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A POSITIVE THEORY OF MONETARY POLICY IN A NATURAL-RATE MODEL

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ABSTRACT

Natural-rate models suggest that the systematic parts of monetary policy will not have important consequences for the business cycle. Nevertheless, we often observe high and variable rates of monetary growth, and a tendency for monetary authorities to pursue countercyclical policies. This behavior is shown to be consistent with a rational expectations equilibrium in a discretionary environment where the policymaker pursues a "reasonable" objective, but where precommitments on monetary growth are precluded. At each point in time, the policymaker optimizes subject to given inflationary expectations, which determine a Phillips Curve-type tradeoff between monetary growth/inflation and unemployment. Inflationary expectations are formed with the knowledge that policymakers will be in this situation. Accordingly, equilibrium excludes systematic deviations between actual and expected inflation, which means that the equilibrium unemployment rate ends up independent of "policy" in our model. However, the equilibrium rates of monetary growth/inflation depend on various parameters, including the slope of the Phillips Curve, the costs attached to unemployment versus inflation, and the level of the natural unemployment rate. The monetary authority determines an average inflation rate that is "excessive," and also tends to behave countercyclically. Outcomes are shown to improve if a costlessly operating rule is implemented in order to precommit future policy choices in the appropriate manner. The value of these precommitments--that is, of long-term agreements between the government and the private sector--underlies the argument for rules over discretion. Discretion is the sub-set of rules that provides no guarantees about the government's future behavior.

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The primary puppose of this paper is to develop a positive theory of monetary/inflation policy. The conclusions accord with two perceptions about the world for recent years:

1) average rates of inflation and monetary growth are excessive relative to an efficiency criterion, and
2) there is a tendency to pursue activist, countercyclical monetary/inflation policies.

Yet, the model exhibits three other properties:

3) the unemployment rate (real economic activity) is invariant with monetary/inflation policy (neglecting the familiar deadweight-loss aspect of inflation),
4) the policymaker and the public all act rationally, subject to their environments, and
5) the policymaker's objectives reflect the "public's" preferences.[1]

Natural-rate models with rational expectations--such as Sargent and Wallace (1975)--suggest that the systematic parts of monetary policy are irrelevant for real economic activity. Some empirical evidence on the real effects of monetary disturbances in the post-World War II U.S. (e.g., Barro, 1977, 1981) is consistent with this result--in particular, there is some support for the proposition that anticipated monetary changes are neutral with respect to output, unemployment, etc. On the other hand, these empirical studies and others indicate the presence of countercyclical monetary policy at least for the post-World War II U.S.--rises in the unemployment rate appear to generate subsequent expansions in monetary growth. Within the natural-rate framework, it is difficult to reconcile this observed countercyclical monetary behavior with rationality of the policymaker.[2] A principal objective of this analysis is to achieve this reconciliation.

The natural-rate models that have appeared in the macroeconomics literature of the last decade share the characteristic that policy choice is over a class of prespecified monetary rules. With the policy rule predetermined, there is no scope for ongoing policymaking; discretionary policy choice is excluded a priori. If private agents can deduce the characteristics of the monetary process once it is implemented, it defines their expectations. Thus, the policy decision is made subject to the constraint that agents' expectations of future monetary policy will equal the realization. This framework has the advantage of allowing the analysis to be reduced to a pair of single-agent decision problems, which can be considered independently, but excludes consideration of the essentially game-theoretic situation that arises when policy decisions are made on an ongoing basis.

In our framework an equilibrium will include the following features:

(a) a decision rule for private agents, which determines their actions as a function of their current information,

b) an expectations function, which determines the expectations of private agents as a function of their current information,

and

c) a policy rule, which specifies the behavior of policy instruments as a function of the policymaker's current information set.

The outcome is said to be a rational expectations equilibrium if first, the decision rule specified in (a) is optimal for agents given their expectations as calculated under (b), and second, it is optimal for the policymaker, whose actions are described by (c), to perform in accordance with agent's expectations (b), given that the policymaker recognizes the form of the private decision rules under (a). Faced by a maximizing policymaker, it would be unreasonable for agents to maintain expectations from which they know it will be in the policymaker's interest to deviate.

