Chapter 9
INFLATION AND MONETARY POLICY

9.1 Introduction

Inflation and unemployment are two of the main subjects of macroeconomics. They are among the principal concerns of policymakers and the public, and they have been the subject of large amounts of research. In our investigations of fluctuations in Chapters 4 through 6, we encountered various possible sources of short-run movements in both variables. Yet we said little about what determines their average levels over longer periods. This is the focus of the final two chapters. This chapter considers inflation, and Chapter 10 considers unemployment.

Inflation varies greatly both across countries and over time. In Germany and Japan, for example, the price level has risen an average of just a few percent per year over the past few decades, whereas in Italy and the United Kingdom it has risen an average of over 10% per year. In the United States during this period, annual inflation increased slowly and irregularly from around 1% in the late 1950s to almost 10% at the end of the 1970s; it then fell rapidly to less than 5%, and has remained between 2% and 5% since then.

If we consider periods before the past few decades and countries outside the industrialized world, there is even more variation in inflation. Many countries experienced large deflations—that is, declines in prices—after World War I and at the beginning of the Great Depression. And some developing countries, such as Bahrain, Burma, and Singapore, have average inflation rates in recent decades that are similar to Germany's and Japan's. At the other extreme, several countries have recently experienced hyperinflations (traditionally defined as inflation greater than 50% per month). In Argentina, for example, prices rose by a factor of 600 between May 1989 and March 1990, and in some months the price level almost tripled. And many other countries have undergone episodes of triple-digit annual inflation. Yet many of the countries that have experienced hyperinflations or very high inflations have also had extended periods of low inflation.[1]

This chapter's main subject is the causes of inflation. Sections 9.2 and 9.3 explain why inflation is almost always the result of rapid growth of the money supply; they also investigate the effects of money growth on inflation, real balances, and interest rates.

We then turn to the deeper question of what causes growth of the money supply. Most economists believe that average rates of inflation in most countries in the postwar period have been higher than is socially optimal. Since inflation stems mainly from money growth, this suggests that there is some type of *inflationary bias* in monetary policy. There are two main sets of explanations for such a bias.

The first set emphasizes the output-inflation tradeoff. If monetary policy has real effects (or if policymakers believe that it does), policymakers may increase the money supply in an effort to increase output. Theories of how inflation can arise from this tradeoff particularly theories that emphasize the *dynamic inconsistency* of low-inflation policy—are discussed in Sections 9.4 through 9.6. Section 9.6 also considers several related policy questions that arise when monetary policy has real effects, particularly the issues of how much importance policymakers should attach to stabilizing real output versus keeping inflation low and of how monetary policy should be conducted when the economy is subject to shocks.

The second set of explanations of rapid money growth focuses on *seignorage*—the revenue the government gets from printing money. These theories, which are more relevant to less-developed countries than to industrialized ones, and which are at the heart of hyperinflations, are the subject of Section 9.7.

All of this analysis presumes that we understand why inflation is costly and how large its costs are. In fact, however, these are difficult issues. Section 9.8 is therefore devoted to the costs of inflation. This section not only describes the various potential costs of inflation, but also attempts to understand the basis for the intense concern about inflation among policymakers, the business community, and the public.

9.2 Inflation, Money Growth, and Interest Rates

Inflation and Money Growth

The simple diagram from Chapter 5 showing aggregate supply and aggregate demand, which is reproduced as Figure 9.1, provides a framework

[1]The all-time record inflation appears to have occurred in Hungary between August 1945 and July 1946, when the price level rose by a factor of approximately 10^{27}. During the peak month of this inflation, prices on average tripled daily (Sachs and Larrain, 1993).

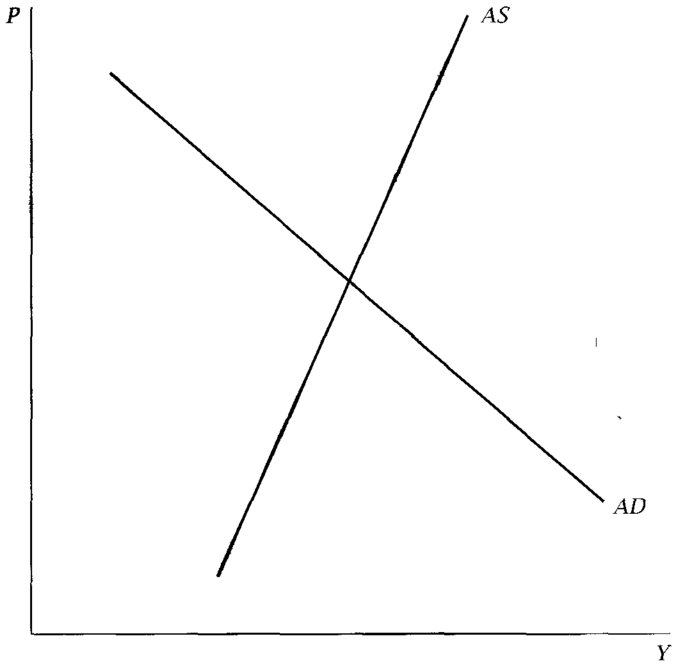


FIGURE 9.1 The aggregate demand and aggregate supply curves

for identifying potential sources of inflation. Since our interest is in prices rather than output, the issue of whether the aggregate supply curve is vertical or merely upward-sloping is not important: in either case, both expansions of aggregate demand and contractions of aggregate supply raise the price level. Thus there are many potential sources of inflation. Negative technology shocks, downward shifts in labor supply, upwardly skewed relative-cost shocks, and other factors that shift the aggregate supply curve to the left cause inflation; the same is true of increases in the money stock, downward shifts in money demand, increases in government purchases, and other factors that shift the aggregate demand curve to the right.[2] Since all of these types of shocks occur to some extent, there are many factors that affect inflation.

Nonetheless, when it comes to understanding inflation over the longer term, economists typically emphasize just one factor: growth of the money supply. The reason for this emphasis is that no other factor is likely to lead to persistent increases in the price level. Repeated increases in prices require either repeated falls in aggregate supply or repeated rises in aggregate demand. Given technological progress, repeated falls in aggregate

[2]Many shocks affect both curves. A rise in government purchases, for example, may not only shift the aggregate demand curve, but also move the aggregate supply curve through its impact on labor supply. The overall effect of any shock on the price level depends on how it affects both curves.

supply are unlikely. And although there are many factors that can increase aggregate demand, most of them are limited in scope. For example, there cannot be repeated large increases in aggregate demand coming from increases in government purchases or reductions in taxes, because there are practical limits on these variables; for instance, we never observe government purchases that are larger than total output, or total taxes that are negative. The money supply, in contrast, can grow at almost any rate, and we observe huge variations in money growth—from large and negative during some deflations to immense and positive during hyperinflations.

To see more clearly why money is crucial to inflation, consider the money market. With the specification of money demand from Chapter 5, the condition for equilibrium in the money market is

$$\frac{M}{P} = L(i, Y), \tag{9.1}$$

where M is the money stock, P the price level, i the nominal interest rate, Y real income, and $L(\bullet)$ the demand for real money balances. This condition implies that the price level is given by

$$P = \frac{M}{L(i, Y)}. \tag{9.2}$$

Conventional estimates of money demand suggest that the income elasticity of money demand is about 1 and the interest elasticity is about −0.2 (see Goldfeld and Sichel, 1990, for example). Thus for the price level to double over some period of time without a change in the money supply, income must fall roughly in half or the interest rate must rise by a factor of about 32. Alternatively, the demand for real balances at a given interest rate and income must fall in half. All of these possibilities are essentially unheard of. In contrast, a doubling of the money supply, either over several years in a moderate inflation or over a few days at the height of a hyperinflation, is not uncommon.

Thus money growth plays a special role in determining inflation not because money affects prices more directly than other factors do, but because empirically variations in money growth account for most of the variation in the growth of aggregate demand. Figure 9.2 provides powerful confirmation of the importance of money growth to inflation. The figure plots average inflation against average money growth in the 1980s for a sample of 65 countries; there is a clear and strong relationship between the two variables.

Money Growth and Interest Rates

Since money growth is the main determinant of inflation, it is natural to examine its effects in more detail. As we will see, there are interesting links between the growth of the nominal money stock and the behavior of inflation, real and nominal interest rates, and real balances.

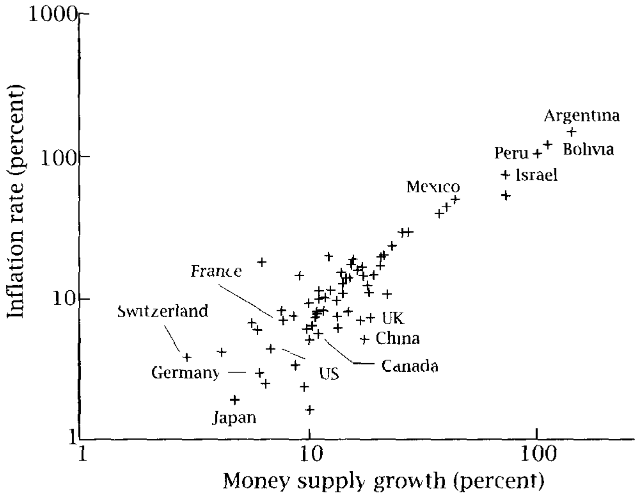


FIGURE 9.2 Money growth and inflation (data from International Financial Statistics)

We begin with the case where prices are completely flexible; this is presumably a good description of the long run. As we know from our analysis of fluctuations, this assumption implies that the money supply does not affect real output or the real interest rate. For simplicity, we assume that these are constant at $\overline{Y}$ and $\overline{r}$, respectively.

By definition, the real interest rate is the difference between the nominal interest rate and expected inflation. That is, $r \equiv i - \pi^e$, or

$$i \equiv r + \pi^e. \tag{9.3}$$

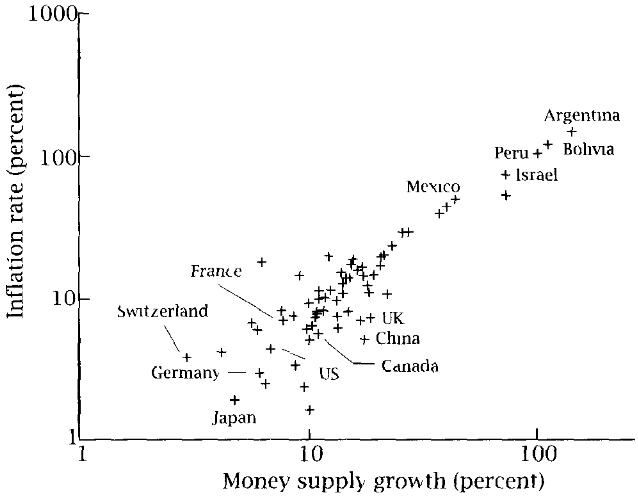
Equation (9.3) is known as the *Fisher identity*.

Using (9.3) and our assumption that r and Y are constant, we can rewrite (9.2) as

$$P = \frac{M}{L(\overline{r} + \pi^e, \overline{Y})}. \tag{9.4}$$

Assume that initially M and P are growing together at some steady rate (so that M/P is constant), and that π^e equals actual inflation. Now suppose that at some time, time t_0, there is a permanent increase in money growth. The resulting path of the money stock is shown in the top panel of Figure 9.3. After the change, since M is growing at a new steady rate and r and Y are constant by assumption, M/P is constant; that is, (9.4) is satisfied with P growing at the same rate as M and with π^e equal to the new rate of money growth.

But what happens at the time of the change? Since the price level rises faster after the change than before, expected inflation jumps up when the change occurs. Thus the nominal interest rate jumps up, and so the quantity



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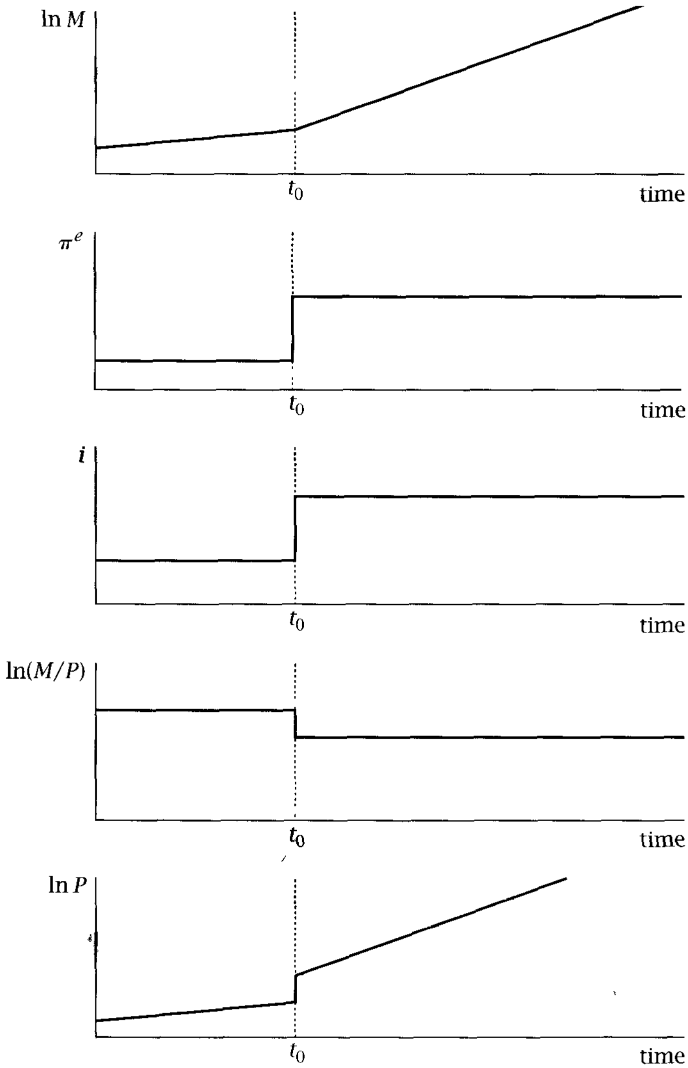

FIGURE 9.3 The effects of an increase in money growth

of real balances demanded falls discontinuously. Since M does not change discontinuously, it follows that P must jump up at the time of the change. This information is summarized in the remaining panels of Figure 9.3.[3]

This analysis has two messages. First, the change in inflation resulting from the change in money growth is reflected one-for-one in the nominal interest rate. The hypothesis that inflation affects the nominal rate

[3]In addition to the path of P described here, there may also be *bubble paths* that satisfy (9.4). Along these paths, P rises at an increasing rate, thereby causing π^e to be rising and the quantity of real balances demanded to be falling. See, for example, Problem 2.20 and Blanchard and Fischer (1989, Chapter 5, Section 3).

one-for-one is known as the *Fisher effect;* it follows from the Fisher identity and the assumption that inflation does not affect the real rate.

Second, a higher growth rate of the *nominal* money stock reduces the *real* money stock. The rise in money growth increases expected inflation, thereby increasing the nominal interest rate. This increase in the opportunity cost of holding money reduces the quantity of real balances that individuals want to hold. Thus equilibrium requires that P rises more than M does. That is, there must be a period when inflation exceeds the rate of money growth. In our model, this occurs at the moment that money growth increases. In models where prices are not completely flexible or individuals cannot adjust their real money holdings costlessly, in contrast, it occurs over a longer period.

A corollary is that a reduction in inflation can be accompanied by a temporary period of unusually high money growth. Rather than taking the path of the money stock as fixed, consider the problem of choosing the path of the money stock to yield some desired path of the price level. Specifically, suppose that policymakers want to reduce inflation and that they do not want the price level to change discontinuously. What path of M is needed to do this? The decline in inflation will reduce expected inflation, and thus lower the nominal interest rate and raise the quantity of real balances demanded. Writing the money market equilibrium condition as $M = PL(i, Y)$, it follows that—since $L(i, Y)$ increases discontinuously and P does not jump—M must jump up. Of course, to keep inflation low, the money stock must then grow slowly from this higher level.

