THE OPTIMAL DEGREE OF COMMITMENT TO AN INTERMEDIATE MONETARY TARGET*

KENNETH ROGOFF

Society can sometimes make itself better off by appointing a central banker who does not share the social objective function, but instead places "too large" a weight on inflation-rate stabilization relative to employment stabilization. Although having such an agent head the central bank reduces the time-consistent rate of inflation, it suboptimally raises the variance of employment when supply shocks are large. Using an envelope theorem, we show that the ideal agent places a large, but finite, weight on inflation. The analysis also provides a new framework for choosing among alternative intermediate monetary targets.

I. INTRODUCTION

It is now widely recognized that even if a country has a perfectly benevolent central bank (one that attempts to maximize the social welfare function), it may suffer from having an inflation rate which is systematically too high.[1] Suppose, for example, that a distortion (such as income taxation) causes the market rate of employment to be suboptimal. Then inflation can arise because wage setters rationally fear that the central bank will try to take advantage of short-term nominal rigidities to raise employment systematically. Only by setting high rates of wage inflation can wage setters discourage the central bank from trying to reduce the real wage below their target level.

This paper considers some institutional responses to the time-consistency problem described above. In particular, we examine the practice of appointing "conservatives" to head the central bank, or of giving the central bank concrete incentives to achieve an intermediate monetary target. Our analysis of intermediate monetary targeting is quite different from conventional analyses in which the central bank is rigidly constrained to follow a particular feedback rule. Indeed, an important conclusion is that it is not generally optimal to legally constrain the central bank to hit its intermediate target (or follow its rule) exactly, or to choose

*I am indebted to Matthew Canzoneri, David Folkerts-Landau, Maurice Obstfeld, Michael Parkin, Alessandro Penati, Franco Spinelli, Lawrence Summers, Clifford Wymer, and to three anonymous referees for helpful comments on an earlier draft.

1. See, for example, Phelps [1967], Kydland and Prescott [1977], or Barro and Gordon [1983a,b].

The Quarterly Journal of Economics, November 1985 CCC 0033-5533/85/041169-21$04.00

"too" conservative an agent to head the central bank. By appointing a conservative or by providing the central bank with incentives to hit an intermediate monetary target, it is possible to induce less inflationary wage bargains. But this comes at the cost of distorting the central bank's responses to unanticipated disturbances, especially supply shocks. This is a cost because although the central bank cannot systematically raise employment (since private agents anticipate its incentives to inflate) monetary policy can still be used to stabilize inflation and employment around their mean market-determined levels.[2] Thus, rigid targeting is appropriate only in certain very special cases. It is important to stress that, while "flexible" monetary targeting is preferable to either fully discretionary monetary policy or rigid monetary targeting, it is not necessarily the first-best solution to the problem of stagflation in this model. That depends on the source of the underlying labor market distortion which causes the market-determined level of employment to be too low. If this distortion can be removed at low social cost, then it would be possible both to raise employment and to lower inflation. A second-best solution, which does nothing to raise the mean level of employment, would be to legally impose a complete state-contingent money supply rule. As is discussed in Section III, there are a number of problems inherent in designing such a rule. But it is only when the first- and second-best solutions are too costly or unachievable that monetary targeting (or appointing a "conservative" central banker) should be used as a "third-best" solution to the problem of stagflation.

Section II of the text describes a stochastic rational expectations macroeconomic model in which, because of wage contracting, there is a well-defined role for central bank stabilization policy. Section III derives the time-consistent equilibrium under fully discretionary monetary policy. Section IV shows how society can make itself better off by appointing as head of the central bank an agent whose dislike for inflation relative to unemployment is known to be stronger than average. Section V reinterprets the formal analysis of Section IV as a model of inflation-rate targeting, and demonstrates how to extend the framework to encompass nominal GNP targeting, money supply targeting, and nominal interest rate targeting. Section VI discusses comparisons

2. This follows from the assumption that there are nominal wage contracts. See, for example, Fischer [1977].

across regimes. Which target works best depends, of course, on the structure of the economy and the nature of the underlying disturbances. (Though we demonstrate that the interest rate is generally an unsatisfactory tool for precommitment.) In Section VII, the Conclusions, we stress the envelope-theorem interpretation of the main result: society wants the central bank to place "too large" a weight on inflation-rate stabilization relative to employment stabilization, but the weight should not be infinite.

II. THE MACROECONOMIC MODEL

Here we develop a stochastic rational expectations IS-LM model. Monetary policy can have short-term real effects in this model because nominal wage contracts are set a period in advance. Due to high administrative and negotiation costs, these contracts are not indexed fully against all possible disturbances.[3]

1. Aggregate Supply

Each of the large number of identical firms in the economy has a Cobb-Douglas production function. In the aggregate,

$$y_t = c_0 + \alpha\bar{k} + (1 - \alpha)n_t + z_t, \tag{1}$$

where y is output, $\bar{k}$ is the fixed capital stock, n is labor, c_0 is a constant term, and z is an aggregate productivity disturbance; $z \sim N(0,\sigma_z^2)$. Throughout, lowercase letters denote natural logarithms and subscript t denotes time. All coefficients are nonnegative. Firms hire labor until the marginal product of labor equals the real wage:

$$c_0 + \log(1 - \alpha) + \alpha\bar{k} - \alpha n_t^d + z_t = w_t - p_t, \tag{2}$$

where w is the nominal wage, p is the price level, and n^d is labor demand.

Labor supply n^s is an upward-sloping function of the real wage:

$$n_t^s = \bar{n} + \omega(w_t - p_t). \tag{3}$$

To simplify algebra without loss of generality, $\bar{n}$ is set equal to $\bar{k} + (1/\alpha)[\log(1 - \alpha) + c_0]$. As we shall later discuss, the above labor supply curve (3) is assumed to embody a distortion that

3. The aggregate demand specification is the same as in Canzoneri, Henderson, and Rogoff [1983]. The aggregate supply specification is based on Gray [1976].

raises the real wage required to induce a given level of labor supply.