If policy is precommited, the only reasonable expectations that agents can hold are those defined by the rule. But, if policy is sequentially chosen, the equality of policy expectations and realizations is a characteristic of equilibrium--not a prior constraint. The question to be addressed is then what expectations can agents hold that they can reasonably expect to be realized.

The policymaker is viewed as attempting to maximize an objective that reflects "society's" preferences on inflation and unemployment (or output). (Additional arguments for the preference function are introduced later.) Although the equilibrium involves a path of unemployment that is invariant with policy, the rational policymaker adopts an activist rule. The extent of countercyclical response is dictated, among other things, by society's relative dislikes for inflation and unemployment. There is an apparent contradiction because an activist policy is pursued that ends up having no desirable effects--in fact, unemployment is unaltered but inflation ends up being excessive. This outcome reflects the assumed inability of the policymaker--that is, of the institutional apparatus that is set up to manage monetary affairs--to precommit its course of future actions. This feature has been stressed in an important paper by Kydland and Prescott (1977). If precommitment were feasible through legal arrangements or other procedures, the countercyclical aspect of monetary/inflation policy would disappear (and, abstracting from costs of erecting and maintaining institutions, everyone would be better off). When this type of advance restriction is precluded, so that the policymaker sets instruments at each date subject only to the initial conditions prevailing for that date (which do not include restraints on policy choices), the equilibrium may involve an activist form of policy. This solution conforms to optimal behavior of private agents subject to a rationally anticipated policy rule. It corresponds also to optimality for the policymaker each period, subject to agents' decision rules. Although an equilibrium obtains, the results are sub-optimal, relative to outcomes where precommitment is permitted. Given an environment where this type of policy precommitment is absent--as appears to characterize the U.S. and other countries in recent years--the results constitute a positive theory of monetary growth and inflation.

1. The Model of Unemployment and Inflation

The general results are illustrated by a simple economic model, which is based on an example that was set out by Kydland and Prescott (1977, pp. 477-80) and extended in Gordon (1980). The unemployment rate U_t, which is a convenient proxy for the overall state of real activity, equals a "natural rate," U_t^n, plus a term that depends negatively on contemporaneously unexpected inflation, $\pi_t - \pi_t^e$,

$$(1) \qquad U_t = U_t^n - \alpha(\pi_t - \pi_t^e), \ \alpha > 0.$$

For convenience, the "Phillips-Curve slope" parameter, α, is treated as a constant.[3] Given the relevant inflationary expectations, π_t^e, equation (1) is assumed to reflect the maximizing behavior of private agents on decentralized markets. The formulation of π_t^e is detailed below. Equation (1) could be reformulated without changing the main conclusions by expressing U_t as a reduced-form function of monetary shocks.

The natural unemployment rate can shift over time due to autonomous real shocks, ε_t. A single real disturbance is allowed to have a persisting influence on unemployment, output, etc. This behavior is modeled as

$$(2) \qquad U_t^n = \lambda U_{t-1}^n + (1-\lambda)\overline{U^n} + \varepsilon_t, \quad 0 \leq \lambda \leq 1,$$

where ε_t is independently, identically distributed with zero mean. If $0 < \lambda < 1$ applies, then the realization for ε_t affects future natural unemployment rates in the same direction. For example, for the one-period-ahead forecast, $E(U_t | I_{t-1}) = \lambda U_{t-1}^n + (1-\lambda)\overline{U^n}$, where I_{t-1} denotes date t-1 information, which includes the observation of U_{t-1}^n. The effect of ε_t on future natural unemployment rates dissipates gradually over time--equation (2) implies that the long-run mean of the natural unemployment rate is $\lim_{i \to \infty} E(U_{t+i}^n | I_{t-1}) = \overline{U^n}$, a constant. For convenience, U_t in equation (1) is assumed to depend only on contemporaneously unexpected inflation, $\pi_t - \pi_t^e$, and not on lagged values. These additional terms could be introduced without changing the main results (see below).