Thus, the monetary policy that is consistent with a permanent drop in inflation is a sudden upward jump in the money supply, followed by low growth. And, in fact, the clearest examples of declines in inflation—the ends of hyperinflations—are accompanied by spurts of very high money growth that continue for a time after prices have stabilized (Sargent, 1982).[4]

The Case of Incomplete Price Flexibility

In the preceding analysis, an increase in money growth increases nominal interest rates. In practice, however, the immediate effect of a monetary expansion is to lower short-term nominal rates. This negative effect of monetary expansions on nominal rates is known as the *liquidity effect.*

The conventional explanation of the liquidity effect is that monetary expansions reduce real rates. If prices are not completely flexible, an increase in the money stock raises output, which requires a decline in the real interest rate; in terms of the *IS-LM* framework of Chapter 5, the *LM* curve shifts to the right along the downward-sloping *IS* curve. If the decline in

[4]This analysis raises the question of why expected inflation falls when the money supply is exploding. We return to this issue in Section 9.7.

the real rate is large enough, it more than offsets the effect of the increase in expected inflation.[5]

If prices are fully flexible in the long run, then the real rate eventually returns to normal following a shift to higher money growth. Thus if the real-rate effect dominates the expected-inflation effect in the short run, the shift depresses the nominal rate in the short run but increases it in the long run. As Friedman (1969) pointed out, this appears to provide an accurate description of the effects of monetary policy in practice. The Federal Reserve's expansionary policies in the late 1960s, for example, seem to have lowered nominal rates for several years, but, by generating inflation, to have raised them over the longer term.

9.3 Monetary Policy and the Term Structure of Interest Rates

In many situations, we are interested in the behavior not just of short-term interest rates, but also of long-term rates. To understand how monetary policy affects long-term rates, we must consider the relationship between short-term and long-term rates. The relationship among interest rates over different horizons is known as the *term structure of interest rates*, and the standard theory of that relationship is known as the *expectations theory of the term structure*. This section describes this theory and considers its implications for the effects of monetary policy.

The Expectations Theory of the Term Structure

Consider the problem of an investor deciding how to invest a dollar over the next n periods; assume for simplicity that there is no uncertainty about future interest rates. Suppose first the investor puts the dollar in an n-period zero-coupon bond (that is, a bond whose entire payoff comes after n periods). If the bond has a continuously compounded return of i_t^n per period, the investor has $\exp(ni_t^n)$ dollars after n periods. Now consider what happens if he or she puts the dollar into a sequence of 1-period bonds paying continuously compounded rates of return of $i_t^1, i_{t+1}^1, \ldots, i_{t+n-1}^1$ over the n periods. In this case, he or she ends up with $\exp(i_t^1 + i_{t+1}^1 + \cdots + i_{t+n-1}^1)$ dollars.

Equilibrium requires that investors are willing to hold both 1-period and n-period bonds. Thus the returns on the investor's two strategies must be the same. This requires

[5] See Problem 9.2. In addition, if inflation is completely unresponsive to monetary policy for any interval of time, then expectations of inflation over that interval do not rise; thus in this case short-term nominal rates necessarily fall.

$$i_t^n = \frac{i_t^1 + i_{t+1}^1 + \cdots + i_{t+n-1}^1}{n}. \tag{9.5}$$

That is, the interest rate on the long-term bond must equal the average of the interest rates on short-term bonds over its lifetime.

In this example, since there is no uncertainty, rationality alone implies that the term structure is determined by the path that short-term interest rates will take. With uncertainty, under plausible assumptions expectations concerning future short-term rates continue to play an important role in the determination of the term structure. A typical formulation is

$$i_t^n = \frac{i_t^1 + E_t i_{t+1}^1 + \cdots + E_t i_{t+n-1}^1}{n} + \theta_t, \tag{9.6}$$

where E_t denotes expectations as of period t. With uncertainty, the strategies of buying a single n-period bond and a sequence of 1-period bonds generally involve different risks. Thus rationality does not imply that the expected returns on the two strategies must be equal. This is reflected by the inclusion of θ, the *term premium* to holding the long-term bond, in (9.6).

The expectations theory of the term structure is the hypothesis that changes in the term structure are determined by changes in expectations of future interest rates (rather than by changes in the term premium). Typically, though not always, the expectations are assumed to be rational.[6]

As described at the end of Section 9.2, even if prices are not completely flexible, a permanent increase in money growth eventually increases the short-term nominal interest rate permanently. Thus even if short-term rates fall for some period, (9.5) implies that interest rates for sufficiently long maturities (that is, for sufficiently large n) immediately rise. Thus our analysis implies that a monetary expansion is likely to reduce short-term rates but increase long-term ones.

Empirical Application: The Response of the Term Structure to Changes in the Federal Reserve's Federal-Funds-Rate Target

In many periods, the Federal Reserve has had a target level of a particular interest rate, the Federal funds rate, and has implemented monetary policy through discrete changes in that target. The Federal funds rate is the interest rate that banks charge each other on one-day loans of reserves; thus it is a very short-term rate. Because changes in the Federal Reserve's target are discrete, it is usually clear what the target is and when it changes. Cook and Hahn (1989) use this fact to investigate the impact that monetary policy has

[6] See Shiller (1990) for an overview of the study of the term structure.

on interest rates on bonds of different maturities. They focus on the period 1974–1979, which was a time when the Federal Reserve was targeting the funds rate.

Cook and Hahn begin by compiling a record of the changes in the Federal Reserve's target over this period. They examine both the records of the Federal Reserve Bank of New York (which implemented the changes) and the reports of the changes in the *Wall Street Journal.* They find that the *Journal*'s reports are almost always correct; thus it is reasonable to think of the changes in the target reported by the *Journal* as publicly observed.

As Cook and Hahn describe, the actual Federal funds rate moves closely with the Federal Reserve's target. Moreover, it is highly implausible that the Federal Reserve is changing the target in response to factors that would have moved the funds rate in the absence of the policy changes. For example, it is unlikely that, absent the Federal Reserve's actions, the funds rate would move by discrete amounts. In addition, there is often a lag of several days between the Federal Reserve's decision to change the target and the actual change; thus arguing that the Federal Reserve is responding to forces that would have moved the funds rate in any event requires arguing that the Federal Reserve has advance knowledge of those forces.

The close link between the actual funds rate and the Federal Reserve's target thus provides strong evidence that monetary policy affects short-term interest rates. As Cook and Hahn describe, earlier investigations of this issue mainly regressed changes in interest rates over periods of a month or a quarter on changes in the money supply over those periods; the regressions produced no clear evidence of the Federal Reserve's ability to influence interest rates. The reason appears to be that the regressions are complicated by the same types of issues that complicate the money-output regressions discussed in Section 5.6: the money supply is not determined solely by the Federal Reserve, the Federal Reserve adjusts policy in response to information about the economy, and so on.

Cook and Hahn then examine the impact of changes in the Federal Reserve's target on longer-term interest rates. Specifically, they estimate regressions of the form

$$\Delta R_t^i = b_1^i + b_2^i \, \Delta FF_t + u_t^i, \tag{9.7}$$

where ΔR_t^i is the change in the nominal interest rate on a bond of maturity i on day t, and ΔFF_t is the change in the target Federal funds rate on that day.

Cook and Hahn find, contrary to the predictions of the analysis in the first part of this section, that increases in the Federal-funds-rate target raise nominal interest rates at all horizons. An increase in the target of 100 basis points (that is, one percentage point) is associated with increases in the 3-month interest rate of 55 basis points (with a standard error of 6.8 basis points), in the 1-year rate of 50 basis points (5.2), in the 5-year rate of 21 basis points (3.2), and the 20-year rate of 10 basis points (1.8).

The idea that contractionary monetary policy should immediately lower long-term nominal interest rates is intuitive: contractionary policy is likely to raise real interest rates only briefly and is likely to lower inflation over the longer term. Yet, as Cook and Hahn's results show, the evidence does not support this prediction.

There are at least four possible explanations of this anomaly. First, the response of the real rate to monetary policy may be so persistent, and the response of inflation so slow, that the real-interest-rate effect dominates the expected-inflation effect even at fairly long horizons. Second, the Federal Reserve may be changing policy on the basis of information that it has, and that market participants do not have, concerning future inflation. If this is correct, when market participants observe a shift to tighter policy, they revise up their estimates of future inflation, and so long-term rates rise. Third, the behavior of the money supply may be sufficiently complicated that lower current money growth is on average associated with higher rather than lower money growth in the future (Barro, 1989).[7] And finally, rational expectations of future short-term rates may not be the main determinant of the response of long-term rates to changes in monetary policy. For example, term premia may change systematically, or market participants may form their expectations partly on the basis of rules of thumb. Some support for this possibility is provided by the fact that the rational-expectations theory of the term structure does not seem to fit the data particularly well (see, for example, Mankiw and Miron, 1986). Whether it fails as a description of how longer-term rates react to changes in monetary policy is an open question, however.

9.4 The Dynamic Inconsistency of Low-Inflation Monetary Policy

Our analysis thus far suggests that money growth is the key determinant of inflation. Thus to understand what causes high inflation, we need to understand what causes high money growth. For the major industrialized countries, where government revenue from money creation does not appear important, the leading candidate is the existence of a perceived output-inflation tradeoff. If policymakers believe that aggregate demand movements affect real output, they may increase the money supply to try to push output above its normal level. Or, if they are faced with inflation that they believe is too high, they may be reluctant to undergo a recession to reduce it.

Any theory of how an output-inflation tradeoff can lead to inflation must confront the fact that there is no tradeoff in the long run. Since average inflation has no effect on average output, it might seem that the existence

[7] This explanation also implies that contractionary monetary policy can raise the short-term nominal rate without increasing the real rate.

of a short-run tradeoff is irrelevant to the determination of average inflation. Consider, for example, two monetary policies that differ only because money growth is lower by a constant amount in every situation under one policy than the other. If the public is aware of the difference, there is no reason for output to behave differently under the low-inflation policy than under the high-inflation one.

In a famous paper, however, Kydland and Prescott (1977) show that the inability of policymakers to commit themselves to such a low-inflation policy can give rise to excessive inflation despite the absence of a long-run tradeoff (see also Barro and Gordon, 1983a). Kydland and Prescott's basic observation is that if expected inflation is low, so that the marginal cost of additional inflation is low, policymakers will pursue expansionary policies to push output temporarily above its normal level. But the public's knowledge that policymakers have this incentive means that they will not in fact expect low inflation. The end result is that policymakers' ability to pursue discretionary policy results in inflation without any increase in output. This section presents a simple model that formalizes this idea.

Assumptions

Kydland and Prescott consider an economy where aggregate demand disturbances have real effects and expectations concerning inflation affect aggregate supply. We can capture both of these effects by assuming that aggregate supply is given by the Lucas supply curve (see equations [5.38] and [6.21]):

$$y = \overline{y} + b(\pi - \pi^e), \qquad b > 0, \tag{9.8}$$

where y is the log of output and $\overline{y}$ is the log of its flexible-price level.[8] Kydland and Prescott assume that the flexible-price level of output is less than the socially optimal level. This could arise from positive marginal tax rates (so that individuals do not capture the full benefits of additional labor supply), or from imperfect competition (so that firms do not capture the full benefits of additional output). In addition, they assume that inflation above some level is costly, and that the marginal cost of inflation increases as inflation rises. A simple way to capture these assumptions is to make social welfare quadratic in both output and inflation. Thus the policymaker minimizes:

$$L = \frac{1}{2}(y - y^*)^2 + \frac{1}{2}a(\pi - \pi^*)^2, \qquad y^* > \overline{y}, \quad a > 0. \tag{9.9}$$

[8]The assumption that only unexpected inflation matters is not essential. For example, a model along the lines of equation (5.39), in Section 5.5, where core inflation is given by a weighted average of past inflation and expected inflation, has similar implications.

The parameter a reflects the relative importance of output and inflation in social welfare.[9]

Finally, the policymaker controls money growth, which determines the behavior of aggregate demand. Since there is no uncertainty, we can think of the policymaker as choosing inflation directly, subject to the constraint that inflation and output are related by the aggregate supply curve, (9.8).

Analyzing the Model

To see the model's implications, consider two ways that monetary policy and expected inflation could be determined. In the first, the policymaker makes a binding commitment about what inflation will be before expected inflation is determined. Since the commitment is binding, expected inflation equals actual inflation, and so (by [9.8]) output equals its natural rate. Thus the policymaker's problem is to choose π to minimize $(\bar{y} - y^*)^2/2 + a(\pi - \pi^*)^2/2$. The solution is simply $\pi = \pi^*$.

In the second situation, the policymaker chooses inflation taking expectations of inflation as given. This could occur either if expected inflation is determined before money growth is, or if π and π^e are determined simultaneously. Substituting (9.8) into (9.9) implies that the policymaker's problem is

$$\min_{\pi} \frac{1}{2}[\bar{y} + b(\pi - \pi^e) - y^*]^2 + \frac{1}{2}a(\pi - \pi^*)^2. \tag{9.10}$$

The first-order condition is

$$[\bar{y} + b(\pi - \pi^e) - y^*]b + a(\pi - \pi^*) = 0. \tag{9.11}$$

Solving (9.11) for π yields

$$\begin{aligned} \pi &= \frac{b^2\pi^e + a\pi^* + b(y^* - \bar{y})}{a + b^2} \\ &= \pi^* + \frac{b}{a + b^2}(y^* - \bar{y}) + \frac{b^2}{a + b^2}(\pi^e - \pi^*). \end{aligned} \tag{9.12}$$

[9]Equation (9.9) is intended to reflect not just the policymaker's preferences, but also the representative individual's. The reason that the decentralized equilibrium with flexible prices does not achieve the first-best level of output is that (because of the taxes or imperfect competition) there are positive externalities from higher output. That is, neglecting inflation for the moment, we can think of the representative individual's welfare as depending on his or her own output (or labor supply), y_i, and average economy-wide output, y: $U_i = V(y_i, y)$. The assumption underlying (9.9) is that $\bar{y}$ is the Nash equilibrium (so $V_1(\bar{y}, \bar{y}) = 0$ and $V_{11}(\bar{y}, \bar{y}) < 0$, where subscripts denote partial derivatives), but is less than the social optimum (so $V_2(\bar{y}, \bar{y}) > 0$).

Figure 9.4 plots the policymaker's choice of π as a function of π^e. The relationship is upward sloping with a slope less than 1. The figure and equation (9.12) show the policymaker's incentive to pursue expansionary policy. If the public expects the policymaker to choose the optimal rate of inflation, π^*, the marginal cost of slightly higher inflation is zero, and the marginal benefit of the resulting higher output is positive. Thus in this situation the policymaker chooses an inflation rate greater than π^*.

Since there is no uncertainty, equilibrium requires that expected and actual inflation are equal. As Figure 9.4 shows, there is a unique inflation rate for which this is true. If we impose $\pi = \pi^e$ in (9.12) and then solve for this inflation rate, we obtain

$$\begin{aligned} \pi^e &= \pi^* + \frac{b}{a}(y^* - \overline{y}) \\ &\equiv \pi^{EQ}. \end{aligned} \tag{9.13}$$

If expected inflation exceeds this level, actual inflation is less than individuals expect, and thus the economy is not in equilibrium. Similarly, if π^e is less than π^{EQ}, π exceeds π^e.

