi)$. Given those costs, the authorities will change the exchange rate only when z is high

37. It is quite plausible that the public would not know $C(\pi)$ but would only have priors on it. For a characterization of the reputational equilibria that can arise in this case, see Rogoff (1987) and Froot and Rogoff (1991).

enough to make $\mathcal{L}^{\mathrm{FIX}} - \mathcal{L}^{\mathrm{FLEX}} > \bar{c}$ (in which case the currency is devalued), or low enough to make $\mathcal{L}^{\mathrm{FIX}} - \mathcal{L}^{\mathrm{FLEX}} > \underline{c}$ (in which case the currency is revalued). Devaluation thus occurs when $z > \bar{z}$, where

$$\bar{z} = \sqrt{\bar{c}(1+\chi)} - k - \pi^{\mathrm{e}}, \tag{55}$$

and devaluation when $z < \underline{z}$, where

$$\underline{z} = -\sqrt{\underline{c}(1+\chi)} - k - \pi^{\mathrm{e}}. \tag{56}$$

For shock realizations $z \in [\underline{z}, \bar{z}]$, the fixed exchange rate is maintained.

This policy response is akin to the escape-clause models of Flood and Isard (1989) and Lohmann (1992). The monetary authorities defend the fixed exchange rate against all but very large (in absolute value) shocks, in which case they pay the fixed costs of devaluation (revaluation) in order to use monetary policy for output stabilization. (Of course, once the fixed cost is paid, it will no longer serve as a check on the monetary authorities' aspirations to raise output systematically.)

The rational expectation of inflation (depreciation) π in the next period, given wage setters' expectations π^{e}, is

$$\mathrm{E}\pi = \mathrm{E}\{\pi \mid z < \underline{z}\}\Pr(z < \underline{z}) + \mathrm{E}\{\pi \mid z > \bar{z}\}\Pr(z > \bar{z}), \tag{57}$$

where $\Pr(\cdot)$ denotes probability. (Recall that depreciation is zero when $\underline{z} \le z \le \bar{z}$.) Expected inflation π^{e} enters here both in determining the inflation rate the government chooses conditional on choosing to realign, and in determining the probability of a realignment. The fact that ex post inflation depends on π^{e} in a potentially very complicated way gives rise to the possibility that there are multiple equilibrium expected inflation rates under the "fixed but adjustable" exchange-rate scheme.

To see a parametric example of how multiple equilibria can arise, let us assume that z is uniformly distributed on $[-Z, Z]$.[38] Making use of eqs. (55)–(57) and (51), we calculate

$$\mathrm{E}\pi = \frac{1}{1+\chi}\left[\left(1 - \frac{\bar{z} - \underline{z}}{2Z}\right)(k + \pi^{\mathrm{e}}) - \frac{\bar{z}^2 - \underline{z}^2}{4Z}\right] \tag{58}$$

38. In this case z is bounded and we must formally modify eq. (55) to read

$$\bar{z} = \max\left[\min\left\{\sqrt{\bar{c}(1+\chi)} - k - \pi^{\mathrm{e}}, Z\right\}, -Z\right],$$

whereas eq. (56) becomes

$$\underline{z} = \min\left[\max\left\{-\sqrt{\underline{c}(1+\chi)} - k - \pi^{\mathrm{e}}, -Z\right\}, Z\right].$$

For example, if $\sqrt{\bar{c}(1+\chi)} - k - \pi^{\mathrm{e}} > Z$ (implying that the cost of devaluing is prohibitively high given χ, k, and π^{e}), devaluations will never occur.

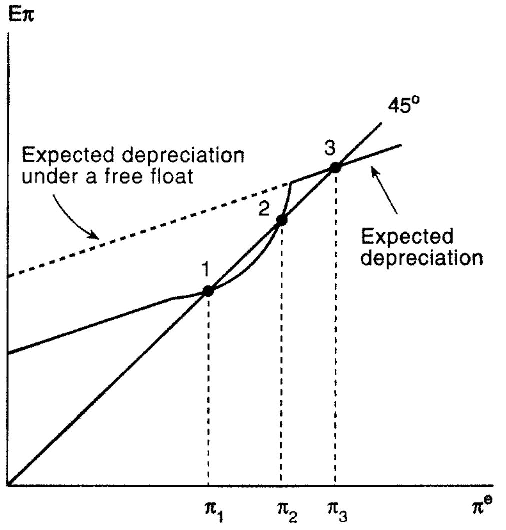

Figure 9.12
Multiple equilibria for expected depreciation

for a uniformly distributed shock z.