The nominal wage rate for period t is negotiated (on a firm-by-firm basis) at the end of period $t - 1$. The nature of the employment contract is that laborers agree to supply whatever amount of labor is demanded by firms in period t, provided that firms pay the negotiated wage rate $\overline{w}_t$. The level of employment in period t is thus found by substituting $\overline{w}_t$ into equation (2):

$$n_t = \overline{n} + (p_t - \overline{w}_t)/\alpha + z_t/\alpha. \tag{4}$$

In choosing $\overline{w}_t$, wage setters seek to minimize $E_{t-1}(n_t - \overline{n}_t')^2$, where E_{t-1} denotes expectations based on period $t - 1$ information and $\overline{n}_t'$ is the level of employment that would arise if contracts could be negotiated after observing the productivity disturbance z_t and all other period t information. $\overline{n}_t'$ is found using the labor supply and demand equations (2) and (3):

$$\overline{n}_t' = \overline{n} + \omega z_t/(1 + \alpha\omega). \tag{5}$$

From equations (4) and (5),

$$n_t - \overline{n}_t' = z_t/\eta + (p_t - \overline{w}_t)/\alpha, \tag{6}$$

where $\eta \equiv \alpha(1 + \alpha\omega)$. It is clear from equation (6) that $E_{t-1}(n_t - \overline{n}_t')^2$ is minimized by setting $\overline{w}_t = E_{t-1}(p_t)$.[4] (The possibility of indexing wages to the price level will be discussed later.)

With equations (1) and (4), together with the analytically convenient normalization that $-c_0 = \alpha\overline{k} + (1 - \alpha)\overline{n}$ so that $E_{t-1}(y_t) = 0$, one can write the aggregate supply equation as

$$y_t^s = (1 - \alpha)(p_t - \overline{w}_t)/\alpha + z_t/\alpha, \tag{7}$$

It is very important to note that output and employment stabilization are not equivalent to price prediction error minimization in the presence of a productivity shock (z).

2. Aggregate Demand

Demand for the good that firms produce is a decreasing function of the real interest rate:

$$y_t^d = -\delta\{r - [E_t(p_{t+1}) - p_t]\} + u_t, \tag{8}$$

4. This is the first of many times throughout the paper where use is made of the fact that certainty equivalence holds when the loss function is quadratic; see Sargent [1979].

where r is the *level* of the nominal interest rate and $E_t(p_{t+1}) - p_t$ represents the rate of inflation expected by investors, based on complete period t information. The serially uncorrelated goods market demand disturbance is $u_t \sim N(0,\sigma_u^2)$; u may be viewed as a transitory shift in intertemporal consumption preferences.

The demand for real money balances is a decreasing function of the nominal interest rate and an increasing function of output:

$$m_t - p_t = -\lambda r_t + \phi y_t + v_t, \tag{9}$$

where m is the logarithm of the nominal money supply and v is a shift in portfolio preferences between money and bonds; $v \sim N(0,\sigma_v^2)$. To simplify exposition, the disturbances, v, u, and z, are assumed to be independent and serially uncorrelated.

3. *The Social Loss Function*

The principal differences between the present paper and previous rational expectations cum wage contracting analyses of monetary stabilization policy derive from the specification of the social objective function. Because most models embody the natural rate hypothesis, the issue of whether or not the central bank *wishes* it could lower the average level of employment is commonly ignored. But this potential source of tension is fundamental to the conduct of stabilization policy. Indeed, if there does not exist any temptation for the monetary authorities to inflate systematically, then there is no reason to consider any regime other than fully discretionary monetary policy. (Note that the central bank's incentives to inflate need not be motivated by employment considerations, but can also arise due to the presence of nominal government debt or short-term rigidities in the tax system.)

Here we shall assume that some factor such as income taxation or unemployment insurance distorts the labor-leisure decision and causes the market-determined level of employment $\bar{n}_t'$ to lie below the socially optimal level of employment $\tilde{n}_t'$ (see Barro and Gordon [1983a]). We shall further assume that $\tilde{n}_t' - \bar{n}_t'$ is constant and equal to $\tilde{n} - \bar{n}$.

The social loss function Λ depends on deviations of employment and inflation from their optimal (socially desired) levels:[5]

5. A similar social objective function is employed in Kydland and Prescott [1977] and Barro and Gordon [1983a]. Although the analysis below would have to be modified substantially if the central bank had a multiperiod objective function, the main points would still obtain.

$$\Lambda_t = (n_t - \tilde{n}_t')^2 + \chi(\pi_t - \tilde{\pi})^2, \tag{10}$$

where $\pi_t \equiv p_t - p_{t-1}$, $\tilde{\pi}$ is the socially desired trend inflation rate, and χ is the relative weight society places on inflation stabilization versus employment stabilization.

It is somewhat difficult, in the context of a rational expectations model, to argue that the level of the inflation rate has much direct weight in the social loss function.[6] (However, the analysis below does not depend on χ being particularly large.) The costs of inflation include the administrative costs of posting new prices and the costs of adjusting the tax system to be fully neutral with respect to inflation. And, of course, high rates of inflation force agents to economize on their holdings of non-interest-bearing money—the so-called "shoe leather cost of inflation." Despite the foregoing considerations, $\tilde{\pi}$ may be nonzero if alternative taxes to seignorage also generate deadweight costs through distortions (see Phelps [1973]).

III. Time-Consistent Equilibrium Under Fully Discretionary Monetary Policy

Here, stochastic equilibrium is derived under the assumption that the monetary authorities attempt to minimize the social loss function Λ, given by equation (10) above.

Expectations about the future path of the money supply are not exogenously given in this model, but depend endogenously on agents' expectations about the monetary authorities' future short-run stabilization objectives. Wage setters will not believe promised future paths for the money supply that are not time-consistent. Instead, equilibrium nominal wage increases are set at a sufficiently high level so that, in the absence of disturbances, the central bank will not choose to inflate the money supply beyond the point consistent with wage setters' desired real wage. At this high level of inflation, the central bank finds that the marginal gain from trying to raise employment above the natural rate is fully offset by the marginal cost of still higher inflation. Note also, that no individual group of wage setters has any incentive to change their wage bargain in the time-consistent equilibrium. Even though individual wage setters are concerned about infla-

6. Unanticipated inflation enters *indirectly* into the social loss function (10) through its effect on employment. Fischer and Modigliani [1978] catalog the economic costs of both anticipated and unanticipated inflation.

tion, the contract at their firm has only a small impact on the aggregate inflation rate.