Thus the only equilibrium is for π and π^e to equal π^{EQ}, and for y to therefore equal $\overline{y}$. Intuitively, expected inflation rises to the point where the policymaker, taking π^e as given, chooses to set π equal to π^e. In short,

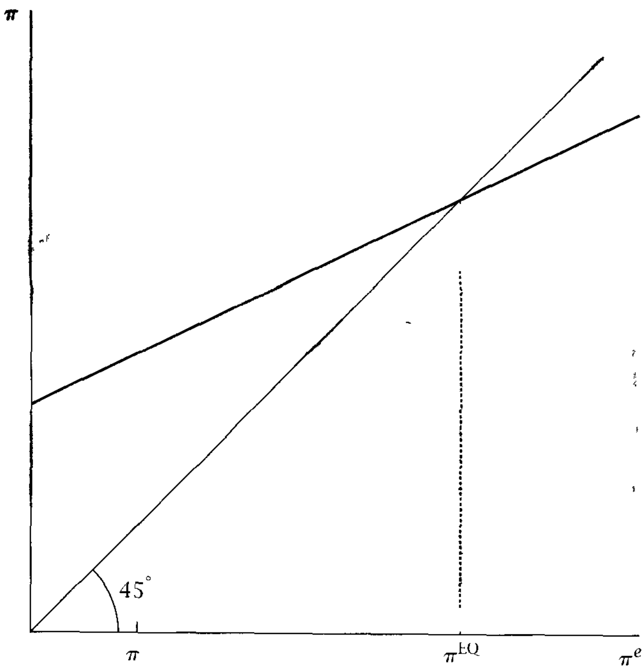

FIGURE 9.4 The determination of inflation in the absence of commitment

all that the policymaker's discretion does is to increase inflation without affecting output.[10]

Discussion

The reason that the ability to choose inflation after expected inflation is determined makes the policymaker worse off is that the policy of announcing that inflation will be π^*, and then producing that inflation rate after expected inflation is determined, is not *dynamically consistent* (equivalently, it is not *subgame-perfect*). If the policymaker announces that inflation will equal π^* and the public forms its expectations accordingly, the policymaker will deviate from the policy once expectations are formed. The public's knowledge that the policymaker would do this causes it to expect inflation greater than π^*; this expected inflation worsens the menu of choices that the policymaker faces.

To see that it is the knowledge that the policymaker has discretion, rather than just the discretion itself, that is the source of the problem, consider what happens if the public believes the policymaker can commit but he or she in fact has discretion. In this case, the policymaker can announce that inflation will equal π^*, and thereby cause expected inflation to equal π^*. But the policymaker can then set inflation according to (9.12). Since (9.12) is the solution to the problem of minimizing the social loss function given expected inflation, this "reneging" on the commitment raises social welfare.[11]

Dynamic inconsistency arises in many other situations. Policymakers choosing how to tax capital may want to encourage capital accumulation by adopting a low tax rate. Once the capital has been accumulated, however, taxing it is nondistortionary; thus it is optimal for policymakers to tax it at high rates. As a result, the low tax rate is not dynamically consistent.[12] To give another example, policymakers who want individuals to obey a law may

[10] None of these results depend on the use of specific functional forms. With general functional forms, the equilibrium is for expected and actual inflation to rise to the point where the marginal cost of inflation just balances its marginal benefit through higher output. Thus output equals its natural rate and inflation is above the optimal level. The equilibrium if the policymaker can make a binding commitment is still for inflation to equal its optimal level and output to equal its natural rate.

[11] In fact, the policymaker can do even better by announcing that inflation will equal $\pi^* - (y^* - \bar{y})/b$ and then setting $\pi = \pi^*$; this yields $y = y^*$ and $\pi = \pi^*$.

[12] A corollary of this observation is that low-inflation policy can be dynamically inconsistent not because of an output-inflation tradeoff, but because of government debt. Since government debt is denominated in nominal terms, unanticipated inflation is a lump-sum tax on debt holders. As a result, even if monetary shocks do not have real affects, a policy of setting $\pi = \pi^*$ is not dynamically consistent as long as the government has nominally denominated debt (Calvo, 1978b).

want to promise that violators will be punished harshly. Once individuals have decided whether to comply, however, there is no benefit to punishing violators. Thus again the optimal policy is not dynamically consistent.

9.5 Addressing the Dynamic-Inconsistency Problem

Kydland and Prescott's analysis shows that under fairly mild conditions, discretionary monetary policy gives rise to inefficiently high inflation. This naturally raises the question of what can be done to avoid, or at least mitigate, this possibility.

One approach, of course, is to have monetary policy determined by rules rather than discretion. It is important to emphasize, however, that the rules must be binding. Suppose the policymaker just announces that he or she is going to determine monetary policy according to some procedure, such as pegging the exchange rate or making the money stock grow at a constant rate. If the public believes this announcement and therefore expects low inflation, the policymaker can raise social welfare by departing from the announced policy and choosing a higher rate of money growth. Thus the public will not believe the announcement. Only if the monetary authority relinquishes the ability to determine the money supply does a rule solve the problem.

There are two problems, however, with using binding rules to overcome the dynamic-inconsistency problem. One is normative, the other positive. The normative problem is that rules cannot account for completely unexpected circumstances. There is no difficulty in constructing a rule that makes money growth respond to normal economic developments (such as changes in unemployment and movements in indexes of leading indicators). But sometimes there are events that could not plausibly have been expected. In the 1980s, for example, the United States experienced a major stock market crash that caused a severe liquidity crisis, a "capital crunch" that may have significantly affected banks' lending, and a collapse of the relationships between economic activity and many standard measures of the money stock. It is almost inconceivable that a binding rule would have anticipated all of these possibilities.

The positive problem with binding rules as the solution to the dynamic-inconsistency problem is that we observe low rates of inflation in many situations (such as the United States in the 1950s and in recent years, and Germany over most of the postwar period) where policy is not made according to fixed rules. Thus there must be ways of alleviating the dynamic-inconsistency problem that do not involve binding commitments.

Because of considerations like these, there has been considerable interest in other ways of dealing with dynamic inconsistency. The two approaches that have received the most attention are reputation and delegation.[13]

A Model of Reputation

Reputation can be used to address the dynamic-inconsistency problem if policymakers are in office for more than one period and the public is unsure of their characteristics. For example, the public may not know policymakers' preferences between output and inflation or their beliefs about the output-inflation tradeoff, or whether their announcements about future policy are binding. In such situations, policymakers' behavior conveys information about their characteristics, and thus affects the public's expectations of inflation in subsequent periods. Since policymakers face a more favorable menu of output-inflation choices when expected inflation is lower, this gives them an incentive to pursue low-inflation policies.

To see this formally, consider the following model, which is based on Backus and Driffill (1985) and Barro (1986). Policymakers are in office for two periods, and the output-inflation relationship is given by (9.8) each period; thus $y_t = \bar{y} + b(\pi_t - \pi_t^e)$. It simplifies the algebra to assume that social welfare is linear rather than quadratic in output, and that π^* is zero. Thus social welfare in period t is

$$\begin{aligned} w_t &= (y_t - \bar{y}) - \frac{1}{2}a\pi_t^2 \\ &= b(\pi_t - \pi_t^e) - \frac{1}{2}a\pi_t^2. \end{aligned} \tag{9.14}$$

There are two possible types of policymaker; the public does not know in advance which type it is dealing with. A Type-1 policymaker, which occurs with probability p, shares the public's preferences concerning output and inflation. He or she therefore maximizes

$$W = w_1 + \beta w_2, \qquad 0 < \beta \leq 1, \tag{9.15}$$

[13]Two other possibilities are punishment equilibria and incentive contracts. Punishment equilibria (which are often described as models of reputation, but which differ fundamentally from the models considered below) arise in infinite-horizon models. These models typically have multiple equilibria, including ones where inflation stays below the one-time discretionary level (that is, below π^{EQ}). Low inflation is sustained by beliefs that if the policymaker were to choose high inflation, the public would "punish" him or her by expecting high inflation in subsequent periods; the punishments are structured so that the expectations of high inflation would in fact be rational if that situation ever arose. See, for example, Barro and Gordon (1983b); Rogoff (1987); and Problems 9.8–9.10. Incentive contracts are arrangements in which the central banker is penalized (either financially or through loss of prestige) for inflation. In simple models, the appropriate choice of penalties produces the optimal policy (Persson and Tabellini, 1993; Walsh, 1995). The empirical relevance of such contracts is not clear, however.

where β reflects the importance of the second period in social welfare. A Type-2 policymaker, which occurs with probability $1 - p$, cares only about inflation, and therefore sets inflation to zero in both periods.[14]

Analyzing the Model

Since a Type-2 policymaker always sets inflation to zero, we focus on the behavior of a Type-1 policymaker. In the second period, he or she takes π_2^e as given, and therefore chooses π_2 to maximize $b(\pi_2 - \pi_2^e) - a\pi_2^2/2$. The solution is $\pi_2 = b/a$.

The policymaker's first-period problem is more complicated, because his or her choice of inflation affects expected inflation in the second period. If the policymaker chooses any value of π_1 other than zero, the public learns that it is facing a Type-1 policymaker, and therefore expects inflation of b/a in the second period. Conditional on π_1 not equaling 0, the choice of π_1 has no effect on π_2^e. Thus if the policymaker chooses a nonzero first-period inflation rate, he or she chooses it to maximize $b(\pi_1 - \pi_1^e) - a\pi_1^2/2$, and therefore sets $\pi_1 = b/a$. π_2^e and π_2 are then both equal to b/a, and y_2 equals $\bar{y}$. The value of the objective function for the two periods in this case is thus

$$\begin{aligned} W_{\text{INF}} &= \left[b\left(\frac{b}{a} - \pi_1^e\right) - \frac{1}{2}a\left(\frac{b}{a}\right)^2\right] - \beta\frac{1}{2}a\left(\frac{b}{a}\right)^2 \\ &= \frac{b^2}{a}\frac{1}{2}(1-\beta) - b\pi_1^e. \end{aligned} \tag{9.16}$$

The Type-1 policymaker's other possibility is to set π_1 to 0. It turns out that in equilibrium, he or she may randomize between $\pi_1 = b/a$ and $\pi_1 = 0$. Thus, let q denote the probability that the Type-1 policymaker chooses $\pi_1 = 0$. Now consider the public's inference problem if it observes zero inflation. It knows that this means either that the policymaker is a Type 2 (which occurs with probability $1 - p$), or that the policymaker is a Type 1 but chose zero inflation (which occurs with probability pq). Thus, by Bayes's law, its estimate of the probability that the policymaker is a Type 1 is $qp/[(1-p) + qp]$. Its expectation of π_2 is therefore $\{qp/[(1-p)+qp]\}(b/a)$, which is less than b/a.

This analysis implies that the value of the objective function when the policymaker chooses $\pi_1 = 0$ is

$$\begin{aligned} W_0(q) &= b(-\pi_1^e) + \beta\left\{b\left[\frac{b}{a} - \frac{qp}{(1-p)+qp}\frac{b}{a}\right] - \frac{1}{2}a\left(\frac{b}{a}\right)^2\right\}. \\ &= \frac{b^2}{a}\beta\left[\frac{1}{2} - \frac{qp}{(1-p)+qp}\right] - b\pi_1^e. \end{aligned} \tag{9.17}$$

[14] The key assumption is that the two types have different preferences, not that one type always chooses zero inflation.

Note that $W_0(q)$ is decreasing in q, the probability that the Type-1 policymaker chooses zero inflation in the first period: a higher q implies a higher value of π_2^e if $\pi_1 = 0$, and thus a smaller value to the policymaker of choosing $\pi_1 = 0$.

The equilibrium of the model can take three possible forms. The first possibility occurs if $W_0(0)$ is less than W_{INF}. In this case, even if the Type-1 policymaker can cause the public to be certain that it is facing a Type-2 policymaker by setting $\pi_1 = 0$, he or she will not want to do so. Thus in this case the Type-1 policymaker always chooses $\pi_1 = b/a$. Equations (9.16) and (9.17) imply that $W_0(0)$ is less than W_{INF} when

$$\frac{b^2}{a}\beta\frac{1}{2} - b\pi_1^e < \frac{b^2}{a}\frac{1}{2}(1-\beta) - b\pi_1^e, \tag{9.18}$$

or simply

$$\beta < \frac{1}{2}. \tag{9.19}$$

Thus if the weight on the second period is sufficiently small, the public's uncertainty about the policymaker's type has no effects.

The second possibility arises when $W_0(1)$ is greater than W_{INF}. In this situation, the Type-1 policymaker always chooses $\pi_1 = 0$: even if the public learns nothing about the policymaker's type from observing $\pi_1 = 0$, the cost of revealing that he or she is a Type-1 is enough to dissuade the policymaker from choosing positive inflation. Equations (9.16) and (9.17) imply that $W_0(1)$ exceeds W_{INF} when

$$\frac{b^2}{a}\beta\left(\frac{1}{2} - p\right) - b\pi_1^e > \frac{b^2}{a}\frac{1}{2}(1-\beta) - b\pi_1^e. \tag{9.20}$$

This condition simplifies to

$$\beta > \frac{1}{2}\frac{1}{1-p}. \tag{9.21}$$

The final possibility arises when $W_0(0) > W_{\text{INF}} > W_0(1)$; the preceding analysis implies that this occurs when $1/2 < \beta < (1/2)[1/(1-p)]$. In this case, Type-1 policymakers would choose zero first-period inflation if the public believes they would choose positive inflation, and would choose positive inflation if the public believes they would choose zero. As a result, the economy can be in equilibrium only if the Type-1 policymakers sometimes choose positive inflation and sometimes choose zero. Specifically, q must adjust to the point where the Type-1 policymakers are indifferent between $\pi_1 = 0$ and $\pi_1 = b/a$. Equating (9.16) and (9.17) and solving for q shows that this requires

$$q = \frac{1-p}{p}(2\beta - 1) \qquad \text{if } \frac{1}{2} < \beta < \frac{1}{2}\frac{1}{1-p}. \tag{9.22}$$

Discussion

Although this model is highly stylized, the basic idea is simple. The public is unsure about what policies the government will follow in future periods. Under plausible assumptions, the lower the inflation it observes today, the lower its expectations of inflation in future periods. This gives policymakers an incentive to keep inflation low. Because of the simplicity of the central idea, the basic result that uncertainty about policymakers' characteristics reduces inflation is highly robust (see, for example, Vickers, 1986; Cukierman and Meltzer, 1986; Rogoff, 1987; and Problem 9.11).

This analysis implies that the impact of reputational considerations on inflation is greater when policymakers place more weight on future periods. Specifically, q—the probability that a Type-1 policymaker chooses $\pi_1 = 0$—is increasing in β for $1/2 < \beta < (1/2)[1/(1-p)]$, and is independent of β elsewhere. Similarly, one can show that the impact of the reputational considerations is greater when there are more periods.

The model also implies that the impact on inflation is greater when there is more uncertainty about policymakers' characteristics. To see this, consider, for simplicity, the case of $\beta = 1$. If the policymaker's type is publicly observed, the Type 1's always set $\pi_1 = b/a$ and the Type 2's always set $\pi_1 = 0$. Under imperfect information, however, the Type 1's set $\pi_1 = 0$ with probability q. Thus the uncertainty lowers average first-period inflation by $pq(b/a)$. With $\beta = 1$, (9.21) implies that $q = 1$ when $p < 1/2$; thus for these values of p, the reduction in average first-period inflation is pb/a. And (9.22) implies that $q = (1-p)/p$ when $p > 1/2$; thus for these values, the reduction is $(1-p)b/a$. The maximum reduction thus occurs at $p = 1/2$, and equals $b/2a$. In short, the impact of the reputational considerations is greater when the difference between the two types' preferred inflation rates is larger (that is, when b/a is larger) and when there is more uncertainty about the policymaker's type (that is, when p is closer to 1/2).[15]

The idea that reputational considerations cause policymakers to pursue less expansionary policies seems not only theoretically robust, but also realistic. Central bankers appear to be very concerned with establishing reputations as being tough on inflation and as being credible. If the public were certain of policymakers' preferences and beliefs, there would be no reason for this. Only if the public is uncertain and if expectations matter is this concern appropriate.