In equilibrium, wage setters' depreciation expectations must be rational,

$$\pi^{e} = \mathrm{E}\pi,$$

where $\mathrm{E}\pi$ is given by eq. (58), with $\bar{z}$ and $\underline{z}$ given by eqs. (55) and (56). In the basic one-shot-game credibility model of section 9.5.1, there was only one solution π^{e} to this last equation. But now there can be several such equilibria. To illustrate the fixed points of eq. (58), Figure 9.12 graphs it together with the 45° line. Let $-\mathrm{i}^*$ denote the minimum possible level of π^{e},[39] and assume that $\underline{c}$ and $\bar{c}$ are small enough so that at $\pi^{e} = -\mathrm{i}^*$, $\underline{z} > -Z$ and $\bar{z} < Z$.

We calculate the slope of eq. (58) by differentiating it using formulas (55) and (56) to ascertain how $\bar{z}$ and $\underline{z}$ change as π^{e} rises. You can verify that $\mathrm{d}\bar{z}/\mathrm{d}\pi^{e} = \mathrm{d}\underline{z}/\mathrm{d}\pi^{e} = -1$ as long as $\underline{z} > -Z$. But as π^{e} rises, $\underline{z}$ falls. Output conditional on no realignment is falling, so progressively larger (in absolute value) negative shocks are needed to justify incurring the fixed cost of revaluation. Eventually as π^{e} rises, $\underline{z}$ hits its minimum value of $-Z$. Plainly, $\mathrm{d}\underline{z}/\mathrm{d}\pi^{e} = 0$ once this has happened.

Similarly, $\bar{z}$ too falls as π^{e} rises, because even relatively small positive shocks may warrant devaluation when output conditional on no devaluation is very low. Eventually as π^{e} rises, $\bar{z}$ reaches $-Z$, meaning that devaluation occurs for any

39. Assuming interest parity, this assumption gives the domestic nominal interest rate a lower bound of 0.

shock realization. At this point, obviously, $\mathrm{d}\bar{z}/\mathrm{d}\pi^{\mathrm{e}} = 0$. Putting this information together, we find that the slope of eq. (58) is

$$\frac{\mathrm{dE}\pi}{\mathrm{d}\pi^{\mathrm{e}}} = \begin{cases} \dfrac{1}{1+\chi} & (\text{for } \underline{z} > -Z) \\ \dfrac{1}{1+\chi}\left[\dfrac{1}{2} + \dfrac{1}{2Z}\left(k+\pi^{\mathrm{e}}\right)\right] & (\text{for } \underline{z} = -Z,\ \bar{z} > -Z) \\ \dfrac{1}{1+\chi} & (\text{for } \bar{z} = -Z). \end{cases}$$

Once π^{e} has risen high enough that the devaluation threshold $\bar{z}$ is stuck at $-Z$, the government's reaction function reduces to eq. (51) and depreciation expectation (57) is the same as under a completely flexible exchange rate.

Figure 9.12 illustrates a situation with three possible equilibria, corresponding to different devaluation probabilities and different realignment magnitudes conditional on devaluation. In equilibrium 3, the expected rate of depreciation is given by $\pi^{\mathrm{e}} = k/\chi$, which is exactly the mean expected rate of depreciation that would obtain under a free float; recall eq. (34). Equilibria 2 and 1 entail successively lower expected inflation.[40]

What are the implications of multiple equilibria? Having adopted a fixed but adjustable exchange rate, the government is powerless to enforce its favored low-inflation equilibrium at point 1. It may even end up being gamed into a free float, paying the fixed cost $\bar{c}$ with no benefit from having partially committed to a fixed rate. The root problem is that high expected depreciation in and of itself, by incipiently raising unemployment, creates an incentive for the government to validate expectations ex post by devaluing.