The policymaker's (and society's) objective for each period is summarized by cost, Z_t, that depends on that period's values for the unemployment rate and inflation. A simple quadratic form is assumed:

$$(3) \qquad Z_t = a(U_t - kU_t^n)^2 + b(\pi_t)^2; \quad a, b > 0; \; 0 \leq k \leq 1.$$

This paper does not consider any divergence across individuals in their assessments of relative costs for unemployment and inflation.

The first term in equation (3) indicates that costs rise with the departure of U_t from a "target" unemployment rate, kU_t^n, which depends positively on the contemporaneous natural rate. In the absence of external effects, k = 1 would correspond to an efficiency criterion--that is, departures of U_t from U_t^n in either direction would be penalized. In the presence of unemployment compensation, income taxation and the like, U_t^n will tend to exceed the efficient level--that is, privately-chosen quantities of marketable output and employment will tend to be too low. The inequality, k < 1, captures this possibility.[4] Not surprisingly, k < 1 is a necessary condition for activist policy to arise in the present model.

Governmental decisions on taxes and transfers will generally influence the value of k. However, given that some government expenditures are to be carried out, it will generally be infeasible to select a fiscal policy that avoids all distortions and yields k = 1. We assume that the government's optimization on the fiscal side--which we do not analyze explicitly--results in a value of k that satisfies 0 < k < 1. The choice of monetary policy is then carried out conditional on this value of k.

Equation (3) regards departures of π_t from zero as generating costs. We do not offer explanations here for the sources of these costs due to inflation. However, the form could be modified to $(\pi_t - \bar{\pi}_t)^2$, where $\bar{\pi}_t$ might involve the optimal rate of taxation on cash balances. A later section expands the analysis to consider the revenue from money creation.

The policymaker is assumed to control an instrument--say, monetary growth, μ_t--which has a direct connection to inflation, π_t, in each period. This specification neglects any dynamic relation between inflation and monetary growth or a correlation between $(\pi_t - \mu_t)$ and the real disturbances, ϵ_t, ϵ_{t-1}, ... In effect, the analysis is simplified by pretending that the policymaker chooses π_t directly in each period. A later section expands the analysis to allow a separation between inflation and monetary growth.

The choice of π_t at each date is designed to minimize the expected present value of costs, as calculated at some starting date 0,

$$(4) \qquad \text{Minimize} \qquad E[\sum_{t=1}^{\infty} Z_t/(1+r)^t]|I_0,$$

where I_0 represents the initial state of information and r is a constant, exogenous real discount rate. It should be stressed that the policymaker's objective conforms with society's preferences.

The determination of inflation and unemployment can be characterized as a "game" between the policymaker and a large number of private-sector agents. The structure of this game is as follows. The policymaker enters period t with the information set, I_{t-1}. The inflation rate, π_t, is set based on I_{t-1} in order to be consistent with the cost-minimization objective that is set out in equation (4). Simultaneously, each individual formulates expectations, π_t^e, for the policymaker's choice of inflation for period t. These expectations are assumed to be based on the same information set, I_{t-1}, as that available to the policymaker. Most importantly, in forming inflationary expectations, people incorporate the knowledge that π_t will emerge from the policymaker's cost-minimization problem that is specified in equation (4). Finally, the choices for π_t and π_t^e, together with the random disturbance, ε_t, determine U_t and the cost, Z_t, in accordance with equations (1)--(3).

The Expectations Mechanism

In order to determine π_t^e, agents must consider the policymaker's optimization problem, which determines the choice of π_t. Suppose for the moment that the policymaker when selecting π_t treats π_t^e and all future values of inflationary expectations, π_{t+i}^e, as given. Variations in π_t will affect U_t through the usual Phillips-curve mechanism in equation (1). As the model is set out, this effect would not carry forward to direct effects on future unemployment rates, although this channel of persistence could be incorporated. The current choice of inflation, π_t, is assumed also to imply no direct constraints on future policy choices, π_{t+i}. Therefore, with current and future inflationary expectations held fixed, the determination of π_t involves only a one-period tradeoff between higher inflation and lower unemployment in accordance with the cost function of equation (3).