By substituting equation (6) into equation (10), and recalling that $\tilde{n}' - \bar{n}' = \tilde{n} - \bar{n}$, the central bank's objective function under fully discretionary monetary policy may be written as

$$D_t = \Lambda_t = [z_t/\eta + (p_t - \overline{w}_t^D)/\alpha - (\tilde{n} - \bar{n})]^2 + \chi[p_t - p_{t-1} - \tilde{\pi}]^2, \tag{11}$$

where superscript D stand for "fully discretionary regime." The central bank maximizes social welfare by choosing a level of the money supply consistent with p_t^D, the period t price level that minimizes Λ_t:[7]

$$p_t^D = \left[\frac{\overline{w}_t^D}{\alpha^2} + \frac{\tilde{n} - \bar{n} - z_t/\eta}{\alpha} + \chi(p_{t-1} + \tilde{\pi})\right] \Big/ \left[\chi + (1/\alpha)^2\right]. \tag{12}$$

Recall that (the logarithm of) wage setters' target real wage is zero. Thus, wage setters select $\overline{w}_t^D$ by taking expectations across (12) and setting $\overline{w}_t^D = E_{t-1}(p_t^D)$:[8]

$$\overline{w}_t^D = E_{t-1}(p_t^D) = p_{t-1} + \tilde{\pi} + (\tilde{n} - \bar{n})/\chi\alpha = p_{t-1} + \overline{\pi}^D. \tag{13}$$

By choosing $\overline{w}_t^D$ according to (13), wage setters assure themselves that the monetary authorities will not systematically drive down the real wage. Thus, as Kydland and Prescott [1977] point out, the time-consistent rate of inflation is too high when $\tilde{n} > \bar{n}$.

We are now prepared to evaluate social welfare under fully discretionary monetary policy. But to facilitate exposition in later sections, we shall first develop a notation for evaluating the expected value of the social welfare function under any arbitrary monetary policy regime "A", Λ_t^A:

7. p_t^D is found by setting $\partial D_t/\partial p_t = 0$. The second-order conditions for a minimum are met; given the quadratic form of D, the minimum is global.

8. Investors can apply the same algorithm repeatedly to derive a time-consistent path for all future prices:

$$E_{t-1}(p_{t+s}^D) = (\tilde{n} - \bar{n})(s + 1)/\chi\alpha + (s + 1)\tilde{\pi} + p_{t+1}, \qquad s \geqq 0. \tag{8.1}$$

(For simplicity, we treat the monetary authorities' objective function as constant.) Note that we are treating the price level as if the monetary authorities controlled it directly, ignoring the fact that the central bank directly controls only the money supply. The anticipated future path of the money supply consistent with (8.1) may be found using the macro model of equations (7)–(9), together with the assumption of saddlepath stability. (For microeconomic justification of the saddlepath assumption in monetary models, see Obstfeld and Rogoff [1983].)

$$(14) \qquad \Lambda_t^A = (\tilde{n} - \bar{n})^2 + \chi\Pi^A + \Gamma^A,$$

where $\Pi^A \equiv (\bar{\pi}^A - \tilde{\pi})^2$ and

$$\Gamma^A \equiv E_{t-1}\{[z_t/\eta + (p_t^A - E_{t-1}(p_t^A))/\alpha]^2 + \chi[p_t^A - E_{t-1}(p_t^A)]^2\}$$

(we have made use of the fact that $E_{t-1}(p_t) = \bar{w}_t$). The first component of Λ_t^A is nonstochastic and invariant across monetary regimes. It represents the deadweight loss due to the labor market distortion. This loss cannot be reduced through monetary policy in a time-consistent rational expectations equilibrium. The second term depends on the difference between the expected rate of inflation and society's target rate. This term is also nonstochastic but does depend on the choice of monetary policy regime. The final term, Γ^A, represents the "stabilization" component of the loss function. It measures how successfully the central bank offsets disturbances to stabilize employment and inflation around their mean *market-determined* values.

We have already solved for the mean level of inflation under fully discretionary monetary policy $\bar{\pi}^D$; see equation (13). To derive Γ^D, first multiply both sides of equation (12) by $(E_t - E_{t-1})$, noting that $\bar{w}_t^D = E_{t-1}(p_t^D)$. This yields

$$(15) \qquad [p_t - E_{t-1}(p_t)]^D \equiv dp_t^D = -z_t/\eta[\alpha\chi + (1/\alpha)] \equiv \rho^D z_t.$$

Note that u and v do not enter the expression for the price prediction error that the central bank allows to occur. The central bank offsets the price level effects of aggregate demand shocks to the best of its ability (here perfect, because of the complete information assumption), because offsetting these shocks is consistent with both employment stabilization and inflation-rate stabilization. By substituting (15) into (14), and simplifying, one can obtain

$$(16) \qquad \Gamma^D = (\sigma_z^2/\eta^2)[\chi/(\chi + (1/\alpha)^2)].$$

It should be observed that an individual group of wage setters has little incentive to index positively to the price level under the fully discretionary regime. The monetary authorities fully offset the effects of demand shocks, and because inflation as well as employment enters the social objective function, they do not allow the price level to move *enough* to optimally offset the employment effects of aggregate supply shocks.

Obviously, a first-best solution to the stagflation problem described above would be to remove the labor market distortion. If this cannot be achieved at low social cost, a second-best solution would be to design a permanent constitutional reform that absolutely ruled out systematic inflation, and yet left the central bank scope to respond to disturbances. However, there are some practical drawbacks with constitutionally instituting a state-contingent money supply rule. To be fully effective, a rule must be set in place in such a way that it is very difficult to change. This, in turn, raises the danger that the rule will be difficult to alter after it becomes outmoded. Such problems might well arise because it is very difficult to predict the qualitative nature of the shocks buffeting the economy decades in advance. In the sixties, for example, it might have been difficult to anticipate the supply shocks of the seventies. Other factors such as innovations in transactions technology, regulatory changes, and the evolution of financial intermediaries all complicate the problem of designing a permanent monetary rule. (We are not suggesting that these problems are necessarily insurmountable.)