With multiple equilibria some seemingly unimportant event could trigger an abrupt change in expectations, shifting the equilibrium from one in which only a very bad realization of z forces the government off the fixed rate to one in which even a relatively small z does so. Such an event would look much like the sudden speculative attacks on exchange rates we analyzed using a very different setup in Chapter 8. But here the situation is analogous to a bank run in which withdrawals sparked by depositor fears can themselves cause an otherwise viable bank to fail.

It is important to note that a government with strong fundamentals (e.g., $\bar{c}$ and χ large, k low) is less vulnerable to speculative attacks taking the form of a shift in

40. For the free-float equilibrium to exist, we require the parameter restriction

$$\frac{1+\chi}{\chi}k - Z \geq \sqrt{\bar{c}(1+\chi)},$$

a condition that is more likely to be met if inflation aversion χ is low, $\bar{c}$ is low, and the "credibility distortion" k is high. One can see from the figure that there can only be multiple equilibria if this condition is met (though for more general probability distributions of z, there can be multiple equilibria even if there is no free-float equlibrium).

equilibria. (Conversely, a government with weak inflation fundamentals is more likely to find itself in a situation with multiple equilibria.) This point holds in a wide range of models (see Jeanne, 1995; Obstfeld, 1996b; or Velasco, 1996). Thus, even if speculative attacks are driven by "sunspots," countries with weak fundamentals are more likely to be vulnerable to them. For example, fears that a government will fail to service a big debt can themselves induce debt devaluation, possibly through an exchange rate change (see Calvo, 1988; Obstfeld, 1994d; and Cole and T. Kehoe, in press). Speculative attacks can contain a self-fulfilling element, being somewhat arbitrary in timing and weakening currency pegs that might have been sustainable for some time absent the attack. But it would be wrong to view the type of speculative attack analyzed here as being entirely divorced from fundamentals.

In stochastic versions of the classical balance-of-payments crisis model from Chapter 8, attacks typically are preceded by a period of rising domestic-foreign interest differentials, reflecting rising expectations of depreciation. But as Rose and Svensson (1994) show for the September 1992 attacks on the EMS, and Obstfeld and Rogoff (1995c) show for the December 1994 Mexican peso collapse, one-month to one-year interest differentials often remain fairly constant prior to an attack, rising sharply only when a crisis is imminent. Models with multiple equilibria, of the type considered in this section, may better be able to explain this phenomenon.

Application: Openness and Inflation

The preceding analysis treats the inflation problem in open economies in exact analogy to the closed-economy case. The dynamic consistency problem may be somewhat mitigated, however, in an open economy that takes world monetary policy as exogenous. The case of a flexible exchange rate is easiest to understand, though that assumption is not necessary. In the Dornbusch model discussed earlier in this chapter, we saw that unanticipated monetary expansion by a small open economy will, in general, lead to a real currency depreciation. Rogoff (1985a) has shown that this tendency for the exchange rate to depreciate following a monetary expansion may temper the incentives of a country's monetary authorities to inflate, unless the country's trade partners inflate at the same time. If the price index that the monetary authorities seek to stabilize includes foreign goods, real currency depreciation exacerbates the CPI inflation cost of unilateral monetary expansion. At the same time, if wages are partially indexed to the CPI or if foreign goods enter as intermediate goods into the production function, the employment (output) gain to monetary expansion is reduced when the real exchange rate depreciates. Overall, the output-inflation Phillips curve trade-off is worse in an open economy than in a closed economy. Therefore, if other things are equal, the monetary authorities have less temptation to inflate, and the time-consistent rate of inflation is lower.