In the present framework the determination of π_t^e is divorced from the particular realization of π_t. At the start of period t, agents form π_t^e by forecasting the policymaker's "best" action, contingent on the information set, I_{t-1}. The expectation, π_t^e, is not conditioned on π_t itself. Therefore, the policymaker (possessed with "free will") faces a choice problem in which π_t^e is appropriately held fixed while π_t is selected. Further, in formulating π_t^e, the private agents understand that the policymaker is in this position.

The connection between π_t and future inflationary expectations, π^e_{t+i}, is less clear. As noted above, the present model allows for no direct connection between π_t (even with π^e_t held fixed) and future "objective" characteristics of the economy. There is also no scope for learning over time about the economy's structure; in particular, π_t supplies no additional information about the objective or technology of the policymaker. Accordingly, one would be inclined to search for an equilibrium in which π^e_{t+i} did not depend on "extraneous" past variables, such as π_t. However, the severing of a link beween π_t and π^e_{t+i} eliminates some possibly interesting equilibria in which the government can invest in its reputation--that is, in "credibility." The nature of these solutions is discussed later. For present purposes we examine situations in which future expectations, π^e_{t+i}, are invariant with π_t.

Given that future values of U and π^e are independent of π_t, there is no channel for π_t to affect future costs, Z_{t+i}. Therefore, the objective posed in equation (4) reduces to the one-period problem of selecting π_t in order to minimize $E_{t-1}Z_t$.

In a solution to the model the public will view the policymaker as setting π_t in accordance with the information set, I_{t-1}, which is available at the start of period t. Suppose that people perceive this process as described by the reaction function, $h^e(I_{t-1})$.[5] Therefore, inflationary expectations--formed on the basis of I_{t-1}--would be given by[6]

(5) $$\pi^e_t = h^e(I_{t-1}).$$

A solution to the model involves finding a function $h^e(\cdot)$, such that setting $\pi_t = h^e(I_{t-1})$ is a solution to the policymaker's cost-minimization problem, <u>given</u> that $\pi^e_t = h^e(I_{t-1})$. Expecting inflation as specified by $h^e(\cdot)$

must not contradict the policymaker's minimization of expected costs, as set out in equation (3). The previous discussion suggests that lagged values of inflation will not appear as parts of the solution, $h^e(\cdot)$. That is, we are looking for an equilibrium where $\partial\pi^e_t/\partial\pi_{t-i} = \partial h^e/\partial\pi_{t-i} = 0$ applies for all $i > 0$. We also look for a solution where the policymaker understands that π^e_t is generated from equation (5).

The unemployment rate is determined from equation (1) after substitution for U^n_t from equation (2) and for π^e_t from equation (5) as

$$(6) \qquad U_t = \lambda U^n_{t-1} + (1-\lambda)\overline{U^n} + \varepsilon_t - \alpha[\pi_t - h^e(I_{t-1})].$$

Costs for period t are determined by substituting for U_t and π^e_t in equation (3) as

$$(7) \qquad Z_t = a\{(1-k)[\lambda U^n_{t-1} + (1-\lambda)\overline{U^n} + \varepsilon_t] - \alpha[\pi_t - h^e(I_{t-1})]\}^2 + b(\pi_t)^2.$$

Given that inflationary expectations for period t are $\overline{\pi}^e_t = \overline{h}^e(I_{t-1})$, the policymaker will select π_t in order to minimize $E_{t-1}Z_t$, where Z_t appears in equation (7). The first-order condition, $\frac{\partial}{\partial\pi_t}(E_{t-1}Z_t) = 0$, implies that the chosen inflation rate, denoted by $\hat{\pi}_t$, will satisfy the condition,

$$(8) \qquad \hat{\pi}_t = \frac{a\alpha}{b}\{-\alpha[\hat{\pi}_t - h^e(I_{t-1})] + (1-k)[\lambda U^n_{t-1} + (1-\lambda)\overline{U^n}]\}.$$

The property, $E(\varepsilon_t|I_{t-1}) = 0$, has been used here. The second-order condition for a minimum is satisfied.