IV. Social Welfare Under a "Conservative" Central Banker

Here we consider an alternative, less drastic, response to the stagflation problem posed above. We demonstrate that society can make itself better off by selecting an agent to head the independent central bank who is known to place a greater weight on inflation stabilization (relative to unemployment stabilization) than is embodied in the social loss function Λ. The term of the agent need last only one period, though in a multiperiod setting, reputational considerations will further help ameliorate the central bank's time-consistency problems.[9] However, in choosing among potential candidates, it is never optimal to choose an individual who is known to care "too little" about unemployment, in a sense that will be made precise below.

Suppose, for example, that in period $t - 1$ society selects an agent to head the central bank in period t. The reputation of this individual is such that it is known that if he is appointed to head the central bank, he will maximize the following objective function (henceforth, time t subscripts are omitted where the meaning is obvious):

$$(17) \qquad I = (n - \tilde{n}')^2 + (\chi + \varepsilon)(\pi - \tilde{\pi})^2, \qquad \chi + \varepsilon > 0.$$

9. See Barro and Gordon [1983b], for example.

When ε is strictly greater than zero, then this agent places a greater relative weight on inflation stabilization than society does.

The algorithm for deriving the time-consistent equilibrium is exactly the same as in the previous section. Equations (18), (19), and (20) are the "I" regime counterparts of equations (13), (15), and (16), respectively:

$$\Pi^I = (\bar{\pi}^I - \tilde{\pi})^2 = [(\tilde{n} - \bar{n})/\alpha(\chi + \varepsilon)]^2, \tag{18}$$

$$[p_t - E_{t-1}(p_t)]^I = dp_t^I = -z_t/\eta[(1/\alpha) + \alpha\chi + \alpha\varepsilon], \tag{19}$$

$$\Gamma^I = (\sigma_z^2/\eta^2)[(\chi + \varepsilon)^2 + (\chi/\alpha^2)]/[(1/\alpha)^2 + \chi + \varepsilon]^2. \tag{20}$$

Note that Γ^I is obtained by plugging dp_t^I into Γ^A, as defined in equation (14). The regime should be evaluated on the basis of the expected value of the social loss function, not the expected value of the central banker's loss function. The reader can confirm that equations (18)–(20) are the same as (13), (15), and (16) when $\varepsilon = 0$. The expected value of the social loss function under regime "I" is

$$\Lambda^I = (\tilde{n} - \bar{n})^2 + \chi\Pi^I + \Gamma^I. \tag{21}$$

To solve for the value of ε that minimizes Λ^I, differentiate (21) with respect to ε:

$$\frac{\partial\Lambda^I}{\partial\varepsilon} = \chi\left(\frac{\partial\Pi^I}{\partial\varepsilon}\right) + \frac{\partial\Gamma^I}{\partial\varepsilon}, \tag{22a}$$

$$\frac{\partial\Gamma^I}{\partial\varepsilon} = 2\left(\frac{\sigma_z^2}{\eta^2}\right)\left[\left(\frac{\varepsilon}{\alpha^2}\right) \Big/ (\alpha^{-2} + \chi + \varepsilon)^3\right], \tag{22b}$$

$$\frac{\partial\Pi^I}{\partial\varepsilon} = -\frac{2[(\tilde{n} - \bar{n})/\alpha]^2}{(\chi + \varepsilon)^3}. \tag{22c}$$

Define $\varepsilon^{\min}$ as the value of ε that minimizes Λ^I.[10] We are now ready to prove:

THEOREM. For $\tilde{n} > \bar{n}$, $0 < \varepsilon^{\min} < \infty$.

Proof. Note that $\varepsilon > -\chi$ by assumption. Thus, by inspection of (22c), $\partial\Pi^I/\partial\varepsilon$ is strictly negative. Note also, by inspection of (22b), that $\partial\Gamma^I/\partial\varepsilon$ is strictly negative for $-\chi < \varepsilon < 0$, zero when $\varepsilon = 0$, and positive for $\varepsilon > 0$. Therefore, $\partial\Lambda^I/\partial\varepsilon$ is strictly negative for $\varepsilon \leqq 0$. $\partial\Lambda^I/\partial\varepsilon$ must change from negative to positive at some

10. Although it is extremely difficult to write down a closed-form solution for $\varepsilon^{\min}$, one can prove that $\varepsilon^{\min}$ is the unique positive real root of $\partial\Lambda^I/\partial\varepsilon = 0$, and therefore that Λ^I is concave in ε.

sufficiently large value of ε, since as ε approaches positive infinity, $\partial\Gamma^I/\partial\varepsilon$ converges to zero at rate ε^{-2}, whereas $\partial\Pi^I/\partial\varepsilon$ converges to zero at rate ε^{-3}. Therefore, $\varepsilon^{\min} < \infty$.

Q.E.D.

It follows immediately that for $\tilde{n} = \bar{n}$, $\varepsilon^{\min} = 0$. The Theorem states that in the presence of a labor market distortion, it is optimal to choose an agent to head the central bank who places a greater, but not infinitely greater, weight on inflation than society does. To interpret the Theorem intuitively, consider the effects of raising ε from zero. By increasing the central bank's commitment to fighting inflation, the time-consistent average rate of wage inflation is reduced. But the relative weight the central bank places on inflation versus employment stabilization is altered, and this distorts the monetary authorities' responses to unanticipated shocks. To see why the benefit outweighs the cost at $\varepsilon = 0$, it is suggestive to expand (22a) as follows:

$$\frac{\partial\Lambda^I}{\partial\varepsilon} = \left[\frac{\partial\Lambda^I}{\partial(\bar{\pi} - \tilde{\pi})^I}\right]\left[\frac{\partial(\bar{\pi} - \tilde{\pi})^I}{\partial\varepsilon}\right] + \frac{\partial\Gamma^I}{\partial\varepsilon}. \tag{23}$$

In the neighborhood of $\varepsilon = 0$, the monetary authorities are minimizing Γ^I (they are stabilizing optimally), so that $\partial\Gamma^I/\partial\varepsilon$ is zero. But inflation is not being minimized, so that neither term in $(\bar{\pi} - \tilde{\pi})$ is zero. We can argue similarly to suggest why $\varepsilon^{\min} < \infty$. As ε becomes large, $\bar{\pi}^I$ goes to $\tilde{\pi}$ and Π^I is being minimized. Thus, for large ε, the marginal inflation cost of reducing ε is small relative to the stabilization gain. Of course, when there is no labor market distortion, so that $\tilde{n} = \bar{n}$, then $\bar{\pi}^D = \tilde{\pi}$, and it does not pay to appoint a central banker who minimizes anything other than the social loss function.