D. Romer (1993) tests the proposition that more open economies have lower inflation rates. (He gauges openness by the ratio of imports plus exports to GDP.) Looking at average inflation rates and openness across a broad cross-section of countries, Romer finds that more open countries indeed appear to have lower inflation, and he generally finds this conclusion to be quite robust. The main qualification is that openness and inflation do not appear to be correlated for OECD countries. Romer argues that these countries may have already found institutional resolutions to the dynamic consistency problem (for example, an independent central bank), so that their degree of openness is not so important.[41] ■

9.5.5 International Monetary Policy Coordination

Two-country sticky-price models, even of the traditional ad hoc variety, can quickly become quite elaborate. For this reason, we have not given them much role in this chapter, preferring to defer our discussion until Chapter 10, where we develop a newer framework based on microfoundations for analyzing sticky-price economies. However, we cannot conclude our discussion of strategic considerations in monetary policy without at least some mention of the global dimensions of the problem. International policy cooperation is a fundamental topic in international economics, one that flows naturally from the fact that the world is populated by sovereign governments answerable mainly to domestic residents. Hamada (1974) was the pioneer in formally modeling the macroeconomic policy coordination problem.

For large actors such as the United States, the European Union, or Japan, monetary policies have spillover effects on the rest of the world. When a large country inflates, the shift in world demand toward its goods can have a big impact on other countries, and there can also be an important effect on world real interest rates. As in any setting with spillovers, there can be gains to cooperation. A simple example illustrates the basic problem. (For the example, we temporarily abstract from any wedge between the natural level of output and the output level targeted by the authorities.) Consider a crude Keynesian setting in which Home output is given by

$$y_t - \bar{y} = a_1[\Delta m_t - E_{t-1}\Delta m_t] + a_2[\Delta m_t^* - E_{t-1}\Delta m_t^*] + \epsilon_t,$$

where $\Delta m_t \equiv m_t - m_{t-1}$. Think of the above equation as a reduced form from a two-country Keyensian model in which nominal prices (wages) are set a period

41. Lane (1995) argues that country size should be an important determinant of inflation as well. He finds that, controlling for country size, openness and inflation are negatively correlated even for OECD countries. For additional evidence, see Campillo and Miron (in press) and Terra (1995).

in advance. Monetary policy induces deviations in Home output from its natural rate only to the extent it is unanticipated; the shock ϵ captures other exogenous shocks. Foreign money growth shocks enter the preceding equation for reasons we have just discussed. In the canonical two-country Mundell-Fleming-Dornbusch model, the sign of the spillover term (the sign of a_2) is ambiguous. Foreign monetary expansion leads to a short-run real appreciation of Home's currency, with an expenditure-switching effect that tends to lower global demand for Home output. But (unanticipated) Foreign inflation also lowers the world real interest rate, producing a general rise in world demand that tends to raise Home output. Which effect dominates typically depends on the empirical parameters of the model.

An equation similar to the preceding one holds for Foreign,

$$y_t^* - \bar{y} = a_1[\Delta m_t^* - E_{t-1}\Delta m_t^*] + a_2[\Delta m_t - E_{t-1}\Delta m_t] + \epsilon_t^*$$

where we have imposed structural symmetry (though ϵ_t need not be perfectly correlated with ϵ_t^*).

If the only goal of both countries were to stabilize output around its natural rate, then it would not matter whether or not they conducted their monetary policies in concert. Holding constant $E_{t-1}\Delta m_t$ and $E_{t-1}\Delta m_t^*$, which are predetermined as of time t, the monetary authorities have two instruments (Home and Foreign money growth) to hit two targets. Both countries can stabilize output exactly with or without cooperation. What if, however, countries have more targets than instruments? Suppose, for example, that authorities also care about the absolute levels of money growth, Δm_t for Home and Δm_t^* for Foreign. In particular, suppose they have loss functions given by

$$\mathcal{L}_t = (y_t - \bar{y})^2 + \chi(\Delta m_t)^2,$$

$$\mathcal{L}_t^* = (y_t^* - \bar{y})^2 + \chi(\Delta m_t^*)^2.$$

(Think of the money-growth terms on the right-hand sides as capturing trend inflation.) Now there are four targets in all but still only two instruments, and it therefore makes a difference whether the countries cooperate. In the absence of cooperation (and assuming a one-shot-game Nash equilibrium), the Home authority sets Δm_t (it actually chooses m_t, since m_{t-1} is predetermined) so that

$$\frac{\partial \mathcal{L}_t}{\partial m_t} = 2a_1(y_t - \bar{y}) + 2\chi\Delta m_t = 0.$$