Delegation

A second way to overcome the dynamic inconsistency of low-inflation monetary policy is to delegate policy to individuals who do not share the public's

[15] For a general value of $\beta > 1/2$, one can show that the maximum effect occurs at $p = (2\beta - 1)/2\beta$, and equals $[(2\beta - 1)/2\beta]b/a$. For $\beta < 1/2$, there is no effect.

view about the relative importance of output and inflation. The idea, due to Rogoff (1985), is simple: inflation—and hence expected inflation—is lower when monetary policy is controlled by someone who is known to be especially averse to inflation.

To see how delegation can address the dynamic-inconsistency problem, suppose that the output-inflation relationship and social welfare are given by (9.8) and (9.9); thus $y = \overline{y} + b(\pi - \pi^e)$ and $L = [(y - y^*)^2/2] + [a(\pi - \pi^*)^2/2]$. Suppose, however, that monetary policy is determined by an individual whose objective function is

$$L' = \frac{1}{2}(y - y^*)^2 + \frac{1}{2}a'(\pi - \pi^*)^2, \qquad y^* > \overline{y}, \quad a' > 0. \tag{9.23}$$

a' may differ from a, the weight that society as a whole places on inflation. Solving the policymaker's maximization problem along the lines of (9.10) implies that his or her choice of π, given π^e, is given by (9.12) with a' in place of a. Thus,

$$\pi = \pi^* + \frac{b}{a' + b^2}(y^* - \overline{y}) + \frac{b^2}{a' + b^2}(\pi^e - \pi^*). \tag{9.24}$$

Figure 9.5 shows the effects of delegating policy to an individual with a value of a' greater than a. Because the policymaker puts more weight on inflation

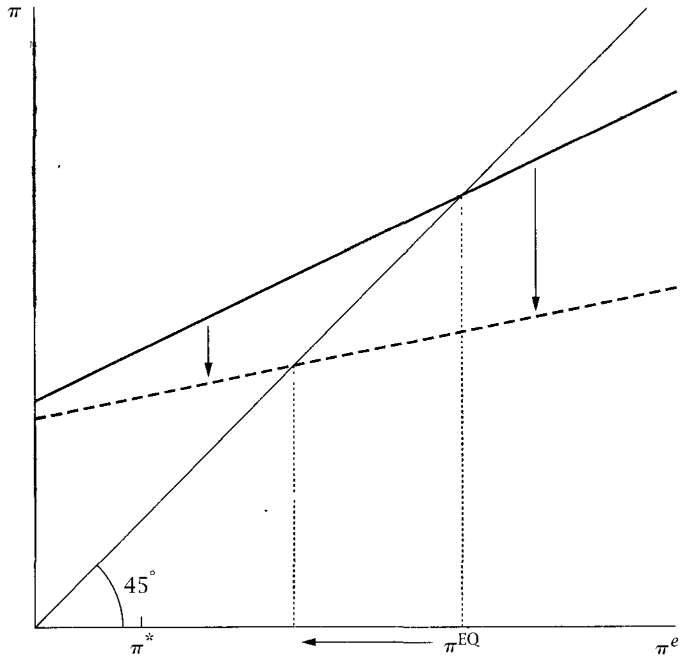

FIGURE 9.5 The effect of delegation to a conservative policymaker on equilibrium inflation

than before, he or she chooses a lower value of inflation for a given level of expected inflation (at least over the range where $\pi^e \geq \pi^*$); in addition, his or her response function is flatter.

As before, the public knows how inflation is determined. Thus equilibrium again requires that expected and actual inflation are equal. As a result, when we solve for expected inflation we find that it is given by (9.13) with a' in place of a:

$$\pi^{\mathrm{EQ}} = \pi^* + \frac{b}{a'}(y^* - \overline{y}). \tag{9.25}$$

The equilibrium is for both actual and expected inflation to be given by (9.25), and for output to equal its natural rate.

Now consider social welfare, which is higher the lower is $(y - y^*)^2/2 + a(\pi - \pi^*)^2/2$. Output is equal to $\overline{y}$ regardless of a'. But the higher a' is, the closer π is to π^*. Thus the higher a' is, the higher social welfare is. Intuitively, when monetary policy is controlled by someone who cares strongly about inflation, the public realizes that the policymaker has little desire to pursue expansionary policy; the result is that expected inflation is low.

Rogoff extends this analysis to the case where the economy is affected by shocks. Under plausible assumptions, a policymaker whose preferences between output and inflation differ from society's does not respond optimally to shocks. Thus in choosing whom to delegate monetary policy to, there is a tradeoff: choosing someone with a stronger dislike of inflation produces a better performance in terms of average inflation, but a worse one in terms of responses to disturbances. As a result, there is some optimal level of "conservatism" for central bankers.[16]

Again, the idea that societies can address the dynamic-inconsistency problem by letting individuals who particularly dislike inflation control monetary policy appears realistic. In many countries, monetary policy is determined by independent central banks rather than by the central government. And the central government often seeks out individuals who are known to be particularly averse to inflation to run those banks. The result is that those who control monetary policy are often known for being more concerned about inflation than society as a whole, and only rarely for being less concerned.

Empirical Application: Central-Bank Independence and Inflation

Theories that attribute inflation to the dynamic inconsistency of low-inflation monetary policy are difficult to test. The theories suggest that inflation is related to such variables as the costs of inflation, policymakers' ability to commit, their ability to establish reputations, and the extent to

[16]This idea is developed in Problem 9.12.

which policy is delegated to individuals who particularly dislike inflation. All of these are hard to measure.

One variable that has received considerable attention is the independence of the central bank. Alesina (1988) argues that central-bank independence provides a measure of the delegation of policymaking to conservative policymakers. Intuitively, the greater the independence of the central bank, the greater the government's ability to delegate policy to individuals who especially dislike inflation. Empirically, central-bank independence is generally measured by qualitative indexes based on such factors as how its governor and board are appointed and dismissed, whether there are government representatives on the board, and the government's ability to veto or directly control the bank's decisions.

Investigations of the relation between these measures of independence and inflation produce a consistent result: independence and inflation are strongly negatively related (Alesina, 1988; Grilli, Masciandaro, and Tabellini, 1991; Cukierman, Webb, and Neyapti, 1992). Figure 9.6 is representative of the results. Thus it appears that delegation is an important determinant of inflation.

There are two limitations to this finding, however. First, the fact that there is a negative relation between central-bank independence and inflation does not mean that the independence is the source of the low inflation. As Posen (1993) observes, countries whose citizens are particularly averse to inflation are likely to try to insulate their central banks from political pressure. For example, it is widely believed that Germans especially dislike inflation, perhaps because of the hyperinflation that Germany experienced after World War I. And the institutions governing Germany's central bank appear to have been created largely because of this desire to avoid inflation. Thus some of Germany's low inflation is almost surely the result of the general aversion to inflation, rather than of the independence of its central bank.

Second, it is not clear that theories of dynamic inconsistency and delegation predict that greater central-bank independence will produce lower inflation. The argument that they do predict this implicitly assumes that both central bankers' and government policymakers' preferences do not vary systematically with central-bank independence. But the delegation hypothesis implies that they will. Suppose, for example, that monetary policy depends on the central bank's and the government's preferences, with the weight on the bank's preferences increasing in its independence. Then when the bank is less independent, government officials should compensate by appointing more inflation-averse individuals to the bank. Similarly, when the government is less able to delegate policy to the bank, voters should elect more inflation-averse governments. These effects will mitigate, and might even offset, the effects of reduced central-bank independence.[17] In short,

[17]In addition, the usual measures of central-bank independence appear to be biased in favor of finding a link between independence and low inflation. For example, the measures often put some weight on whether the bank's charter gives low inflation as its principal goal (Pollard, 1993).

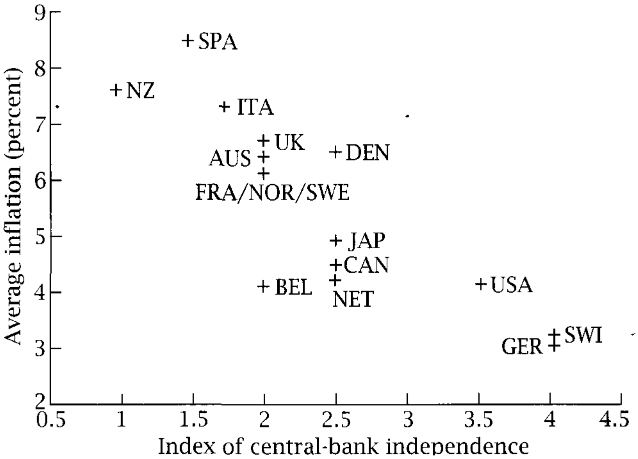

FIGURE 9.6 Central-bank independence and inflation[18]

although the relationship between central-bank independence and inflation is striking, its ultimate implications remain to be determined.

Limitations of Dynamic-Inconsistency Theories of Inflation

Theories based on dynamic inconsistency provide a simple and appealing explanation of inflation. Unfortunately, it is not clear that their explanation is important to actual inflation, particularly for the industrialized countries. There are two problems. First, the importance of forward-looking expectations to aggregate supply, which is central to the dynamic-inconsistency explanation, is not well established. For example, Canada and New Zealand have recently taken strong measures to commit themselves to low-inflation monetary policies. New Zealand, for instance, has modified the central bank's charter to make price stability the sole objective of policy and to provide for the dismissal of the bank's governor if inflation falls outside a target range. Yet, contrary to the predictions of dynamic-inconsistency models, these measures do not appear to have had a major impact on the output-inflation relationship in these countries (Debelle, 1994).

Second, there is a great deal of variation in inflation that the dynamic-inconsistency models have difficulty accounting for. In the United States, for example, policymakers were able to reduce inflation from about 10% at the end of the 1970s to under 5% just a few years later, and to maintain the lower inflation, without any significant change in the institutions or

[18] Figure 9.6, from "Central Bank Independence and Macroeconomic Performance" by Alberto Alesina and Lawrence H. Summers, *Journal of Money, Credit, and Banking,* Vol. 25, No. 2 (May 1993), is reprinted by permission. Copyright 1993 by the Ohio State University Press. All rights reserved.

rules governing monetary policy. Similarly, Japan has had consistently low inflation despite the fact that its central bank is not particularly independent. Indeed, if one is not willing to interpret the correlation between central-bank independence and inflation as reflecting the effects of dynamic inconsistency and delegation, it is hard to identify any important part of either the time-series or cross-section variations in inflation in the industrialized countries that is due to dynamic-inconsistency considerations.[19]

These weaknesses of dynamic-inconsistency theories suggest that we should consider other ways that inflation could come about. In addition, there are a variety of important issues concerning how monetary policy should be conducted that do not involve dynamic inconsistency. The next section discusses some of those issues and considers several ways that inflation could arise from other sources.

9.6 Some Macroeconomic Policy Issues

The discussion in the previous two sections makes it appear that monetary policymakers face a single problem: they must find a way of getting inflation to its optimal level. Actual policymaking is much more complicated. There are two issues. First, it is not clear what the optimal rate of inflation is; this issue is addressed in Section 9.8. Second, various kinds of disturbances are continually affecting the economy. This section addresses some of the issues that are raised by the presence of these shocks.

What Can Policy Accomplish? A Baseline Case

How much weight should policymakers put on stabilizing output as opposed to other objectives, such as keeping inflation low and predictable? To address this issue, it is useful to begin with a simple case. Suppose that aggregate supply relates the change in inflation linearly to the departure of the unemployment rate from the natural rate, and that it has no forward-looking element (see equations [5.36]-[5.37]):

$$\pi_t = \pi_{t-1} - \alpha(u_t - \overline{u}) + \varepsilon_t^S, \qquad \alpha > 0, \tag{9.26}$$

[19] D. Romer (1993b) argues that dynamic-inconsistency models predict that more open economies will have lower inflation, and that the evidence from outside the industrialized world strongly supports this prediction. He does not find any relation between openness and inflation among industrialized countries, however. Similarly, Cukierman, Edwards, and Tabellini (1992) find that inflation is higher in countries that are less politically stable, and they observe that this may reflect the diminished importance of reputation when policymakers' horizons are shorter. The variation in instability among industrialized countries is small, however, and thus this variable also fails to account for much of the differences in inflation among these countries.

where ε_t^S represents supply shocks. In addition, suppose that social welfare depends on unemployment and inflation, and that the dependence on unemployment is linear:

$$W_t = -cu_t - f(\pi_t), \qquad c > 0, \quad f''(\bullet) > 0. \tag{9.27}$$

This simple model has strong implications for policy. First, the aggregate supply curve, (9.26), implies that policy has no control over average unemployment unless policymakers are willing to accept ever-increasing (or ever-decreasing) inflation. Equation (9.26) implies that the average change in inflation is determined by average unemployment and average supply shocks. Thus altering average unemployment alters the average change in inflation. But if the average change in inflation is anything other than zero, the level of inflation grows (or falls) without bound.[20]

This result, coupled with the assumption that social welfare is linear in unemployment, implies that policy should put essentially no weight on unemployment. Suppose that policymakers' discount rate is zero, and consider the first-order condition for π_t.[21] Raising π_t by a small amount $d\pi$ changes current-period social welfare by both its direct effect, $-f'(\pi_t)d\pi$, and its effect via unemployment, $c\alpha d\pi$. In addition, the increase in current inflation means (for given next-period inflation) higher unemployment next period; this contributes $-c\alpha d\pi$ to social welfare. Thus the first-order condition for π_t is simply $f'(\pi_t) = 0$: policymakers should keep inflation at its optimal level and pay no attention to unemployment. This is true regardless of the importance of unemployment (that is, regardless of c), and regardless of what supply shocks are buffeting the economy. Intuitively, any change in the path of inflation that does not permanently raise inflation can only rearrange the timing of unemployment, which has no effect on welfare. And with a discount rate of zero, any policy that permanently raises inflation above the optimal level has infinite costs regardless of how small inflation's costs are.

With discounting, one can show that the first-order condition for π_t is

$$\frac{1+\rho}{\rho} f'(\pi_t) = c\alpha, \tag{9.28}$$

where ρ is policymakers' discount rate.[22] Thus inflation should be set at the level where the cost of a permanent increase in inflation just balances the benefit of the associated one-time decrease in unemployment. Even with discounting, there is little scope for sophisticated stabilization policy:

[20] In addition, as described in Chapter 5, if policymakers allow inflation to grow without bound, the aggregate supply curve (9.26) will almost surely break down. This is not relevant to the point made here, however.

[21] We are assuming for the moment that policymakers can control inflation perfectly, subject to (9.26).

[22] That is, policymakers maximize $\sum_{t=0}^{\infty}(1+\rho)^{-t}W_t$.

because the first-order condition does not depend on π_{t-1} or ε_t^S, the optimal policy is to go directly to the inflation rate that satisfies (9.28) regardless of the current state of the economy. Indeed, if policymakers respond to high inflation by creating an extended recession that brings inflation down to the level satisfying (9.28) only slowly, the total amount of unemployment will be no different than it would have been if they had reduced inflation all at once. Thus they will have subjected the economy to an extended period of above-normal inflation for no benefit.

This baseline case implies that policymakers should not attempt to stabilize unemployment in the face of supply shocks. It also implies that the benefits of using policy to offset aggregate demand shocks come only from reducing the variability of inflation. The linearity of aggregate supply implies that if policymakers allow demand shocks to cause fluctuations in unemployment and inflation, average unemployment is unaffected; and the linearity of social welfare implies that fluctuations in unemployment do not affect welfare. Thus the only costs of the fluctuations come from the costs of the variation in inflation. If inflation variability has low costs over the relevant range, policymakers should attach little importance to offsetting demand shocks.

Is There a Case for Stabilization Policy?