We have assumed that the preferences of the agent appointed to head the central bank can be known with certainty. Clearly, many strategic problems arise when this assumption is relaxed. However, as long as there is some information on the probable preferences of alternative candidates, the basic point of the above analysis is still germane.[11] The model is certainly consistent with the fact that central bankers are typically chosen from conservative elements of the financial community. One incentive that the head of the central bank might have for holding down inflation

11. For an illustration of some issues that arise when the monetary authorities' preferences are unknown, see Backus and Driffill's [1985] interpretation of Kreps and Wilson's [1982] analysis.

is that he can thereby improve his standing in the financial community, and thus earn greater remuneration upon returning to the private sector.

V. Intermediate Monetary Targeting

In the previous section we demonstrated conditions under which society can make itself better off by appointing an individual to head the central bank who is (somewhat) more inflation-conscious than average. The same model can be employed to explain many of the measures that countries take to insulate their central banks from inflationary pressures. For example, central banks are often endowed with a significant measure of political and fiscal independence. The analysis also suggests why it would be desirable to have a central bank's operations financed in such a way that its expenditures are independent of the government's seignorage revenues. (It is interesting to observe that during the high inflation years of the late sixties and the seventies, architecturally stunning new Federal Reserve buildings sprouted up all over the United States.)

In some sense, the widespread adoption of intermediate monetary targeting during the seventies may be viewed as an institutional response to the time-consistency problem. Suppose, for example, that through a system of rewards and punishments the central bank's incentives are altered so that it places some direct weight on achieving a low rate of growth for a nominal variable such as the price level, nominal GNP, or the money supply. Although these alternative targets have different stabilization properties, credibly increasing the central bank's commitment to achieving any of them would reduce the time-consistent rate of inflation (as can be demonstrated along the lines of the Theorem in Section IV). A very direct way of making the commitment credible would be to tie the annual remuneration or budget of the monetary authorities to their success in hitting their intermediate monetary targets. This could perhaps be accomplished through a system of bonuses or by fixing their income in nominal terms. Other explicit penalties might include requiring the central bank to devote substantial resources to publicly justifying a deviation from its targets. An implicit penalty would be if the central bank's powers and independence are affected by how well it succeeds in hitting its stated targets. (Of course, if the central bank is already controlled by inflation-conscious forces, measures to reduce its independence could raise the time-consistent inflation rate.)

A. *Inflation-Rate (Price Level) Targeting*

Using the above interpretation of monetary targeting, we may view the analysis of Section IV as formally equivalent to an analysis of inflation-rate (price-level) targeting.[12] With this interpretation, the ε term in the central bank's objective function (17) measures the extra incentives (rewards or punishments) the central bank has for fulfilling its inflation-rate target. These incentives are additional to the fact that the inflation rate enters directly into the social objective function Λ.

In the absence of productivity disturbances, inflation-rate targeting works extremely well, since there is then no tradeoff with employment stabilization. Indeed, it would then make sense to make ε as large as possible; raising ε lowers the time-consistent inflation rate without placing any constraints on the ability of the monetary authorities to offset aggregate demand disturbances. If money supply changes transmit quickly into price level changes, then CPI targeting would be relatively easy to implement. The CPI is published monthly in many countries, and it would not be extraordinarily expensive to gather data at higher frequencies. The present model abstracts, however, from problems that arise if there are long lags in the monetary transmission mechanism.

If supply shocks are important, then it is natural to ask whether there are other intermediate targets that would allow the central bank to bring down the mean inflation rate at lower stabilization cost. We shall consider, in turn, nominal GNP targeting, money supply targeting, and interest rate targeting.

B. *Nominal GNP Targeting*

Because a positive supply shock tends to raise output and lower the price level, one would expect there to be some circumstances in which nominal GNP targeting is more appropriate than inflation-rate targeting. Suppose then that the central bank's target is nominal GNP so that its objective function is given by

12. Price-level targeting and inflation-rate targeting are equivalent here, since p_{t-1} is known at the time the central bank commits itself to achieving a target for $p_t - p_{t-1}$.

$$G = (n - \tilde{n}')^2 + \chi(\pi - \tilde{\pi})^2 + \tau(y_t + p_t - \bar{y} - p_{t-1} - \tilde{\pi})^2, \tag{24}$$

where G stands for "nominal GNP targeting regime," and the index parameter τ gives the weight that the central bank places on achieving its intermediate target relative to the weight it places on directly maximizing the social objective function Λ; $\bar{y}$ is the level of output corresponding to $n = \bar{n}$, and $z = 0$. The assumption that the central bank's nominal GNP target is consistent with the natural rate $\bar{n}$ rather than the socially optimal $\tilde{n}$ is nontrivial. It may be politically difficult for the central bank to commit to a nominal GNP target consistent with a level of employment lower than the socially optimal rate $\tilde{n}$. If $\bar{y}$ is replaced by $\tilde{y}$ in (24), the stabilization properties (Γ) of nominal GNP targeting would remain unchanged, but the mean inflation rate would be higher for any level of τ. In particular $\bar{\pi} - \tilde{\pi}$ will not converge to zero but to $(1 - \alpha)(\tilde{n} - \bar{n})$ as $\tau \rightarrow \infty$. This problem is not sufficient to reject nominal GNP targeting when the variance of supply shocks is large, but is an important drawback.