This first-order condition plainly ignores the spillover effect of m_t on y_t^*. (Remember, $t-1$ expectations have been determined by the time monetary authorities move on date t.) Foreign similarly sets

$$\frac{\partial \mathcal{L}_t^*}{\partial m_t^*} = 2a_1(y_t^* - \bar{y}) + 2\chi\Delta m_t^* = 0.$$

Suppose instead that Home and Foreign monetary policy were set by a central planner aiming to maximize

$$x\mathfrak{L}_t + (1-x)\mathfrak{L}_t^*.$$

The first-order conditions for the planner are

$$x\frac{\partial \mathfrak{L}_t}{\partial \mathsf{m}_t} + (1-x)\frac{\partial \mathfrak{L}_t^*}{\partial \mathsf{m}_t} = 0,$$

$$x\frac{\partial \mathfrak{L}_t}{\partial \mathsf{m}_t^*} + (1-x)\frac{\partial \mathfrak{L}_t^*}{\partial \mathsf{m}_t^*} = 0,$$

which generally differ from those underlying the Nash equilibrium if there are international spillover effects (if $a_2 \neq 0$).[42] Depending on whether the spillover effects are positive or negative, the planning solution may involve higher or lower levels of monetary expansion than the noncooperative Nash solution. This is the fundamental insight of the literature on international monetary cooperation. Anyone schooled in the basics of game theory (or indeed who has read the preceding material in this chapter) will realize that one can introduce a host of strategic complexities into this setup, such as allowing for cooperation via repeated play, information problems, and so on.[43]

One very important nuance becomes evident if we restore the assumption that there may be a wedge between the rate of output targeted by the monetary authority and the rate targeted by wage setters. In this case, the strategic interactions across the two monetary authorities can become intertwined with the strategic interactions of each monetary authority with its own private sector. Rogoff (1985a) demonstrates that in this case, one can no longer automatically assume that the monetary authorities will enjoy systematically higher utility if they cooperate with each other. Because coordinated monetary expansion may yield greater output expansion for any given level of inflation, cooperation may actually raise the monetary authorities' incentives to inflate. This can in turn exacerbate their credibility problem vis-à-vis their own private sectors and lead to a higher time-consistent rate of inflation.

A serious treatment of international monetary policy cooperation is somewhat beyond the scope of this book. Our main justification for not treating the issue in more detail is that virtually all of the literature is based on obsolete Keynesian models, which lack the microfoundations needed for proper welfare analysis. While some may view microfoundations as being of second-order importance in this context, they are quite wrong as the model of Chapter 10 will illustrate. Because ad

42. Exercise: Solve for the levels of monetary growth in both the Nash and planner solutions.

43. For a discussion of some of the many gaming issues in monetary policy coordination, see Hamada (1985) and Canzoneri and Henderson (1991). See also Persson and Tabellini (1995), who emphasize the importance of institutional reform in promoting better outcomes.

hoc Keynesian analyses of cooperation can yield seriously misleading policy prescriptions, there is a compelling case for basing policy-coordination analysis on choice-theoretic models such as the ones we consider in the next chapter.[44]

Exercises

1. *Disinflation with sticky prices.* Consider the small-country sticky-price exchange rate model presented in section 9.2. Suppose a small open economy is initially in a steady state with a high, constant inflation rate of $m_t - m_{t-1} = \mu$. In the initial steady state, prices and exchange rates are also rising at rate μ. Suppose that at time 0, the government unexpectedly initiates a draconian deflation plan, whereby money growth is immediately reduced to $m_t - m_{t-1} = 0, \forall t \geq 0$.

   (a) Analyze the effects on the path of output, real interest rates, and the real exchange rate.

   (b) Is there any way (in this model) for the monetary authorities to lower the inflation rate to 0 without putting the economy through a prolonged spell of low output? (This is tricky!) Briefly discuss why or why not, and how reasonable your answer is.

2. *Anticipated real depreciation.* Analyze the effects of an anticipated rise in the equilibrium real exchange rate from $\bar{q}$ to $\bar{q}'$ in the sticky-price exchange rate model of section 9.2. News of the change is learned at time 0, but the rise actually takes place at time T.