The key assumptions behind these results are the linearity of the social welfare function, (9.27), and of the aggregate supply curve, (9.26). Thus for there to be a substantial benefit to stabilization policy, one of these functions must be significantly nonlinear.[23]

Consider first social welfare. Lucas (1987) shows that in a representative-agent setting, the potential welfare gain from stabilizing consumption around its mean is small; that is, he suggests that social welfare is not sufficiently nonlinear in output for there to be a significant gain from stabilization. His argument is straightforward. Suppose that utility takes the constant-relative-risk-aversion form:

$$U(C) = \frac{C^{1-\theta}}{1-\theta}, \qquad \theta > 0, \tag{9.29}$$

where θ is the coefficient of relative risk aversion (see Section 2.1). Since $U''(C) = -\theta C^{-\theta-1}$, a second-order Taylor expansion of $U(\bullet)$ around the mean of consumption implies

$$E[U(C)] \simeq \frac{\overline{C}^{1-\theta}}{1-\theta} - \frac{\theta}{2}\overline{C}^{-\theta-1}\sigma_C^2, \tag{9.30}$$

[23]For demand shocks, this assumes that the costs of moderate inflation variability is low.

where $\overline{C}$ and σ_C^2 are the mean and variance of consumption. Thus eliminating consumption variability would raise expected utility by approximately $(\theta/2)\overline{C}^{-\theta-1}\sigma_C^2$. Similarly, doubling consumption variability would lower welfare by approximately that amount.

To translate this into units that can be interpreted, note that the marginal utility of consumption at $\overline{C}$ is $\overline{C}^{-\theta}$. Thus setting σ_C^2 to zero would raise expected utility by approximately as much as would raising average consumption by $(\theta/2)\overline{C}^{-\theta-1}\sigma_C^2/\overline{C}^{-\theta} = (\theta/2)\overline{C}^{-1}\sigma_C^2$. As a fraction of average consumption, this equals $(\theta/2)\overline{C}^{-1}\sigma_C^2/\overline{C}$, or $(\theta/2)(\sigma_C/\overline{C})^2$.

Lucas argues that a generous estimate of the standard deviation of consumption due to short-run fluctuations is 1.5% of its mean, and that a generous estimate of the coefficient of relative risk aversion is 5. Thus, he concludes, an optimistic figure for the maximum possible welfare gain from more successful stabilization policy is equivalent to $(5/2)(0.015)^2$, or 0.06%, of average consumption—a very small amount.

At first glance, it appears that Lucas's conclusion rests critically on his assumption that there is a representative agent. Actual recessions do not reduce everyone's consumption by a small amount, but reduce the consumption of a small fraction of the population by a large amount; thus their welfare costs are larger than they would be in a representative-agent setting. Atkeson and Phelan (1994) show, however, that accounting for the dispersion of consumption decreases rather than increases the potential gain from stabilization. Indeed, their analysis suggests a basis for the linear social welfare function, (9.27), where there is no gain at all from stabilizing unemployment. Suppose that individuals have one level of consumption, C_E, when they are employed, and another level, C_U, when they are unemployed, and suppose that C_E and C_U do not depend on the state of the economy. Since u is the fraction of individuals who are unemployed, average utility from consumption is $uU(C_U) + (1 - u)U(C_E)$. Thus expected social welfare from consumption is $E[u]U(C_U) + (1 - E[u])U(C_E)$: social welfare is independent of the variance of unemployment. Intuitively, in this case stabilizing unemployment has no effect on the variance of individuals' consumption; individuals have consumption C_E fraction $1-E[u]$ of the time, and C_U fraction $E[u]$ of the time.

Consumption variability is not the only cost of fluctuations, however. The variability of hours of work may have much larger costs than the variability of consumption. The cyclical variability of hours is much larger than that of consumption; and if labor supply is relatively inelastic, utility may be much more sharply curved in hours than in consumption. Ball and D. Romer (1990) find that as a result, it is possible (though by no means clear-cut) that the cost of fluctuations through hours variability is substantial. Intuitively, the utility benefit of the additional leisure during periods of below-normal output may not nearly offset the utility cost of the reduced consumption, whereas the disutility from the additional hours during booms may nearly offset the benefit of the higher consumption.[24] Thus if there is a substantial direct welfare gain from reducing the variance of output, it is likely to be through the impact on hours rather than on consumption.

It is also possible that stabilization policy has important indirect benefits. One natural mechanism is through investment: investment may be higher when the economy is more stable. As a result, stabilization policy could raise income substantially over the long run (see, for example, Meltzer, 1988). As Section 8.6 describes, however, the effect of uncertainty on investment is complicated and not necessarily negative. Thus whether stabilization policy has important benefits through this channel is not known.

There has been little work on nonlinearities in the aggregate supply curve. Many textbook formulations assume that the increase in inflation triggered by a fall in unemployment below the natural rate is larger than the decrease in inflation caused by a comparable rise in unemployment above the natural rate. If this is correct, reducing the variance of unemployment reduces the average increase in inflation, and thus makes a lower average unemployment rate feasible.

In fact, however, most researchers working on aggregate supply have found that a linear specification provides an adequate description of the data (see, for example, Gordon, 1990, and Ball and Mankiw, 1995). There is certainly no strong evidence of any large nonlinearity over the relevant range.[25]

If social welfare or aggregate supply is nonlinear in output, the optimal response to an unfavorable supply shock that raises inflation is to reduce inflation gradually rather than all at once. Thus a supply shock could give rise to an extended period of inflation. At the same time, however, such nonlinearities would also imply that the optimal response to a positive supply shock is to bring inflation back up to its initial level only gradually. Thus although nonlinearities may provide grounds for stabilization policy, they do not provide a simple explanation of high average inflation.

Targets, Indicators, and Instruments

Policy actions affect the economy with a lag. In addition, policymakers have imperfect information about the current condition of the economy, about the path it would follow if policy did not change, and about the effects

[24]Just as with the argument for the cost from consumption variability, Ball and Romer's argument concerning the cost from hours variability requires that not all of the variation in aggregate hours take the form of movements between employment and unemployment.

[25]See De Long and Summers (1989) for one attempt to argue for important nonlinearity of the form that makes stabilization policy beneficial. Ball (1994b), on the other hand, finds evidence of nonlinearity of the opposite form, which implies that stabilization policy could actually increase average unemployment.

a change in policy would have. This naturally raises the issue of how these lags and uncertainties should affect policy.

The traditional analysis of policymaking under uncertainty distinguishes among objectives, instruments, intermediate targets, and indicators of policy.[26] The objectives are the ultimate goals of policy, such as inflation and unemployment. The instruments are the variables that policymakers can control directly, such as open-market operations, reserve requirements, tax rates, and government purchases.

Indicators and intermediate targets fall between the instruments and the objectives. Indicators are variables that provide information about the current or future behavior of the objectives. Some examples are orders for new goods, prices of raw materials, and measures of money and lending. As policymakers obtain new information about the likely behavior of the objectives by observing the indicators, they may adjust the settings of the instruments. Intermediate targets, in contrast, are variables that policymakers choose to focus on in place of the ultimate objectives. The most famous candidate target is the money stock. Many economists have argued that it is better to instruct policymakers to try to keep the growth rate of a measure of the money stock (such as $M1$ or $M2$) as close as possible to some steady, low rate (such as 3% per year) rather than to try to maximize some broader objective function (see, for example, Friedman, 1960).

To see how instruments, indicators, targets, and objectives are used in practice, consider the following stylized description of U.S. monetary policy in recent years. The main ultimate objectives of policy are the behavior of unemployment (or real output) and inflation. Policymakers appear to want inflation to be around 2% or 3% per year and to avoid large swings in unemployment.[27] Thus, for example, when inflation is above the 2–3% range, policymakers have sought to reduce it gradually. Other objectives, such as keeping exchange rates and interest rates moderately stable, also appear to get some weight in policymakers' objective function.

Over the short term (say, day-to-day and week-to-week), the key intermediate target of policy is the Federal funds rate. The Federal Reserve conducts its daily open-market operations to try to keep the funds rate close to its current target level.[28] Although on a day-to-day basis there are noticeable departures of the funds rate from the target, on a weekly or longer-term basis the Federal Reserve usually hits the target quite accurately.

Over the slightly longer term (say, month-to-month), the Federal Reserve does not focus on any single intermediate target. Instead, it adjusts the target level of the funds rate in response to many variables that can provide information about the future paths of real activity and inflation.

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[26] This analysis was pioneered by Tinbergen (1952).

[27] As the discussion earlier in this section suggests, it is not clear that this is what policymakers should in fact be trying to achieve.

[28] Meulendyke (1990) describes the specifics of the Federal Reserve's operating procedures.

Finally, over the medium term (say, quarter-to-quarter), there usually is clearer information about how real output and unemployment are likely to behave than about inflation. Thus over this horizon, real output and unemployment are not only among the main objectives of policy, but are also the main indicators or intermediate targets. When inflation is above the desired range, for example, policymakers typically aim to keep unemployment moderately above the natural rate; when inflation is in the desired range, they usually try to maintain unemployment roughly at the natural rate.[29] In either situation, policymakers adjust the target as they obtain more information about the behavior of inflation.

The Traditional Argument for Rules

A natural question about indicators and intermediate targets is why policymakers would ever adopt an intermediate target. It seems that policymakers should take all relevant information into account in their efforts to achieve their ultimate goals. A particular indicator, such as a measure of the money stock, may turn out to be particularly informative; but even then, it appears that there is a cost and no benefit to targeting that variable.

One possible answer involves the dynamic-inconsistency issue, discussed in Sections 9.4 and 9.5: adopting a binding rule about the behavior of an intermediate target can overcome the dynamic-inconsistency problem, and can therefore lead to lower average inflation. But support for money-stock rules and other intermediate targets long predates concern about dynamic inconsistency. Moreover, many proposed ways of adopting intermediate targets do not involve binding commitments, and thus would not overcome the problem.

The basis for the traditional argument for instructing policymakers to target some intermediate variable is twofold. Consider for concreteness a money-stock target. The first, and less important, part of the argument for targeting the money stock is that the relation between the money stock and the ultimate objectives of policy is strong enough, and the uncertainty about the effects of departures of the money stock from a path of steady growth large enough, that the potential for improvement over a money-stock rule is small. And since the rule would not be completely binding, in the event of a calamitous breakdown it could be abandoned.

The second, and more important, part of the argument is that instructing policymakers to try to achieve the ultimate goals of policy to the best of their ability may lead to systematic errors in policy. Those potential errors have several sources.

[29]For the United States today, estimates of the natural rate range from under 6% to almost 7%. Obviously where in this range the true figure lies has important implications for policy.

First, policymakers are subject to political pressures. Policymakers outside the Federal Reserve, and the public, may place too much weight on the short-run cost of lower unemployment relative to the long-run cost of higher inflation. This could arise from a higher discount rate than is appropriate, or from a failure to understand how the economy operates. Some evidence for this view is provided by the fact that during periods (such as 1979–1982) when the Federal Reserve has pursued policies that involved very high interest rates, it has not explicitly acknowledged that it was doing so. Instead, policymakers have characterized policy as focusing on some intermediate target (such as *nonborrowed reserves* in 1979–1982) and as not being directly concerned with interest rates.

Second, monetary policymakers may have objectives other than maximizing social welfare, and providing them with only vague instructions about how to conduct policy may increase their ability to pursue those objectives. For example, they may wish to improve the President's chances of being reelected, or to increase seignorage revenues.[30]

Finally, policymakers may genuinely try to maximize social welfare but may nonetheless make systematic errors. Individuals are often overconfident in their judgments (of the state of the economy, or of the likely effects of policy, for example). In addition, they may be reluctant to admit that, given the lags and uncertainties in the effects of policies, the best reaction to a problem may be to do little or nothing. As a result, policy may systematically overreact, easing too much in recessions and thereby causing the subsequent expansions to be too strong, and tightening too much in expansions and thereby causing recessions (see, for example, Friedman, 1960). Similarly, given the suffering associated with unemployment, policymakers may have a tendency to read the evidence about the natural rate optimistically. This can generate an inflationary bias in policy. And, as with the tendency to overreact, it can generate fluctuations. Policymakers may first, out of concern about unemployment and in hopes that the natural rate is low, push unemployment below the natural rate; then, when signs of rising inflation become clear, they may tighten and cause a recession.[31]

This discussion suggests several potential sources of inflation other than dynamic inconsistency: political pressures on policymakers, policymakers' pursuit of objectives other than social welfare, and overoptimism about the

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[30]The possibility of the Federal Reserve pursuing objectives other than social welfare (either because of its own preferences or because of political pressures) suggests that fluctuations can arise from political forces rather than exogenous disturbances. For examples of theories of such *political business cycles,* see Nordhaus (1975); Alesina and Sachs (1988); Rogoff and Sibert (1988); and Harrington (1993).

[31]Karamouzis and Lombra (1989) present one piece of evidence of a tendency for overoptimism among policymakers: during the 1970s, the Federal Open Market Committee tended to adopt combinations of interest-rate and money-growth targets that were systematically off the frontier (in the direction of lower money growth and lower interest rates) of possibilities presented by the staff as being feasible.

level of unemployment that is sustainable.[32] None of these theories, however, have yet been formulated rigorously or tested empirically.

9.7 Seignorage and Inflation

The existence of an output-inflation tradeoff cannot plausibly lead to hyperinflations, or even to very high rates of inflation that fall short of hyperinflation. By the time inflation reaches triple digits, the costs of inflation are almost surely large, and the real effects of monetary changes are almost surely small. No reasonable policymaker would choose to subject an economy to such large costs out of a desire to obtain such modest output gains.

The underlying cause of most, if not all, episodes of high inflation and hyperinflation is government's need to obtain seignorage—that is, revenue from printing money (Bresciani-Turroni, 1937; Cagan, 1956). Wars, falls in export prices, tax evasion, and political stalemate frequently leave governments with large budget deficits. And often investors do not have enough confidence that the government will honor its debts to be willing to buy its bonds. Thus the government's only choice is to resort to seignorage.[33]

This section therefore investigates the interactions among seignorage needs, money growth, and inflation. We begin by considering a situation where seignorage needs are sustainable, and see how this can lead to high inflation. We then consider what happens when the seignorage needs are unsustainable, and see how that can lead to hyperinflation.

The Inflation Rate and Seignorage

As in Section 9.2, assume that real money demand depends negatively on the nominal interest rate and positively on real income (see equation [9.1]):

$$\begin{aligned} \frac{M}{P} &= L(i, Y) \\ &= L(r + \pi^e, Y), \qquad L_i < 0, \quad L_Y > 0. \end{aligned} \tag{9.31}$$

Since we are interested in the government's revenue from money creation,

[32] Inflation can also arise if policymakers do not know the correct model of the economy. Suppose that policymakers believe that the costs of moderate inflation are small and that there is (or that there may be) a permanent output-inflation tradeoff. Then they are likely to pursue expansionary policies, and to be slow to disinflate when inflation sets in. This may be a good description of what happened in the United States in the 1960s and 1970s (see, for example, Freedman, 1993).

[33] An important question is how the political process leads to situations that require such large amounts of seignorage. The puzzle is that given the apparent high costs of the resulting inflation, there appear to be alternatives that all parties prefer. See Alesina and Drazen (1991) for one attempt to answer this question.

M should be interpreted as high-powered money (that is, currency and reserves issued by the government). Thus $L(\bullet)$ is the demand for high-powered money.

For the moment we focus on steady states. It is therefore reasonable to assume that output and the real interest rate are unaffected by the rate of money growth, and that actual inflation and expected inflation are equal. If we neglect output growth for simplicity, then in steady state the quantity of real balances is constant. This implies that inflation equals the rate of money growth. Thus we can rewrite (9.31) as

$$\frac{M}{P} = L(\overline{r} + g_M, \overline{Y}), \tag{9.32}$$

where $\overline{r}$ and $\overline{Y}$ are the real interest rate and output and where g_M is the rate of money growth, $\dot{M}/M$.