We can rewrite the objective function G by using equations (6) and (7):

$$G = \left[\frac{z_t}{\eta} + \frac{p_t - \overline{w}_t^G}{\alpha} - (\tilde{n} - \bar{n})\right]^2 + \chi[p_t - p_{t-1} - \tilde{\pi}]^2 + \tau\left[\frac{z_t}{\alpha} + (1 - \alpha)\left(\frac{p_t - \overline{w}_t^G}{\alpha}\right) + p_t - p_{t-1} - \tilde{\pi}\right]^2, \tau \geqq 0. \tag{25}$$

To find the time-consistent path of the economy under nominal GNP targeting, we again follow the algorithm of Section III:

$$\Pi^G = (\overline{\pi}^G - \tilde{\pi})^2 = (\tilde{n} - \bar{n})^2/[\tau + \chi\alpha]^2, \tag{26}$$

$$dp_t^G = - z_t[(\alpha/\eta) + \tau]/[1 + \tau + \alpha^2\chi] = \rho^G z_t, \tag{27}$$

$$\Gamma^G = \frac{\sigma_z^2 \{[(\chi\alpha^2/\eta) - (\tau\alpha\omega/\eta)]^2 + \chi[\alpha/\eta + \tau]^2\}}{(1 + \tau + \alpha^2\chi)^2}. \tag{28}$$

As in the case of inflation-rate targeting, one can prove that $0 < \tau^{\min} < \infty$.[13] Nominal GNP targeting and fully discretionary monetary policy always imply the same response to aggregate

13. The fact that $0 < \tau^{\min} < \infty$ may be demonstrated analogously to the Theorem in Section IV. A simpler proof makes use of the fact that Γ^A is minimized at $\rho^A = \rho^D$, and that Γ^A is strictly increasing in $|\rho^A - \rho^D|$.

demand disturbances; in both cases the central bank tries to stabilize the price level. The response to supply shocks is in general different. However, if wages are indexed to unanticipated movements in the price level (so that $w_t = \overline{w} + \beta(p_t - \overline{w}_t)$, $0 \leqq \beta \leqq 1$), then there does exist one special parameter configuration such that fixing nominal GNP is exactly what the monetary authorities would do if unconstrained. Obviously, $\tau^{\min} = \infty$ in this case.[14]

C. Money-Supply Targeting

Because the formal analysis of money-supply targeting is quite similar to that of the preceding sections, we shall focus only on the special features of this case. The central bank's objective function under money-supply targeting is assumed to be given by

$$(29) \quad M = (n - \tilde{n}') + \chi(\pi - \tilde{\pi})^2 + \mu(m_t - \tilde{m}_t)^2, \qquad \mu \geqq 0,$$

where $\tilde{m}_t = \tilde{\pi} + p_{t-1} + \lambda\overline{\pi}^M$; superscript M denotes the money-supply targeting regimes. Employing the macro model of equations (7)–(9), one can demonstrate that the target level of the money supply $\tilde{m}_t$ is the level of m_t that would be consistent with society's desired inflation rate $\tilde{\pi}$ provided that (a) there are no disturbances in period t, and (b) $\overline{\pi}^M$ is the expected inflation rate between periods t and $t + 1$.

The fact that the demand for money is interest elastic creates some problems in selecting an appropriate level for $\tilde{m}_t$. In setting $\tilde{m}_t$, the central bank needs to form an estimate at time $t - 1$ of $\overline{\pi}_{t+1}$, which depends in turn on the policy regime expected to prevail in period $t + 1$. Here we have assumed that everyone expects the same money-supply targeting regime to remain in place. Because the nominal contract rigidities last only one period, this assumption is not crucial. It is crucial, however, that the central bank's money supply target be set at a level consistent with market expectations of $\overline{\pi}_{t+1}$. If the central bank were to set $\tilde{m}$ optimistically under the assumption that $E_t(\pi_{t+1}) = \tilde{\pi}$, it would overestimate the demand for real balances and choose too high a level of $\tilde{m}$. Choosing a target level for $\tilde{m}$ that is too high would not affect the stabilization properties of money-supply targeting, but would raise the time-consistent inflation rate for any level of μ. This problem with medium-term money-supply targeting is

14. $\tau^{\min} = \infty$ if $(1 - \beta)^2 + \alpha^2\chi = (1 - \beta)(1 + \alpha\beta - \beta)/(\alpha\omega + 1)$. Note that if $\beta = \omega = 0$, then rigid nominal GNP targeting is equivalent to employment targeting.

quite similar to the problem with medium-term nominal GNP targeting discussed earlier.

Equation (29) can be rewritten with p_t as the central bank's control variable by using equations (7)–(9) to substitute out for m_t:

$$(30)\quad m_t = -\lambda\bar{\pi}^M + \xi p_t + (1-\xi)\bar{w}_t^M - (\lambda/\delta)u_t + (\xi - 1)z_t/(1-\alpha) + v_t,$$

where $\xi \equiv 1 + [(1-\alpha)/\alpha](\lambda/\delta + \phi)$. By substituting into equation (29) using equations (30) and (6), one obtains

$$(31)\quad M = \left[\frac{z_t}{\eta} + \frac{p_t - \bar{w}_t^M}{\alpha} - (\tilde{n} - \bar{n})\right]^2 + \chi[p_t - p_{t-1} + \tilde{\pi}]^2 + \mu\left[\xi p_t + (1-\xi)\bar{w}_t^M - (\lambda/\delta)u_t + (\xi - 1)\left(\frac{z_t}{1-\alpha}\right) + v_t - p_{t-1} - \tilde{\pi}\right]^2.$$

As before, one can demonstrate that $0 < \mu^{\min} < \infty$, except in the special case where there are no aggregate demand shocks ($\sigma_u^2 = \sigma_v^2 = 0$), and one special parameter configuration obtains.[15] In this special case $\rho^M = \rho^D$, and $\mu^{\min} = \infty$. (An infinite μ is equivalent to a k percent rule.) Monetary targeting then can lower the mean rate of inflation to its socially optimal level without any stabilization cost. The condition that the aggregate demand shocks be zero can be relaxed when the monetary authorities have incomplete contemporaneous information.[16]

D. Nominal Interest Rate Targeting

The monetary authorities cannot systematically raise or lower the mean value of the real interest rate in the rational expectations model employed in this paper. But it might seem reasonable for the central bank to try to bring down the inflation rate by committing itself to achieving a low nominal interest rate.[17] Here

15. The condition for $\mu^{\min} = \infty$ is that

$$(1 + \alpha^2\chi)(\xi^2 - \xi)(1 + \alpha\omega) = \xi^2(1 - \alpha).$$

16. An appendix to an earlier version of this paper discusses how to extend the present analysis to the case of incomplete contemporaneous information. This appendix and details of the proofs concerning $\mu^{\min}$ and $\tau^{\min}$ are available from the author on request.

17. As Canzoneri et al. [1983] demonstrate, the central bank can only literally peg the nominal interest rate if it also announces at least one point on a mutually consistent money supply path; otherwise the price level is indeterminate.

we argue that this method of intermediate monetary targeting is counterproductive.