3. *The optimal exchange rate feedback rule.* Consider the following stochastic small-open economy model in which all exogenous variables are constant except for serially uncorrelated shocks, and p^*, i^*, $\bar{y}$, and $\bar{q}$ are all normalized to 0:

$$i_{t+1} = E_t e_{t+1} - e_t,$$

$$y_t^s = \theta(p_t - E_{t-1} p_t),$$

$$y_t^d = \delta(e_t - p_t) + \epsilon_t,$$

$$m_t - p_t = -\eta i_{t+1} + \phi y_t + \upsilon_t.$$

   Here, $\epsilon \sim \mathcal{N}(0, \sigma_\epsilon^2)$ and $\upsilon \sim \mathcal{N}(0, \sigma_\upsilon^2)$ are independent, serially uncorrelated, normally distributed shocks. The second equation above is a simple rational-expectations supply curve, in which one-period price surprises can raise or lower output. (One rationalization for this would be if nominal wage contracts were set a period in advance.) The shock ϵ may be thought of as a shock to the demand for the country's goods, and υ is a shock to the demand for real money balances. We assume that the objective function of the monetary authorities is to minimize the one-period conditional variance of output, $E_{t-1}\{y_t^2\}$. (In this example, one can think of the objective of the monetary authorities as trying to smooth prices to save the private sector the cost of indexing.)

44. Issues of international policy coordination naturally arise in spheres other than that of monetary policy, and can be important even when prices are flexible. For discussions of fiscal policy coordination, see, for example, Hamada (1986) and Kehoe (1987). Once again, Persson and Tabellini (1995) provide a good overview.

(a) First consider a fixed money supply rule under which $\mathsf{m}_t = \bar{\mathsf{m}}$ in all periods, and calculate $\mathrm{E}_{t-1}\{\mathsf{y}_t^2\}$ as a function of σ_ϵ^2, σ_v^2, and the other parameters of the model. [Hint: You will find that under this policy, $\mathrm{E}_t\mathsf{e}_s = \mathrm{E}_t\mathsf{p}_s = \bar{\mathsf{m}}$, $\forall s > t$.]

(b) Now suppose that the monetary authorities fix the exchange rate at $\bar{\mathsf{e}} = \bar{\mathsf{m}}$ by adjusting $\mathsf{m}_t - \bar{\mathsf{m}}$ in response to the shocks each period as necessary to hold the exchange rate constant. They do not, however, alter the announced future path of money, which is expected to remain at $\bar{\mathsf{m}}$ in the absence of future shocks. (That is, $\mathrm{E}_t\mathsf{m}_{t+s} = \bar{\mathsf{m}}$, $\forall s > t$.) Again calculate $\mathrm{E}_{t-1}\{\mathsf{y}_t^2\}$.

(c) Show that as $\sigma_\epsilon^2/\sigma_v^2 \to 0$, the policy in part b of a fixed exchange rate is always superior to the policy in part a of a fixed money supply (a pure float).

(d) (Very hard.) Suppose that instead of limiting themselves to a pure fixed rate or a pure float, the monetary authorities adopt an exchange rate feedback rule, $\mathsf{m}_t - \bar{\mathsf{m}} = \Phi(\mathsf{e}_t - \bar{\mathsf{e}})$. Find the optimal value of Φ, and show that, in general, it is intermediate between 0 (pure float) and ∞ (fixed rate). [Hint: This is not conceptually difficult, but there is a fair amount of algebra. For an intuitive solution approach to this class of problems, see Canzoneri, Henderson, and Rogoff (1983).]

4. *Optimal contracts for central bankers with uncertainty over the relative weight on public versus own welfare.* Suppose that eq. (42) in this chapter is replaced with

$$\mathcal{L}_t^{\mathrm{CB}} = (\pi_t - \pi_t^{\mathrm{e}} - z_t - k)^2 + \chi\pi_t^2 + 2\lambda_t\omega\pi_t,$$

where $\lambda > 0$ is a random variable that captures the relative weight a policymaker places on his own bonus versus public welfare; $\mathrm{E}_{t-1}\lambda_t = 1$, $\mathrm{Var}_{t-1}\lambda_t = \sigma_\lambda^2$.