The quantity of real purchases per unit time that the government finances from money creation equals the increase in the nominal money stock per unit time divided by the price level:

$$\begin{aligned} S &= \frac{\dot{M}}{P} \\ &= \frac{\dot{M}}{M}\frac{M}{P} \\ &= g_M \frac{M}{P}. \end{aligned} \tag{9.33}$$

Equation (9.33) shows that in steady state, real seignorage equals the growth rate of the money stock times the quantity of real balances. The growth rate of money is equal to the rate at which nominal money holdings lose real value, π. Thus, loosely speaking, seignorage equals the "tax rate" on real balances, π, times the amount being taxed, M/P. For this reason, seignorage revenues are often referred to as *inflation-tax* revenues.[34]

Substituting (9.32) into (9.33) yields

$$S = g_M L(\overline{r} + g_M, \overline{Y}). \tag{9.34}$$

Equation (9.34) shows that an increase in g_M increases seignorage by raising the rate at which real money holdings are taxed, but decreases it by reducing the tax base. Formally,

[34]Phelps (1973) shows that it is more natural to think of the tax rate on money balances as the nominal interest rate, since the nominal rate is the difference between the cost to agents of holding money (which is the nominal rate itself) and the cost to the government of producing it (which is essentially zero). In our framework, where the real rate is fixed and the nominal rate therefore moves one-for-one with inflation, this distinction is not important.

$$\frac{dS}{dg_M} = L(\overline{r} + g_M, \overline{Y}) + g_M L_1(\overline{r} + g_M, \overline{Y}), \tag{9.35}$$

where $L_1(\bullet)$ denotes the derivative of $L(\bullet)$ with respect to its first argument.

The first term of (9.35) is positive and the second is negative. The second term approaches zero as g_M approaches zero (unless $L_1(\overline{r} + g_M, \overline{Y})$ approaches minus infinity as g_M approaches zero). Since $L(\overline{r}, \overline{Y})$ is strictly positive, it follows that dS/dg_M is positive for sufficiently low values of g_M. That is, at low tax rates, seignorage is increasing in the tax rate. It is plausible, however, that as g_M becomes large, the second term eventually dominates; that is, it is reasonable to suppose that when the tax rate becomes extreme, further increases in the rate reduce revenue. The resulting "inflation-tax Laffer curve" is shown in Figure 9.7.

As a concrete example of the relation between inflation and steady-state seignorage, consider the money-demand function proposed by Cagan (1956). Cagan suggests that a good description of money demand, particularly under high inflation, is given by

$$\ln \frac{M}{P} = a - bi + \ln Y, \qquad b > 0. \tag{9.36}$$

Converting (9.36) from logs to levels and substituting the resulting expression into (9.34) yields

$$\begin{aligned} S &= g_M e^a \overline{Y} e^{-b(\overline{r}+g_M)} \\ &= C g_M e^{-b g_M}, \end{aligned} \tag{9.37}$$

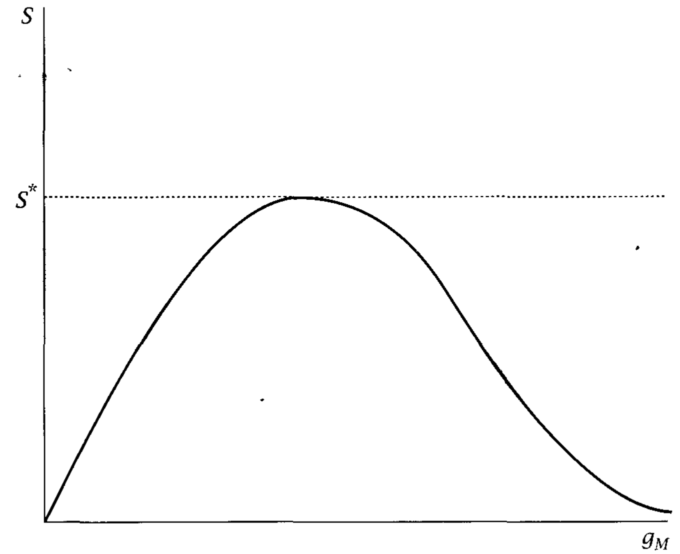

FIGURE 9.7 The inflation-tax Laffer curve

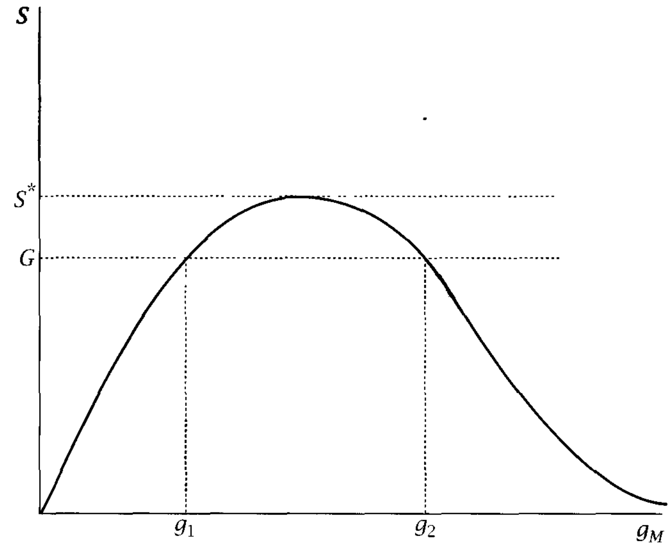

FIGURE 9.8 How seignorage needs determine inflation

where $C \equiv e^a \overline{Y} e^{-b\overline{r}}$. The impact of a change in money growth on seignorage is therefore given by

$$\begin{aligned}\frac{dS}{dg_M} &= Ce^{-bg_M} - bCg_M e^{-bg_M} \\ &= (1 - bg_M)Ce^{-bg_M}.\end{aligned} \tag{9.38}$$

This expression is positive for $g_M < 1/b$ and negative thereafter.

Cagan's estimates suggest that b is between $\frac{1}{3}$ and $\frac{1}{2}$. This implies that the peak of the inflation-tax Laffer curve occurs when g_M is between 2 and 3. This corresponds to a continuously compounded rate of money growth of 200% to 300% per year, which implies an increase in the money stock by a factor of between $e^2 \simeq 7.4$ and $e^3 \simeq 20$ per year. Cagan, Sachs and Larrain (1993), and others suggest that for most countries, seignorage at the peak of the Laffer curve is about 10% of GDP.

Now consider a government that has some amount of real purchases, G, that it needs to finance with seignorage. Assume that G is less than the maximum feasible amount of seignorage, denoted S^*. Then, as Figure 9.8 shows, there are two rates of money growth that can finance the purchases.[35] With one, inflation is low and real balances high; with the

[35] Figure 9.8 implicitly assumes that the seignorage needs are independent of the inflation rate. This assumption omits an important effect of inflation: because taxes are usually specified in nominal terms and collected with a lag, an increase in inflation typically reduces real tax revenues. As a result, seignorage needs are likely to be greater at higher inflation rates. This *Tanzi* (or *Olivera-Tanzi*) effect does not require any basic change in our analysis;

other, inflation is high and real balances low. The high-inflation equilibrium has peculiar comparative-statics properties; for example, a decrease in the government's seignorage needs raises inflation. Since we do not appear to observe such situations in practice, we focus on the low-inflation equilibrium. Thus the rate of money growth—and hence the rate of inflation—is given by g_1.

This analysis provides an explanation of high inflation: it stems from governments' need for seignorage. Suppose, for example, that $b = \frac{1}{3}$ and that seignorage at the peak of the Laffer curve, S^*, is 10% of GDP. Since seignorage is maximized when $g_M = 1/b$, (9.37) implies that S^* is Ce^{-1}/b. Thus for S^* to equal 10% of GDP when b is $\frac{1}{3}$, C must be about 9% of GDP. Straightforward calculations then show that raising 2% of GDP from seignorage requires $g_M \simeq 0.24$, raising 5% requires $g_M \simeq 0.70$, and raising 8% requires $g_M \simeq 1.42$. Thus moderate seignorage needs give rise to substantial inflation, and large seignorage needs produce high inflation.

Seignorage and Hyperinflation

This analysis seems to imply that even governments' need for seignorage cannot account for hyperinflations: if seignorage revenue is maximized at inflation rates of several hundred percent, why do governments ever let inflation go higher? The answer is that the preceding analysis holds only in steady state. If the public does not immediately adjust its money holdings or its expectations of inflation to changes in the economic environment, then in the short run seignorage is always increasing in money growth, and the government can obtain more seignorage than the maximum sustainable amount, S^*. Thus hyperinflations arise when the government's seignorage needs exceed S^* (Cagan, 1956).

Gradual adjustment of money holdings and gradual adjustment of expected inflation have similar implications for the dynamics of inflation. We focus on the case of gradual adjustment of money holdings. Specifically, assume that individuals' desired money holdings are given by the Cagan money-demand function, (9.36). In addition, continue to assume that the real interest rate and output are fixed at $\bar{r}$ and $\bar{Y}$: although both variables are likely to change somewhat over time, the effects of those variations are likely to be small relative to the effects of changes in inflation.

Thus desired real money holdings are

$$m^*(t) = Ce^{b\pi(t)}. \tag{9.39}$$

The key assumption of the model is that actual money holdings adjust gradually toward desired holdings. Specifically, our assumption is

$$\dot{\ln m}(t) = \beta[\ln m^*(t) - \ln m(t)], \tag{9.40}$$

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we only have to replace the horizontal line at G with an upward-sloping line. But the effect can be quantitatively significant, and is therefore important to understanding high inflation in practice.

or

$$\frac{\dot{m}(t)}{m(t)} = \beta[\ln m^*(t) - \ln m(t)] \\ = \beta[\ln C - b\pi(t) - \ln m(t)], \tag{9.41}$$

where the second line uses (9.39) to substitute for $\ln m^*(t)$. The idea behind this assumption of gradual adjustment is that it is difficult for individuals to adjust their money holdings; for example, they may have made arrangements to make certain types of purchases using money. As a result, they adjust their money holdings toward the desired level only gradually. The specific functional form is chosen for convenience. Finally, β is assumed to be positive but less than $1/b$—that is, adjustment is assumed not to be too rapid.[36]

As before, seignorage equals $\dot{M}/P$, or $(\dot{M}/M)(M/P)$; thus

$$S(t) = g_M(t)m(t). \tag{9.42}$$

Suppose that this economy is initially in steady state with G less than S^*, and that G then increases to a value greater than S^*. If adjustment is instantaneous, there is no equilibrium with positive money holdings. Since S^* is the maximum amount of seignorage the government can obtain when individuals have adjusted their real money holdings to their desired level, the government cannot obtain more than this with instantaneous adjustment. As a result, the only possibility is for money to immediately become worthless and for the government to be unable to obtain the seignorage it needs.

With gradual adjustment, on the other hand, the government can obtain the needed seignorage through increasing money growth and inflation. With rising inflation, real money holdings are falling. But because the adjustment is not immediate, the real money stock exceeds $Ce^{-b\pi}$; as a result (as long as the adjustment is not too rapid), the government is able to obtain more than S^*. But with the real money stock falling, the required rate of money growth is rising. The result is explosive inflation.

To see the dynamics of the economy formally, it is easiest to focus on the dynamics of the real money stock, m. Equation (9.41) gives $\dot{m}/m$ in terms of π and m. Thus to characterize the behavior of m, we need to eliminate π from this equation.

To do this, note that the growth rate of real money, $\dot{m}/m$, equals the growth rate of nominal money, g_M, minus the rate of inflation, π. Rewriting

[36] The assumption that the change in real money holdings depends only on the current values of m^* and m implies that individuals are not forward-looking. A more appealing assumption, along the lines of the q model of investment in Chapter 8, is that individuals consider the entire future path of inflation in deciding how to adjust their money holdings. This assumption complicates the analysis greatly without changing the implications for most of the issues we are interested in (but see n. 39, below).

this as an equation for inflation gives us

$$\begin{aligned}\pi(t) &= g_M(t) - \frac{\dot{m}(t)}{m(t)} \\ &= \frac{G}{m(t)} - \frac{\dot{m}(t)}{m(t)},\end{aligned} \tag{9.43}$$

where the second line uses the fact that $m(t)g_M(t) = G$ (see [9.42]). Substituting this expression into (9.41) yields

$$\frac{\dot{m}(t)}{m(t)} = \beta\left\{\ln C - b\left[\frac{G}{m(t)} - \frac{\dot{m}(t)}{m(t)}\right] - \ln m(t)\right\}. \tag{9.44}$$

We can now solve this expression for $\dot{m}(t)/m(t)$; this yields

$$\begin{aligned}\frac{\dot{m}(t)}{m(t)} &= \frac{\beta}{1-b\beta}\left[\ln C - b\frac{G}{m(t)} - \ln m(t)\right]. \\ &= \frac{\beta}{1-b\beta}\frac{b}{m(t)}\left[\frac{\ln C - \ln m(t)}{b}m(t) - G\right].\end{aligned} \tag{9.45}$$

Our assumption that G is greater than S^* implies that the expression in brackets is negative for all values of m. To see this, note first that the rate of inflation needed to make desired money holdings equal m is the solution to $Ce^{-b\pi} = m$; taking logs and rearranging the resulting expression shows

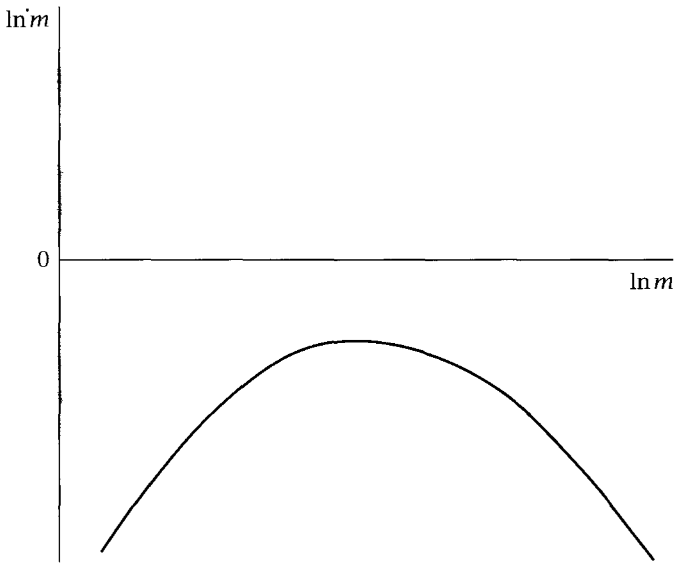

FIGURE 9.9 The dynamics of the real money stock when seignorage needs are unsustainable

that this inflation rate is $(\ln C - \ln m)/b$. Next, recall that if real money holdings are steady, seignorage is πm; thus the sustainable level of seignorage associated with real money balances of m is $[(\ln C - \ln m)/b]m$. Finally, recall that S^* is defined as the maximum sustainable level of seignorage. Thus the assumption that S^* is less than G implies that $[(\ln C - \ln m)/b]m$ is less than G for all values of m. But this means that the expression in brackets in (9.45) is negative.

Thus, since $b\beta$ is less than 1, the right-hand side of (9.45) is everywhere negative: regardless of where it starts, the real money stock continually falls. The associated phase diagram is shown in Figure 9.9.[37] With the real money stock continually falling, money growth must be continually rising for the government to obtain the seignorage it needs (see [9.42]). In short, the government can obtain seignorage greater than S^*, but only at the cost of explosive inflation.