Although the policymaker is not constrained to follow the anticipated rule, $h^e(I_{t-1})$, the public is assumed to understand the nature of the policymaker's optimization problem in each period. In particular, it is understood that the actual choice, $\hat{\pi}_t$, will satisfy equation (8). Therefore, rationality entails using equation (8) in order to calculate $h^e(I_{t-1})$ in equation (5). Consistency requires $h^e(I_{t-1}) = \hat{\pi}_t$. The unexpected inflation term, $\hat{\pi}_t - h^e(I_{t-1})$, then cancels out in equation (8), which leads to the formula for the expectations function,

$$(9) \qquad \pi_t^e = h^e(I_{t-1}) = \frac{a\alpha}{b}(1-k)[\lambda U_{t-1}^n + (1-\lambda)\overline{U^n}] = \frac{a\alpha}{b}(1-k)E_{t-1}U_t^n.$$

Equilibrium Policy

By the construction of the problem, a policymaker who faces the expectations given in equation (9) will be motivated from the first-order condition of equation (8) to choose an inflation rate, $\hat{\pi}_t$, that coincides with π_t^e. Therefore, the equilibrium involves

$$(10) \qquad \hat{\pi}_t = \frac{a\alpha}{b}(1-k)E_{t-1}U_t^n = \pi_t^e.$$

Since $\hat{\pi}_t = \pi_t^e$, $U_t = U_t^n$ applies also as part of the equilibrium.

Equation (10) provides an equilibrium (Nash equilibrium) in the following sense. Given the public's equilibrium perceptions, $\pi_t^e = h^e(\cdot)$, minimization of $E_{t-1}Z_t$ (for a given value of π_t^e) induces the policymaker to choose $\hat{\pi}_t = h^e(\cdot)$ in each period.[7] Expectations are rational and individuals optimize subject to these expectations (as summarized in equations (1) and (2)).

In order to provide perspective on the present framework, it us useful to consider an alternative manner in which the policymaker's choice problem could have been formulated. Policy could have been viewed as the once-and-for-all choice of reaction function, $h(\cdot)$, so that $\pi_t^e = h^e(\cdot) = h(\cdot)$

would hold automatically in every period for all choices of $h(\cdot)$. This perspective is suggested, for example, from the analysis of macropolicy in Sargent and Wallace (1975). In this setting the choice of the function, $h(\cdot)$, affects not only π_t, but also π_t^e in each period. The independence of π_t^e from π_t is necessarily broken in the context of a once-and-for-all selection of policy functions. The condition, $\pi_t - \pi_t^e = \pi_t - h^e(I_{t-1}) = 0$, could then have been substituted into equation (7). In particular, with π_t^e guaranteed to move one-to-one with changes in π_t, the policymaker would have regarded unemployment, $U_t = U_t^n$, as invariant with $h(\cdot)$. Given the simple objective from equation (3), which penalizes departures of π_t from zero, the choice of $h(\cdot)$ that minimizes EZ_t for all periods would then be a variant of the constant-growth-rate-rule,[8]

$$\pi_t^* = h(I_{t-1}) = 0. \tag{11}$$

Note that $U_t = U_t^n$ obtains again as part of this solution.