(a) Solve for π_t^{e} and π_t assuming a one-shot-game equilibrium.

(b) Assuming a social loss function of the form

$$\mathcal{L}_t = (\pi_t - \pi_t^{\mathrm{e}} - z_t - k)^2 + \chi\pi_t^2,$$

solve for $\mathrm{E}_{t-1}\mathcal{L}_t$.

(c) What choice of ω minimizes $\mathrm{E}_{t-1}\mathcal{L}_t$?

5. *Central bank secrecy.* Suppose that in section 9.5.1's model of money and inflation, we replace the monetary authority's loss function (31) by one analogous to eq. (45),

$$\mathcal{L}_t = -\lambda_t(\pi_t - \pi_t^{\mathrm{e}} - k) + \tfrac{1}{2}\pi_t^2,$$

in which there is no supply shock ($z = 0$), but where λ is a random variable such that $\lambda = 0$ with probability $\frac{1}{2}$, and $\lambda = 2$ with probability $\frac{1}{2}$. One may think of λ as capturing shocks that change the relative benefits of output versus inflation (e.g., a war).

(a) Solve for the one-shot-game equilibrium levels of π_t^{e} and π_t.

(b) Suppose the central bank can commit to a reaction function for $\pi_t(\lambda_t)$. Find the optimal reaction function such that $\pi_t^{\mathrm{e}} = 0$. Is $\mathrm{E}_{t-1}\mathcal{L}_t$ lower than in part a?

(c) Suppose now that the central bank knows λ_t in period $t-1$. Calculate $\mathrm{E}_{t-2}\mathcal{L}_t$ under two different regimes. In one, the central bank always reveals λ_t before π_t^{e} is set. In the other, it never reveals λ_t.

10 Sticky-Price Models of Output, the Exchange Rate, and the Current Account

As Chapter 9 showed, many of the central issues in international monetary economics, including exchange-rate determination, the choice of exchange-rate regime, and the design of a central bank constitution, take on much greater significance when monetary policy can affect real output. Unfortunately, the Keynesian models we employed in Chapter 9 have many shortcomings. Given their lack of microfoundations for intertemporal choice, the models have very little to say about current accounts or budget deficits, and even less to say about welfare. But the older Keynesian models do have one very important feature that gives them an empirical edge over flexible-price monetary models: they allow for nominal rigidities. Fortunately, it is possible to introduce nominal rigidities without abandoning the insights of modern intertemporal economics, and in this chapter we illustrate how to do so.

A central element of our analysis involves introducing a monopolistic supply sector. Recent research in macroeconomics and trade theory has emphasized the possible importance of monopoly in explaining a range of phenomena, from business cycle regularities to growth. Monopoly plays a key role in our analysis because it permits one to justify rigorously the Keynesian assumption that output is demand-determined in the short run when prices are fixed. Monopoly also has important welfare implications for the international transmission of macroeconomic policy, and helps justify Chapter 9's assumption that a small country can temporarily affect its terms of trade through unanticipated monetary changes. Most of our analysis assumes sticky prices, but as we show toward the chapter's end, very similar results obtain in the presence of nominally rigid wages.

The reader should be warned that the models of this chapter may appear more challenging technically than most we have presented up until now. If broken down into their component parts, however, the models should seem familiar. For example, we make extensive use of consumption-based price indexes, which we first developed in Chapter 4. Our modeling of product differentiation exploits the constant-elasticity-of-substitution functional form used in Chapters 4, 5, 7, and 8. The money-in-the-utility-function formulation here will be familiar from Chapter 8. Finally, we make extensive use of log-linearizations to obtain closed-form solutions, a device used in Chapter 7's discussion of real business cycle models and in Chapter 4's Dornbusch-Fischer-Samuelson model. The only really new element is the introduction of nominal prices that are preset because of price-adjustment costs.

Our approach in this book generally has been to set out the small-country case before proceeding to more complex general-equilibrium models. Here, however, we plunge immediately into a full-blown two-country model, treating the small-country case as a limit in which one country's relative size goes to zero. Hopefully, the reader will find the greater intuition this strategy yields worth the extra effort. In the first model we develop, all goods are traded. Later in the chapter we consider a