This analysis can also be used to understand the dynamics of the real money stock and inflation under gradual adjustment of money holdings when G is less than S^*. Consider the situation depicted in Figure 9.8. Sustainable seignorage, πm^*, equals G if inflation is either g_1 or g_2; it is greater than G if inflation is between g_1 and g_2; and it is less than G otherwise. The resulting dynamics of the real money stock implied by (9.45) for this case are shown in Figure 9.10. The steady state with the higher real money stock (and thus with the lower inflation rate) is stable, and the steady state with the lower money stock is unstable.[38]

This analysis of the relation between seignorage and inflation explains many of the main characteristics of high inflations and hyperinflations. Most basically, the analysis explains the puzzling fact that inflation often reaches

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[37]By differentiating (9.45) twice, it is straightforward to show that $d^2 \ln \dot{m}/(d \ln m)^2 < 0$, and thus that the phase diagram has the shape shown.

[38]Recall that this analysis depends on the assumption that $\beta < 1/b$. If this assumption fails, the denominator of (9.45) is negative. The stability and dynamics of the model are peculiar in this case. If $G < S^*$, the high-inflation equilibrium is stable and the low-inflation equilibrium is unstable; if $G > S^*$, $\dot{m} < 0$ everywhere, and thus there is explosive deflation. And with G in either range, an increase in G leads to a downward jump in inflation (to see this, note that [9.45] implies that the increase leads to an upward jump in $\dot{m}/m$; from [9.41], this means that π must jump down).

One interpretation of these results is that it is only because parameter values happen to fall in a particular range that we do not observe such unusual outcomes in practice. A more appealing interpretation, however, is that these results suggest that the model omits important features of actual economies. For example, if there is gradual adjustment of both real money holdings and expected inflation, then the stability and dynamics of the model are reasonable regardless of the adjustment speeds. More importantly, Ball (1993) and Cardoso (1991) argue that the assumption that Y is fixed at $\overline{Y}$ omits crucial features of the dynamics of high inflations (though not necessarily of hyperinflations). Ball and Cardoso develop models that combine seignorage-driven monetary policy with the standard Keynesian assumption that aggregate demand policies can reduce inflation only by temporarily depressing real output. They show that with this assumption, only the low-inflation steady state is stable. They then use their models to analyze a variety of aspects of high-inflation economies.

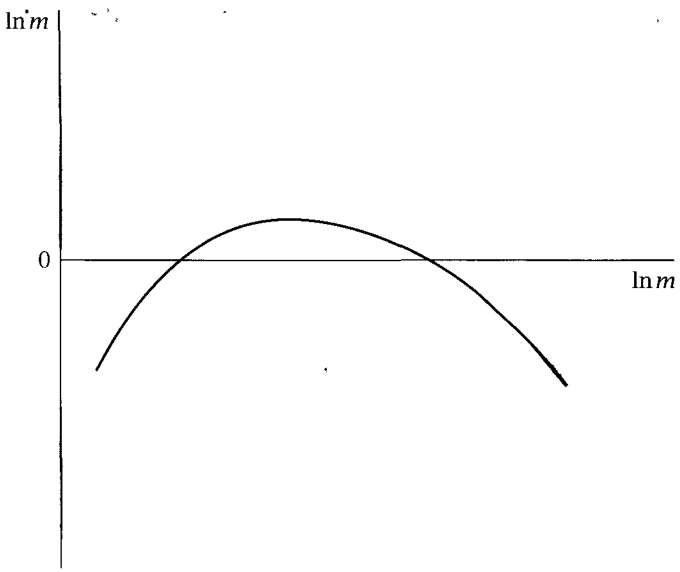

FIGURE 9.10 The dynamics of the real money stock when seignorage needs are sustainable

extremely high levels. The analysis also explains why inflation can reach some level—empirically, in the triple-digit range—without becoming explosive, but that beyond this level it degenerates into hyperinflation. In addition, the model explains the central role of fiscal problems in causing high inflations and hyperinflations, and of fiscal reforms in ending them (Sargent, 1982; Dornbusch and Fischer, 1986).

Finally, the central role of seignorage in hyperinflations explains how the hyperinflations can end before money growth stabilizes. As described in Section 9.2, the increased demand for real money balances after hyperinflations end is satisfied by continued rapid growth of the nominal money stock rather than by declines in the price level. But this leaves the question of why the public expects low inflation when there is still rapid money growth. The answer is that the hyperinflations end when fiscal and monetary reforms eliminate either the deficit or the government's ability to use seignorage to finance it, or both. At the end of the German hyperinflation of 1922–23, for example, Germany's World War I reparations were reduced, and the existing central bank was replaced by a new institution with much greater independence. Because of reforms like these, the public knows that the burst of money growth is only temporary (Sargent, 1982).[39]

[39]To incorporate the effects of the knowledge that the money growth is temporary into our formal analysis, we would have to let the change in real money holdings at a given time depend not just on current holdings and current inflation, but on current holdings and the entire expected path of inflation. See n. 36.

9.8 The Costs of Inflation

All of the analysis so far in this chapter assumes that inflation is costly, and that policymakers know what those costs are and how they vary with inflation. In fact, however, inflation's costs are not well understood.[40] There is a wide gap between the popular view of inflation and the costs of inflation that economists can identify. Inflation is intensely disliked. In periods when inflation is moderately high in the United States, for example, it is often cited in opinion polls as the most important problem facing the country. It appears to have an important effect on the outcome of Presidential elections, and it is blamed for a wide array of problems. Yet economists have difficulty in identifying substantial costs of inflation.

Easily Identifiable Costs of Inflation

In many models, steady inflation just adds an equal amount to the growth rate of all prices and wages and to the nominal interest rate on all assets; it therefore has no effects on relative prices, real wages, or real interest rates. It is this fact that makes it hard to identify large costs of inflation.

The only exception to the statement that steady inflation has no real effects in simple models is that, since high-powered money's nominal return is fixed at zero, inflation necessarily reduces its real return. This gives rise to the most easily identified cost of inflation. The increased gap between the rates of return on money and on other assets causes people to exert effort to reduce their holdings of high-powered money; for example, they make smaller and more frequent conversions of other assets into currency. Since high-powered money is essentially costless for the government to produce, these efforts have no social benefit. Thus they represent a cost of inflation.

These socially unproductive efforts to conserve on money holdings can be eliminated if inflation is chosen so that the nominal interest rate—and hence the opportunity cost of holding money—is zero. Since real interest rates are typically modestly positive, this requires slight deflation.[41]

It seems unlikely, however, that this is all there is to the costs of inflation. Most obviously, the *shoe-leather* costs associated with a positive nominal interest rate are surely small for almost all inflation rates observed in practice. Even if the price level is doubling each month, money is losing value only at a rate of a few percent per day; thus even in this case individuals will not incur extreme costs to reduce their money holdings.

[40]The uncertainty about inflation's costs and benefits raises the possibility that the seemingly high average inflation rates in most industrialized countries in recent decades are in fact optimal. If this is correct, there is not in fact any inflationary bias in monetary policy. We will not pursue this possibility.

[41]See, for example, Tolley (1957) and Friedman (1969).

A second readily identifiable cost of inflation is that nominal prices and wages must be changed more often, or indexing schemes must be adopted. Under natural assumptions about the distribution of relative-price shocks, the frequency of price adjustment is minimized with zero inflation. As Chapter 6 describes, however, the costs of price adjustment and indexation are almost certainly small.

The last cost of inflation that can be easily identified is that it distorts the tax system (see, for example, Feldstein, 1983). In most countries, income from capital gains and interest, and deductions for interest expenses and depreciation, are computed in nominal terms. As a result, inflation can have large effects on incentives for investment and saving. In the United States, the net effect of inflation through these various channels is to raise the effective tax rate on capital income substantially. In addition, inflation can significantly alter the relative attractiveness of different kinds of investment. For example, since the services from owner-occupied housing are generally not taxed and the income generated by ordinary business capital is, even without inflation the tax system encourages investment in owner-occupied housing relative to business capital. The fact that nominal interest payments are deductible from income causes inflation to exacerbate this distortion.

In contrast to the shoe-leather and menu costs of inflation, the costs of inflation through tax distortions may be large. Thus it is important for policymakers to account for these effects. At the same time, these distortions are probably not the source of the public's intense dislike of inflation. These costs are quite specific and could be overcome through indexation. Yet the dislike of inflation seems much broader.

Thus it appears that we must look further to understand the popular view of inflation. There are several ways that inflation may have large costs that are more subtle than the costs just described. Some of the potential costs occur when inflation is anticipated and steady; others arise only if inflation is more variable and less predictable when it is higher.

Other Costs of Steady Inflation

There are at least three ways that steady, anticipated inflation may have large costs. First, because individual prices are not adjusted continuously, even steady inflation causes variations in relative prices as different firms adjust their prices at different times. As a result, inflation increases the departures of relative prices from the values they would have under frictionless price adjustment. Okun (1975) and Carlton (1982) argue informally that this inflation-induced relative-price variability disrupts markets where firms and customers form long-term relationships and prices are not adjusted frequently. For example, it can make it harder for potential customers to decide whether to enter a long-term relationship, or for the parties to a long-term relationship to check the fairness of the price they are trading at by comparing it with other prices. Formal models suggest that inflation can have complicated effects on market structure, long-term relationships, and efficiency (for example, Benabou, 1988, 1992; Benabou and Gertner, 1993; Diamond, 1993; Tommasi, 1994; and Ball and D. Romer, 1993). This literature has not reached any consensus about the effects of inflation, but it does suggest some ways that inflation may have substantial costs. This literature also suggests that the immense disruptions associated with hyperinflations may just represent extreme versions of the effects of more moderate rates of inflation.

Second, individuals and firms may have trouble accounting for inflation (Modigliani and Cohn, 1979; Hall, 1984). Ten percent annual inflation causes the price level to rise by a factor of 45 in 40 years; even 3% inflation causes it to triple over that period. As a result, inflation can cause households and firms, which typically do their financial planning in nominal terms, to make large errors in saving for their retirement, in assessing the real burdens of mortgages, or in making long-term investments.

Finally, steady inflation may be costly not because of any real effects, but simply because people dislike it. People relate to their economic environment in terms of dollar values. They may therefore find large changes in dollar prices and wages disturbing even if they have no consequences for their real incomes. In Okun's (1975) analogy, a switch to a policy of reducing the length of the mile by a fixed amount each year might have few effects on real decisions, but might nonetheless cause considerable unhappiness. Since the ultimate goal of policy is presumably the public's well-being, such effects of inflation would represent genuine costs.

Costs of Variable Inflation

Empirically, inflation is more variable and less predictable when it is higher (see, for example, Okun, 1971; Taylor, 1981; and Ball and Cecchetti, 1990). Okun, Ball and Cecchetti, and others argue that the association arises through the effect of inflation on policy. When inflation is low, there is a consensus that it should be kept low, and so inflation is steady and predictable. When inflation is moderate or high, however, there is disagreement about the importance of reducing it; indeed, the costs of slightly more inflation may appear small. As a result, inflation is variable and difficult to predict.

If this argument is correct, the relationship between the mean and the variance of inflation represents a true effect of the mean on the variance. This implies some potentially important additional costs of inflation. First, since many assets are denominated in nominal terms, unanticipated changes in inflation redistribute wealth. Thus greater inflation variability increases uncertainty and lowers welfare. Second, with debts denominated in nominal terms, increased uncertainty about inflation may make firms and individuals reluctant to undertake investment projects, especially long-term ones.[42] And finally, highly variable inflation (or even higher average inflation alone) can also discourage long-term investment because firms and individuals view it as a symptom of a government that is functioning badly, and that may therefore resort to confiscatory taxation or other polices that are highly detrimental to capital-holders.

Empirically, there is a strong negative association between inflation and investment, and between inflation and growth (Fischer, 1991, 1993; Rudebusch and Wilcox, 1994). At this point, however, there is little evidence concerning whether these relationships are causal. It is not difficult to think of reasons that the associations might not represent true effects of inflation. In the short run, negative supply shocks are associated with both higher inflation and lower productivity growth. In the long run, governments that follow policies detrimental to growth—protectionism, large budget deficits, and so on—are likely to also pursue policies that result in inflation (Sala-i-Martin, 1991b).[43]

For high inflation rates, one can argue that the issue of whether the association between inflation and growth represents an effect of inflation on growth is of limited relevance. For a country to reduce inflation from very high levels, it is likely to need to adopt a broad range of budgetary and policy reforms. Thus growth is likely to rise, even though it may be the other reforms and not the reductions in inflation that bring it about.[44] In contrast, inflation can be reduced from moderate to low levels without fundamental policy reforms. Thus for moderate and low inflation, the issue of causation is crucial.

Potential Benefits of Inflation

So far we have considered only costs of inflation. But inflation can have benefits as well. Tobin (1972) observes that if it is particularly difficult for firms to cut nominal wages, real wages can make needed adjustments to sector-specific shocks more rapidly when inflation is higher. Summers (1991) notes that since nominal interest rates cannot be negative, low inflation (by causing usual nominal rates to be low) may limit the Federal Reserve's ability to stimulate aggregate demand in response to contractionary shocks. And just as inflation above some level can disrupt long-term planning and increase uncertainty, so too can inflation below some level. Given that average inflation has been significantly positive over the last several decades, it is not

[42]If these costs of inflation variability are large, however, there may be large incentives for individuals and firms to write contracts in real rather than nominal terms, or to create markets that allow them to insure against inflation risk. Thus a complete account of large costs of inflation through these channels must explain the absence of these institutions.

[43]Moreover, the estimates of Fischer and of Rudebusch and Wilcox suggest that at moderate inflation rates, a 1-percentage-point reduction in inflation is associated with roughly a 0.2-percentage-point increase in growth. This association is so large that it is difficult to identify plausible ways that it can represent an effect of inflation on growth.

[44]This argument is due to Allan Meltzer.

clear that zero inflation minimizes uncertainty and is least disruptive. Finally, as described above, inflation is a potential source of revenue for the government; under some conditions it is optimal for the government to use this revenue source in addition to more conventional taxes.

In addition, it is possible that the public's aversion to inflation represents not some deep understanding of the costs of inflation that has eluded economists, but a misapprehension. For example, Katona (1976) argues that the public perceives how inflation affects prices but not wages. Thus when inflation rises, individuals attribute only the faster growth of prices to the increase; they therefore incorrectly conclude that it has reduced their standard of living. Alternatively, individuals may dislike inflation just because times of high inflation are also times of low real growth; but if the high inflation is not in fact the source of the low growth, again inflation does not actually make them worse off.

Concluding Comments

As this discussion shows, research has not yet yielded any firm conclusions about the costs of inflation and the optimal rate of inflation. Thus economists and policymakers must rely on their judgment in weighing the different considerations. Loosely speaking, they fall into two groups. One group views inflation as pernicious, and believes that policy should focus on eliminating inflation and pay virtually no attention to other considerations. Members of this group generally believe that policy should aim for zero inflation or moderate deflation. The other group concludes that extremely low inflation is of little benefit, or perhaps even harmful, and believes that policy should aim to keep average inflation low to moderate but should keep other objectives in mind. The opinions of members of this group about the level of inflation that policy should aim for generally range from a few percent to close to 10 percent.

Problems

9.1. Consider a discrete-time version of the analysis of money growth, inflation, and real balances in Section 9.2. Suppose that money demand is given by $m_t - p_t = c - b(E_t p_{t+1} - p_t)$, where m and p are the logs of the money stock and the price level, and where we are implicitly assuming that output and the real interest rate are constant (see [9.36]).

(*a*) Solve for p_t in terms of m_t and $E_t p_{t+1}$.

(*b*) Use the law of iterated projections to express $E_t p_{t+1}$ in terms of $E_t m_{t+1}$ and $E_t p_{t+2}$.

(*c*) Iterate this process forward to express p_t in terms of m_t, $E_t m_{t+1}$, $E_t m_{t+2}$, ... (Assume that $\lim_{i\to\infty} E_t[\{b/(1+b)\}^i p_{t+i}] = 0$. This is a no-bubbles condition analogous to the one in Problem 7.7.)