Consider the objective function,

$$R = (n - \tilde{n}')^2 + \chi(\pi - \tilde{\pi})^2 + \theta(r - \tilde{r})^2, \qquad 0 \leqq \theta < \infty, \tag{32}$$

where $\tilde{r}$ is the nominal interest rate target. Using equations (6)–(8), we may write the objective function (32) as

$$R = \left[\frac{z_t}{\eta} + \left(\frac{p_t - \overline{w}_t^R}{\alpha}\right) - (\tilde{n} - \overline{n})\right]^2 + \chi(p_t - p_{t-1} - \tilde{\pi})^2$$
$$+ \theta\left[\overline{\pi}_{t+1}^A + \left(\frac{1-\alpha}{\delta\alpha}\right)(\overline{w}_t^R - p_t) + \left(\frac{u_t - z_t/\alpha}{\delta}\right) - \tilde{r}\right]^2. \tag{33}$$

As we shall see, the value of $\overline{\pi}_{t+1}^A \equiv E_t(p_{t+1}^A) - p_t$ is crucial to the analysis; it depends on the monetary policy regime expected to prevail in period $t + 1$. Following the algorithm of Section III for deriving the time consistent equilbrium, one obtains

$$\overline{\pi}^R - \tilde{\pi} = [(\tilde{n} - \overline{n}) + (\theta(1 - \alpha)/\delta)(\overline{r}_{t+1}^A - \tilde{r})]/\alpha\chi, \tag{34}$$

where $\overline{r}_{t+1}^A$ has been substituted in for $\overline{\pi}_{t+1}^A$. (Given the assumptions we have made about the parameters of the macro model, the mean real interest rate under any monetary regime is zero.)

A comparison of equations (13) and (33) reveals that $\overline{\pi}^R \gtreqless \overline{\pi}^D$ as $\tilde{r} \lesseqgtr \overline{r}_{t+1}^A$. In other words, suppose that an intermediate targeting regime is put in place for one period, and the central bank is given incentives to bring interest rates below their trend rate, so that $\tilde{r} < \overline{r}_{t+1}^A$. Then, instead of falling, the expected inflation rate and expected nominal interest rate rise. They rise because wage setters recognize that *once wages are set,* the central bank can lower interest rates through money growth. While it is true that the central bank could try to bring down inflation by setting $\tilde{r}$ greater than $\overline{r}_{t+1}^A$, the fact that this would indeed cause the market-determined interest rate $\overline{r}_t$ to be less than $\overline{r}_{t+1}^A$ suggests a serious credibility problem. The central bank has to target high interest rates if it wants low interest rates.

The underlying problem is that given $E_{t-1}(p_{t+1} - p_t)$, announcing a target for r_t is, in fact, tantamount to targeting the real interest rate. For the regimes analyzed earlier, targeting succeeds in at least temporarily lowering the inflation rate regardless of how long the targeting regime is expected to last. This is no longer true when the nominal interest rate is used as a target.[18] (It should be clear that a misguided attempt to target a low real interest rate will produce similar problems.)

The nominal interest rate would not appear to be a suitable instrument for precommitment. This conclusion, of course, does not imply that the interest rate should not be used as an information variable in setting monetary policy, as in Poole [1970].

VI. On Comparing Alternative Targeting Regimes

In more traditional analyses of intermediate monetary targeting, a conventional result is that the optimal target choice depends on all the parameters of the model as well as on the relative sizes of the disturbances.[19] While one must also consider strategic factors in the more general model developed here, the standard stabilization considerations are still relevant. For example, money-supply targeting makes less sense when the monetary authorities have information about how aggregate demand shocks are affecting the price level. Inflation-rate targeting works poorly when supply shocks are significant, etc. Indeed, if we were to restrict our attention to "rigid" targeting regimes (that is, if the monetary authorities are required to hit their target exactly), then (of course) the ranking of regimes depends only on these conventional stabilization considerations (see the Appendix).

Ranking the optimally flexible regimes of Section V is somewhat more difficult because they do not have tractable closed-form solutions. (For specific parameter values, numerical comparisons are easily obtained.) It is worth noting, however, that the ranking of optimally flexible regimes is not necessarily the same as the ranking of "rigid" regimes presented in the Appendix.[20] This is not surprising in view of the "second-best" nature of the rigid targeting regimes; it is almost never optimal to constrain the monetary authorities to hit their target exactly.

18. It can be shown that low nominal interest rate targeting is counterproductive when the regime is expected to last for any finite number of periods, as long as the expected inflation rate in the final period is consistent with a return to fully discretionary monetary policy. The regime fails because the central bank cannot systematically achieve a below-market real interest rate for any future period.

19. See Poole [1975], Friedman [1975], or Parkin [1978] for analyses of the stabilization properties of alternative intermediate monetary targets.

20. Numerical examples of rank reversal are presented in an earlier version of this paper, available on request. Numerical solutions for $\tau^{\min}$ are easier to obtain when $\partial\Lambda^{G}/\partial\tau$ is strictly concave in τ. Using Descartes' Law of Signs, one can derive the sufficient condition $1/(\alpha - \alpha^2) > \chi$. Similarly, $\partial\Lambda^{M}/\partial\mu$ is definitely concave in μ if $[\phi + (\lambda/\delta)]/(\alpha - \alpha^2) > \chi$.

VII. Conclusions

It can be entirely rational for society to structure its central bank in such a way that the monetary authorities have an objective function very different from the social welfare function. Whenever a distortion causes the time-consistent rate of inflation to be too high, then society can be made better off by having the central bank place "too large" a weight on inflation rate stabilization. The model presented here may help explain why many countries set up an independent central bank and choose its governors from conservative elements of the financial community.

Although society does want the central bank to place a large weight on inflation rate stabilization relative to employment stabilization, society will not (in general) want the weight to be infinite. By having the central bank place an infinite weight on inflation stabilization, society could succeed in bringing inflation down to its socially optimal level. But the central bank would also end up responding very inappropriately to supply shocks, allowing them to pass entirely through to employment. By lowering the weight which the central bank places on inflation, society could achieve a first-order stabilization gain at a second-order inflation cost. However, the inflation weight should not be so low that the central bank is placing the same weight on inflation-stabilization as society does. For then the central bank would be stabilizing optimally and by raising the central bank's weight on inflation, it would be possible to achieve a first-order inflation gain at a second-order stabilization cost (by the envelope theorem).