Given the public's perceptions, $\pi_t^e = h^e(I_{t-1})$, U_t depends on the term, $\pi_t - \pi_t^e = \pi_t - h^e(I_{t-1})$. It has been observed (Taylor (1975), Friedman (1979)) that the policymaker can fool the public and reduce unemployment ("temporarily") by setting $\pi_t > \pi_t^e = h^e(I_{t-1})$ in period t. This possibility is ruled out in the case where a once-and-for-all choice of $h(\cdot)$ is made. However, there may be no mechanism in place to constrain the policymaker to stick to the rule, $h(I_{t-1})$, as time evolves. This consideration leads to the setup for policy choice that has been assumed above--namely, for given initial conditions at each date, including the expectations mechanism, $\pi_t^e = h^e(I_{t-1})$, set π_t in order to minimize $E_{t-1}Z_t$. The policymaker is not required to select an inflation rate to equal the given expected inflation rate. However, people also realize that the policymaker has the power to fool them at each date. Since the formation of expectations takes this potential for deception into account, a full equilibrium will ultimately involve $\pi_t = \pi_t^e$. The crucial point is that--unlike for a once-and-for-all choice of policy rules--the policymaker does not regard $\pi_t = \pi_t^e$ as occurring automatically for all possible choices of π_t. For this reason the (non-cooperative) equilibrium does not correspond to equation (11).

Compare the equilibrium solution, $\hat{\pi}_t$ from equation (10), with the choice, $\pi_t^* = 0$, that would arise from a once-and-for-all selection of policy rules. The equilibrium solution delivers the same unemployment rate and a higher rate of inflation at each date. Therefore, the equilibrium cost, $\hat{Z}_t$, exceeds that, Z_t^*, which would arise under the precommitted rule. (Note that, with U_t the same in both cases, costs end up depending only on the path of the inflation rate.) Of course, this conclusion neglects any costs of setting up or operating the different institutional environments. Notably, the costs involved in enforcing precommitments are excluded. With this cost neglected, the present type of result provides a normative argument (and positive theory?) for policy rules--that is, for precommitment on future choices of π_t. This aspect of the results is highlighted later.

It may be useful to demonstrate directly that $\pi_t = 0$ is not an equilibrium for the case where the policymaker optimizes subject to given expectations in each period. Conjecture that $\pi_t^e = h^e(I_{t-1}) = 0$ holds. In this case the choice of $\pi_t > 0$ would reduce unemployment for period t. A tradeoff arises between reduced costs of unemployment and increased costs from inflation. The balancing of these costs determines the chosen inflation rate, as shown in equation (8). Under the assumed conditions (marginal cost of inflation is zero at $\pi_t = 0$ and marginal benefit from reduced unemployment is positive when $U_t = U_t^n$), the selected inflation rate will be positive. However, since people are assumed to understand this policy choice, the result $\pi_t > 0$ is inconsistent with the conjecture that $\pi_t^e = 0$. Zero inflation is not a reasonable expectation for individuals to hold.

An analogous argument can be used to find the positive rate of inflation that does provide an equilibrium. If a small positive value for π_t^e had been conjectured, the policymaker would still have been motivated to select $\pi_t > \pi_t^e$, which would be inconsistent with equilibrium. The equilibrium obtains when π_t^e is sufficiently high, so that $\pi_t = \pi_t^e$ is the policymaker's best choice, given this value of π_t^e. At this point the policymaker retains the option of choosing $\pi_t > \pi_t^e$ (or $\pi_t < \pi_t^e$) so as to accomplish a tradeoff between lower unemployment and higher inflation (or vice versa). However, the level of π_t^e is sufficiently high so that the marginal cost of inflation just balances the marginal gain from reducing unemployment.[9] The inflation rate that corresponds to this equilibrium condition is given in equation (10).

Suppose that precommitment on policy choice is absent, so that optimization occurs on a period-by-period basis, as we have been assuming. Under this "discretionary" regime, the solution for $\hat{\pi}_t$ in equation (10) constitutes a positive theory of inflation (and monetary growth). The major implications are as follows:

1) The average inflation rate exceeds the value (zero in this model) that would be optimal if policy precommitment were feasible. Therefore, an exogenous shift from a regime that involved some precommitment on nominal

values--such as a gold standard or possibly a system with fixed exchange rates--to one without such restraints would produce a rise in the average rate of inflation (and monetary growth).