(d) Explain intuitively why an increase in $E_t m_{t+i}$ for any $i > 0$ raises p_t.

(e) Suppose expected money growth is constant, so $E_t m_{t+i} = m_t + gi$. Solve for p_t in terms of m_t and g. How does an increase in g affect p_t?

9.2. Consider a discrete-time model where prices are completely unresponsive to unanticipated monetary shocks for one period and completely flexible thereafter. Suppose the *IS* and *LM* curves are $y = c - ar$ and $m - p = b + hy - ki$, where y, m, and p are the logs of output, the money supply, and the price level; r is the real interest rate; i is the nominal interest rate; and a, h, and k are positive parameters.

Assume that initially m is constant at some level, which we normalize to zero, and that y is constant at its flexible-price level, which we also normalize to zero. Now suppose that in some period—period 1 for simplicity—the monetary authority shifts unexpectedly to a policy of increasing m by some amount $g > 0$ each period.

(a) What are r, π^e, i, and p before the change in policy?

(b) Once prices have fully adjusted, $\pi^e = g$. Use this fact to find r, i, and p in period 2.

(c) In period 1, what are i, r, p, and the expectation of inflation from period 1 to period 2, $E_1[p_2] - p_1$?

(d) What determines whether the short-run effect of the monetary expansion is to raise or lower the nominal interest rate?

9.3. Assume, as in Problem 9.2, that prices are completely unresponsive to unanticipated monetary shocks for one period and completely flexible thereafter. Assume also that $y = c - ar$ and $m - p = b + hy - ki$ hold each period. Suppose, however, that the money supply follows a random walk: $m_t = m_{t-1} + u_t$, where u_t is a mean-zero, serially uncorrelated disturbance.

(a) Let E_t denote expectations as of period t. Explain why, for any t, $E_t[E_{t+1}[p_{t+2}] - p_{t+1}] = 0$, and thus why $E_t m_{t+1} - E_t p_{t+1} = b + h\bar{y} - k\bar{r}$.

(b) Use the result in part (a) to solve for y_t, p_t, i_t, and r_t in terms of m_{t-1} and u_t.

(c) Does the Fisher effect hold in this economy? That is, are changes in expected inflation reflected one-for-one in the nominal interest rate?

9.4. Suppose you want to test the hypothesis that the real interest rate is constant, so that all changes in the nominal interest rate reflect changes in expected inflation. Thus your hypothesis is $i_t = r + E_t \pi_{t+1}$.

(a) Consider a regression of i_t on a constant and π_{t+1}. Does the hypothesis that the real interest rate is constant make a general prediction about the coefficient on π_{t+1}? Explain. (Hint: for a univariate OLS regression, the coefficient on the right-hand-side variable equals the covariance between the right-hand-side and left-hand-side variables divided by the variance of the right-hand-side variable.)

(b) Consider a regression of π_{t+1} on a constant and i_t. Does the hypothesis that the real interest rate is constant make a general prediction about the coefficient on i_t? Explain.

(*c*) Some argue that the hypothesis that the real interest rate is constant implies that nominal interest rates move one-for-one with actual inflation in the long run—that is, that the hypothesis implies that in a regression of i on a constant and the current and many lagged values of π, the sum of the coefficients on the inflation variables will be 1. Is this claim correct? (Hint: Suppose that the behavior of actual inflation is given by $\pi_t = \rho\pi_{t-1} + e_t$, where e is white noise.)

9.5. Policy rules, rational expectations, and regime changes. (See Lucas, 1976, and Sargent, 1983.) Suppose that aggregate supply is given by the Lucas supply curve, $y_t = \bar{y} + b(\pi_t - \pi_t^e)$, $b > 0$, and suppose that monetary policy is determined by $m_t = m_{t-1} + a + \varepsilon_t$, where ε is a white-noise disturbance. Assume that private agents do not know the current values of m_t or ε_t; thus π_t^e is the expectation of $p_t - p_{t-1}$ given $m_{t-1}, \varepsilon_{t-1}, y_{t-1}$, and p_{t-1}. Finally, assume that aggregate demand is given by $y_t = m_t - p_t$.

(*a*) Find y_t in terms of m_{t-1}, m_t, and any other variables or parameters that are relevant.

(*b*) Are m_{t-1} and m_t all one needs to know about monetary policy to find y_t? Explain intuitively.

(*c*) Suppose that monetary policy is initially determined as above, with $a > 0$, and that the monetary authority then announces that it is switching to a new regime where a is zero. Suppose that private agents believe that the probability that the announcement is true is ρ. What is y_t in terms of m_{t-1}, m_t, ρ, $\bar{y}$, b, and the initial value of a?

(*d*) Using these results, describe how an examination of the money-output relationship might be used to measure the credibility of announcements of regime changes.

9.6. Regime changes and the term structure of interest rates. (See Blanchard, 1984; Mankiw and Miron, 1986; and Mankiw, Miron, and Weil, 1987.) Consider an economy where money is neutral. Specifically, assume that $\pi_t = \Delta m_t$ and that r is constant at zero. Suppose that the money supply is given by $\Delta m_t = k\Delta m_{t-1} + \varepsilon_t$, where ε is a white-noise disturbance.

(*a*) Assume that the rational-expectations theory of the term structure of interest rates holds (see [9.6]). Specifically, assume that the two-period interest rate is given by $i_t^2 = (i_t^1 + E_t i_{t+1}^1)/2$. i_t^1 denotes the nominal interest rate from t to $t+1$; thus, by the Fisher identity, it equals $r_t + E_t[p_{t+1}] - p_t$.

(*i*) What is i_t^1 as a function of Δm_t and k? (Assume that Δm_t is known at time t.)

(*ii*) What is $E_t i_{t+1}^1$ as a function of Δm_t and k?

(*iii*) What is the relation between i_t^2 and i_t^1; that is, what is i_t^2 as a function of i_t^1 and k?

(*iv*) How would a change in k affect the relation between i_t^2 and i_t^1? Explain intuitively.

(*b*) Suppose that the two-period rate includes a time-varying term premium: $i_t^2 = (i_t^1 + E_t i_{t+1}^1)/2 + \theta_t$, where θ is a white-noise disturbance that is independent of ε. Consider the OLS regression $i_{t+1}^1 - i_t^1 = a + b(i_t^2 - i_t^1) + e_{t+1}$.

(*i*) Under the rational-expectations theory of the term structure (with $\theta_t = 0$ for all t), what value would one expect for b? (Hint: for a univariate OLS regression, the coefficient on the right-hand-side variable equals the covariance between the right-hand-side and left-hand-side variables divided by the variance of the right-hand-side variable.)

(*ii*) Now suppose that θ has variance σ_θ^2. What value would one expect for b?

(*iii*) How do changes in k affect your answer to part (*ii*)? What happens to b as k approaches 1?

9.7. (Fischer and Summers, 1989.) Suppose inflation is determined as in Section 9.4. Suppose the government is able to reduce the costs of inflation; that is, suppose it reduces the parameter a in equation (9.9). Is society made better or worse off by this change? Explain intuitively.

9.8. Solving the dynamic-inconsistency problem through punishment. (Barro and Gordon, 1983b.) Consider a policymaker whose objection function is $\sum_{t=0}^{\infty} \beta^t (y_t - a\pi_t^2/2)$, where $a > 0$ and $0 < \beta < 1$. y_t is determined by the Lucas supply curve, (9.8), each period. Expected inflation is determined as follows. If π has equaled $\hat{\pi}$ (where $\hat{\pi}$ is a parameter) in all previous periods, then $\pi^e = \hat{\pi}$. If π ever differs from $\hat{\pi}$, then $\pi^e = b/a$ in all subsequent periods.

(*a*) What is the equilibrium of the model in all subsequent periods if π ever differs from $\hat{\pi}$?

(*b*) Suppose π has always been equal to $\hat{\pi}$, so $\pi^e = \hat{\pi}$. If the monetary authority chooses to depart from $\pi = \hat{\pi}$, what value of π does it choose? What level of its lifetime objective function does it attain under this strategy? If the monetary authority continues to choose $\pi = \hat{\pi}$ every period, what level of its lifetime objective function does it attain?

(*c*) For what values of $\hat{\pi}$ does the monetary authority choose $\pi = \hat{\pi}$? Are there values of a, b, and β such that if $\hat{\pi} = 0$, the monetary authority chooses $\pi = 0$?

9.9. Other equilibria in the Barro–Gordon model. Consider the situation described in Problem 9.8. Find the parameter values (if any) for which each of the following is an equilibrium:

(*a*) **One-period punishment.** π_t^e equals $\hat{\pi}$ if $\pi_{t-1} = \pi_{t-1}^e$ and equals b/a otherwise; $\pi = \hat{\pi}$ each period.

(*b*) **Severe punishment.** (Abreu, 1988, and Rogoff, 1987.) π_t^e equals $\hat{\pi}$ if $\pi_{t-1} = \pi_{t-1}^e$, equals $\pi_0 > b/a$ if $\pi_{t-1}^e = \hat{\pi}$ and $\pi_{t-1} \neq \hat{\pi}$, and equals b/a otherwise; $\pi = \hat{\pi}$ each period.

(*c*) **Repeated discretionary equilibrium.** $\pi = \pi^e = b/a$ each period.

9.10. Consider the situation analyzed in Problem 9.8, but assume that there is only some finite number of periods rather than an infinite number. What is the unique equilibrium? (Hint: reason backward from the last period.)

9.11. More on solving the dynamic-inconsistency problem through reputation. (This is based on Cukierman and Meltzer, 1986.) Consider a policymaker who is in office for two periods and whose objective function is $E[\sum_{t=1}^{2} b(\pi_t - \pi_t^e)+$

$c\pi_t - a\pi_t^2/2$]. The policymaker is chosen randomly from a pool of possible policymakers with differing tastes. Specifically, c is distributed normally over possible policymakers with mean $\overline{c}$ and variance $\sigma_c^2 > 0$. a and b are the same for all possible policymakers.

The policymaker cannot control inflation perfectly. Instead, $\pi_t = \hat{\pi}_t + \varepsilon_t$, where $\hat{\pi}_t$ is chosen by the policymaker (taking π_t^e as given) and where ε_t is normal with mean zero and variance $\sigma_\varepsilon^2 > 0$. ε_1, ε_2, and c are independent. The public does not observe $\hat{\pi}_t$ and ε_t separately, but only π_t. Similarly, the public does not observe c.

Finally, assume that π_2^e is a linear function of π_1: $\pi_2^e = \alpha + \beta\pi_1$.

(*a*) What is the policymaker's choice of $\hat{\pi}_2$? What is the resulting expected value of the policymaker's second-period objective function, $b(\pi_2 - \pi_2^e) + c\pi_2 - a\pi_2^2/2$, as a function of π_2^e?

(*b*) What is the policymaker's choice of $\hat{\pi}_1$ taking α and β as given and accounting for the impact of π_1 on π_2^e?

(*c*) Assuming rational expectations, what is β? (Hint: use the signal-extraction procedure described in Section 6.3).

(*d*) Explain intuitively why the policymaker chooses a lower value of $\hat{\pi}$ in the first period than in the second.

9.12. The tradeoff between low average inflation and flexibility in response to shocks with delegation of control over monetary policy. (Rogoff, 1985.) Suppose that output is given by $y = \overline{y} + b(\pi - \pi^e)$, and that the social welfare function is $\gamma y - a\pi^2/2$, where γ is a random variable with mean $\overline{\gamma}$ and variance σ_γ^2. π^e is determined before γ is observed; the policymaker, however, chooses π after γ is known. Suppose policy is made by someone whose objective function is $c\gamma y - a\pi^2/2$.

(*a*) What is the policymaker's choice of π given π^e, γ, and c?

(*b*) What is π^e?

(*c*) What is the expected value of the true social welfare function, $\gamma y - a\pi^2/2$?

(*d*) What value of c maximizes expected social welfare? Interpret your result.

9.13. (*a*) In the model of reputation analyzed in Section 9.5, is social welfare higher when the policymaker turns out to be a Type 1, or when he or she turns out to be a Type 2?

(*b*) In the model of delegation analyzed in Section 9.5, suppose that the policymaker's preferences are believed to be described by (9.23), with $a' > a$, when π^e is determined. Is social welfare higher if these are actually the policymaker's preferences, or if the policymaker's preferences in fact match the social welfare function, (9.9)?

9.14. Money versus interest-rate targeting. (Poole, 1970.) Suppose the economy is described by linear *IS* and *LM* curves that are subject to disturbances: $y = c - ai + \varepsilon_{IS}$, $m - p = hy - ki + \varepsilon_{LM}$, where ε_{IS} and ε_{LM} are independent, mean-zero shocks with variances σ_{IS}^2 and σ_{LM}^2, and where a, h, and k are positive. Policymakers want to stabilize output, but they cannot observe y or the shocks, ε_{IS} and ε_{LM}. Assume for simplicity that p is fixed.

(*a*) Suppose the policymaker fixes i at some level $\bar{i}$. What is the variance of y?

(*b*) Suppose the policymaker fixes m at some level $\overline{m}$. What is the variance of y?

(*c*) If there are only *LM* shocks (so $\sigma_{IS}^2 = 0$), does money targeting or interest-rate targeting lead to a lower variance of y?

(*d*) If there are only *IS* shocks (so $\sigma_{LM}^2 = 0$), does money or interest-rate targeting lead to a lower variance of y?

(*e*) Explain your results in parts (*c*) and (*d*) intuitively.

(*f*) When there are only *IS* shocks, is there a policy that produces a variance of y that is lower than either money or interest-rate targeting? If so, what policy minimizes the variance of y? If not, why not? (Hint: consider the *LM* curve, $m - p = hy - ki$.)

9.15. Uncertainty and policy. (Brainard, 1967.) Suppose output is given by $y = x + (k + \varepsilon_k)z + u$, where z is some policy instrument controlled by the government and k is the expected value of the multiplier for that instrument. ε_k and u are independent, mean-zero disturbances that are unknown when the policymaker chooses z, and that have variances σ_k^2 and σ_u^2. Finally, x is a disturbance that is known when z is chosen. The policymaker wants to minimize $E[(y - y^*)^2]$.

(*a*) Find $E[(y - y^*)^2]$ as a function of x, k,y^*, σ_k^2, and σ_u^2.

(*b*) Find the first-order condition for z, and solve for z.

(*c*) How, if at all, does σ_u^2 affect how policy should respond to shocks (that is, to the realized value of x)? Thus, how does uncertainty about the state of the economy affect the case for "fine tuning"?

(*d*) How, if at all, does σ_k^2 affect how policy should respond to shocks (that is, to the realized value of x)? Thus, how does uncertainty about the effects of policy affect the case for "fine tuning"?

9.16. Growth and seignorage, and an alternative explanation of the inflation-growth relationship. (Friedman, 1971.) Suppose that money demand is given by $\ln(M/P) = a - bi + \ln Y$, and that Y is growing at rate g_Y. What rate of inflation leads to the highest path of seignorage?

9.17. (Cagan, 1956.) Suppose that instead of adjusting their real money holdings gradually toward the desired level, individuals adjust their expectation of inflation gradually toward actual inflation. Thus equations (9.39) and (9.40) are replaced by $m(t) = Ce^{-b\pi^e(t)}$ and $\dot{\pi}^e(t) = \beta[\pi(t) - \pi^e(t)]$, $0 < \beta < 1/b$.

(*a*) Follow steps analogous to the derivation of (9.45) to find an expression for $\dot{\pi}^e(t)$ as a function of $\pi(t)$.

(*b*) Sketch the resulting phase diagram for the case of $G > S^*$. What are the dynamics of π^e and m?

(*c*) Sketch the phase diagram for the case of $G < S^*$.