When supply shocks are important, society may prefer to give the central bank incentives to focus on a monetary target other than the inflation rate (though again, it is not optimal to have the weight on the target be infinite). It might be expected that the best monetary target would be the one most highly correlated with the society's ultimate objective function. But while this is a useful rule of thumb, the situation is actually somewhat more complicated. If one compares how each of the targets would work if used rigidly, one does not necessarily get the same ranking as when the central bank gives its target an optimal weight relative to direct social objectives. Thus, it can be misleading to analyze separately the stabilization and credibility problems of the central bank. The model also highlights strategic problems that can arise in setting targets at a non-inflationary level. If the central bank sets its nominal GNP target consistent with the socially optimal rate of employment, rather than the lower natural rate (perhaps because of political constraints), then nominal GNP targeting will have an inflationary bias. Money supply targeting presents similar problems if the demand for money is interest elastic. The central bank will overestimate next period's demand for money if it assumes (or is constrained to assume) that *next* period's expected inflation rate will be at the socially desired rate, rather than at the higher time-consistent rate. (This problem does not arise under a permanent k percent rule.) We demonstrated that targeting low nominal interest rates is counterproductive and actually raises the time-consistent inflation rate. The problem is that once nominal wages are set, interest rates fall as money growth rises. Real interest rate targeting presents similar problems.

In order to make the macroeconomic model rich enough to do a meaningful analysis of alternative intermediate monetary targets, it was necessary to choose a rather simple game-theoretic structure. In particular, we did not allow for reputational factors that can be important in a multiperiod setting.[21] However, although reputational considerations can ameliorate the central bank's credibility problems, they do not eliminate them except in certain very special cases. Therefore, the main point of this paper should extend to a more dynamic setting.

APPENDIX

Equations (A1) through (A4) give the expected value of the social loss function (10) under fully discretionary monetary policy, and rigid inflation rate, nominal GNP and money-supply targeting (the common term $(\tilde{n} - \overline{n})^2$ is omitted):

$$\text{(A1)} \qquad \Lambda^D = \left(\frac{\sigma_z^2}{\eta^2}\right)\left[\frac{\alpha^2\chi}{1 + \alpha^2\chi}\right] + \chi\left[\frac{\tilde{n} - \overline{n}}{\alpha\chi}\right]^2,$$

$$\text{(A2)} \qquad \Lambda^I|_{\varepsilon=\infty} = \frac{\sigma_z^2}{\eta^2},$$

$$\text{(A3)} \qquad \Lambda^G|_{\tau=\infty} = \sigma_z^2\left[\left(\frac{1}{\eta}\right)^2 + \left(\frac{1}{\alpha}\right)^2 + \chi - \frac{2}{\alpha\eta}\right],$$

21. See Barro and Gordon [1983b], Backus and Driffill [1985], or Canzoneri [1985].

$$\text{(A4)} \qquad \Lambda^M|_{\mu=\infty} = \sigma_z^2\left[\left(\frac{1}{\eta^2}\right) + \left(\frac{1}{\alpha^2} + \chi\right)J^2 - \frac{2J}{\alpha\eta}\right] + \left[\frac{1}{\alpha^2} + \chi\right]\left[\sigma_v^2 + \left(\frac{\lambda}{\delta}\right)^2\sigma_u^2\right]\Big/\xi^2,$$

where $J \equiv (\xi - 1)/(1 - \alpha)\xi$.

UNIVERSITY OF WISCONSIN—MADISON

REFERENCES

Backus, David, and John Driffill, "Inflation and Reputation," *American Economic Review,* LXXV (1985), 530–38.
Barro, Robert J., and David B. Gordon, "A Positive Theory of Monetary Policy in a Natural-Rate Model," *Journal of Political Economy,* XCI (Aug. 1983a), 589–610.
——, and ——, "Rules, Discretion and Reputation in a Model of Monetary Policy," *Journal of Monetary Economics,* XII (July 1983b), 101–21.
Canzoneri, Matthew B., Dale W. Henderson, and Kenneth Rogoff, "The Information Content of the Interest Rate and Optimal Monetary Policy," this *Journal,* XCVIII (Nov. 1983), 545–66.
Canzoneri, Matthew B., "Monetary Policy Games and the Role of Private Information," *American Economic Review,* LXXV (1985), forthcoming.
Fischer, Stanley, "Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule," *Journal of Political Economy,* LXXXV (Feb. 1977), 191–206.
——, and Franco Modigliani, "Towards an Understanding of the Real Effects and Costs of Inflation," *Weltwirtschaftliches Archiv,* CXIV (1978), 810–33.
Friedman, Benjamin M., "Targets, Instruments, and Indicators of Monetary Policy," *Journal of Monetary Economics,* I (Oct. 1975), 443–73.
Gray, Jo Anna, "Wage Indexation: A Macroeconomic Approach," *Journal of Monetary Economics,* II (April 1976), 221–35.
Kreps, David, and Robert Wilson, "Reputation and Imperfect Information," *Journal of Economic Theory,* XXVII (Aug. 1982), 253–79.
Kydland, Finn E., and Edward C. Prescott, "Rules Rather than Indiscretion: The Inconsistency of Optimal Plans," *Journal of Political Economy,* LXXXV (June 1977), 473–92.
Obstfeld, Maurice, and Kenneth Rogoff, "Speculative Hyperinflations in Maximizing Models: Can We Rule Them Out?" *Journal of Political Economy,* XCI (Aug. 1983), 675–87.
Parkin, Michael, "A Comparison of Alternative Techniques of Monetary Control under Rational Expectations," *The Manchester School,* XI (Sept. 1978), 252–87.
Phelps, Edmund S., "Phillips Curves, Expectations of Inflation and Optimal Employment Over Time," *Economica,* XXXIV (Aug. 1967), 254–81.
——, "Inflation in the Theory of Public Finance," *Swedish Journal of Economics,* LXXV (March 1973), 68–82.
Poole, William, "Optimal Choice of Monetary Instruments in a Simple Stochastic Macro Model," this *Journal,* LXXXIV (May 1970), 197–216.
Sargent, Thomas J., *Macroeconomic Theory* (New York: Academic Press, 1979).