2) Within a discretionary regime, an increase in the long-run average value of the natural unemployment rate, $\overline{U^n}$, raises the average rate of inflation (and monetary growth). A significant rise in $\overline{U^n}$ is generally thought to have occurred in the U.S. over the last 10-15 years.

3) Under a discretionary policy, the inflation rate (monetary policy and aggregate demand management more generally) responds positively to the lagged unemployment rate. (The positive correlation of U_{t-1} with U_t--that is, $\lambda > 0$--is crucial here). The rational policymaker acts countercyclically. In a larger model it would be possible to distinguish the countercyclical response of monetary growth (which seems empirically to be important) from that of inflation--however, these two variables are directly linked in the present model. See the analysis below.

4) The extent of countercyclical response rises with α--the Phillips-Curve slope parameter in equation (1)--and the relative value of the cost-coefficients, a/b, attached to unemployment versus inflation.

The results listed under 3) and 4) are the sorts of normative implications for aggregate demand policy that are delivered by Keynesian models in which policymakers can exploit a systematic (possibly dynamic) tradeoff between inflation and unemployment. However, in the present model

5) unemployment, $U_t = U_t^n$, is invariant with the systematic part of inflation.[10] In this sense policy ends up with no effect on real economic activity.

It has been argued that policymakers do not face a "cruel choice" between inflation and unemployment in a natural-rate environment. This argument is misleading in a context where monetary institutions do not allow for policy choice to be precommitted. Although $U_t = U_t^n$ emerges in equilibrium--that is, unemployment is invariant with policy in this sense--policymakers do optimize in each period subject to the appropriate givens, which include the formation of expectations. <u>Given these expectations</u>, the choice of π_t does influence the unemployment rate "right now"--that is, for date t. The social tradeoff between unemployment and inflation, as expressed by the preference ratio, a/b, is central to the policymaker's decision.[11] No cruel choice arises and $\pi_t = 0$ follows only if the policymaker can precommit future actions. Within the present model, this outcome is infeasible. Counselling stable prices (or constant and small rates of monetary growth) in this environment is analogous to advising firms to produce more output with given inputs. Policymakers in a discretionary regime really are finding the optimal policy, subject to the applicable constraints, when they determine a countercyclical inflation/monetary reaction with positive average rates of inflation.

2. Monetary Growth as the Policy Instrument

We develop a simple model to illustrate some consequences of treating monetary growth, rather than inflation, as the policy instrument. Real balances held, M_t/P_t, are assumed to be directly proportional to period t's real output, which equals $(1 - U_t)$ times a constant. That is, $(1 - U_t)$ is viewed as the fraction of a fixed "potential output" that is actually produced. Real money demanded depends inversely on expected inflation, π_t^e. We use the functional form,

$$(12) \qquad M_t/P_t = A(1-U_t)e^{-\beta\pi_t^e} e^{-\phi_t},$$

where $\beta > 0$, $A > 0$ is a constant, and ϕ_t is a stochastic term. Taking first differences of logarithms, writing $v_t = \phi_t - \phi_{t-1}$ as the stochastic shift to velocity, and approximating $\log(1-U_t) \approx -U_t$ yields a relation between money growth and inflation,

$$(13) \qquad \mu_t \approx \pi_t - (U_t - U_{t-1}) - \beta(\pi_t^e - \pi_{t-1}^e) - v_t.$$

We treat v_t as a white-noise error, which is independent of the real shock, ε_t.

Suppose that the policymaker determines the mean of monetary growth for period t as $\tilde{\mu}_t$, but the actual growth, μ_t, differs from $\tilde{\mu}_t$ by the random error, μ_t^R. We treat μ_t^R as a white-noise error, which is independent of ε_t and v_t.

Using the expressions for U_t from equations (1) and (2) and the condition from equation (13), the inflation rate can be written as

$$(14) \qquad \pi_t \approx \tilde{\mu}_t + \mu_t^R + v_t + \varepsilon_t - (1-\lambda)\varepsilon_{t-1} - \lambda(1-\lambda)(U_{t-2}^n - \overline{U^n})$$

$$- \alpha(\pi_t - \pi_t^e) + \alpha(\pi_{t-1} - \pi_{t-1}^e) + \beta(\pi_t^e - \pi_{t-1}^e).$$

The inflation rate equals the growth rate of money and its velocity, $\tilde{\mu}_t + \mu_t^R + v_t$, plus terms that measure the negative growth rate of output, $U_t - U_{t-1}$, plus a term that captures the effect on velocity of a change in expected inflation. In particular, the current (adverse) supply shock, ε_t, appears as a positive influence on π_t.

Given π_t^e, equation (14) can be solved for π_t in the form,

$$\pi_t \approx (\text{adjusted monetary instrument})_t + (\text{white-noise error})_t$$

$$(15) \quad = \frac{1}{(1+\alpha)}[\tilde{\mu}_t - (1-\lambda)\varepsilon_{t-1} - \lambda(1-\lambda)(U_{t-2}^n - \overline{U^n}) + \alpha\pi_t^e + \alpha(\pi_{t-1} - \pi_{t-1}^e) + \beta(\pi_{t-1}^e - \pi_{t-1}^e)]$$

$$+ \frac{1}{(1+\alpha)}(\mu_t^R + v_t + \varepsilon_t).$$

The adjusted monetary instrument modifies the controlled part of money growth, $\tilde{\mu}_t$, to account for the additional inflationary effects that are known and taken as given by the policymaker at the start of period t. (The effects of the given expectation, π_t^e, are included in this term.) These added inflationary effects arise via the money-demand function from either the anticipated movement in the unemployment rate (and, hence, in output) or from the change in expected inflation. The adjusted instrument equals the policymaker's forecast for π_t, given $\tilde{\mu}_t$ and π_t^e. The white-noise error term in equation (15) is regarded by all agents at the start of the t^{th} period as distributed with zero mean and a given variance. (The effect of $\mu_t^R + v_t + \varepsilon_t$ on π_t is less than one-to-one because of the inverse effect of $\pi_t - \pi_t^e$ on U_t.) The error term determines the difference between π_t and the policymaker's beginning-of-period forecast for inflation.

The cost, Z_t, for period t is still given in equation (7). Rather than π_t being chosen directly by the policymaker, as it was in the original setup, there are two differences now: first, π_t is determined indirectly by the value of the adjustment monetary instrument for period t, as noted in equation (15), and second, π_t can be influenced only up to the uncontrollable random term that is shown also in equation (15). If this random term were absent, the model would coincide with the previous framework once the substitution of the new variable, (adjusted monetary instrument)$_t$, were made for π_t. The solution for $\hat{\pi}_t$ that is given in equation (10), together with the formula for the adjusted instrument that is shown in equation (15), would determine the value of the monetary control, $\tilde{\mu}_t$. Further, with the quadratic-cost structure that is assumed to hold in the present model, this conclusion is undisturbed by the presence of the stochastic term in equation (15). The policymaker chooses $\tilde{\mu}_t$ in each period so as to equate the adjusted monetary instrument for period t--and hence the policymaker's forecast for π_t--to the value of $\hat{\pi}_t$ that is determined in equation (10).

In an equilibrium each agent who understands the policymaker's choice problem and has access to the same information set as the policymaker will derive the same inflation forecast, $\hat{\pi}_t$. Therefore, $\pi_t^e = \hat{\pi}_t$ will again be part of the equilibrium. Using this fact and the form of the adjusted monetary instrument for period t, as given in equation (15), the solution for the monetary control, $\tilde{\mu}_t$, can be shown to be

$$(16) \qquad \tilde{\mu}_t \approx \hat{\pi}_t - \left(\frac{\alpha}{1+\alpha}\right)(\mu_{t-1}^R + v_{t-1} + \varepsilon_{t-1}) + (1-\lambda)\varepsilon_{t-1} + \lambda(1-\lambda)(U_{t-2}^n - \overline{U^n}) - \beta(\hat{\pi}_t - \hat{\pi}_{t-1}).$$

The solution for $\hat{\pi}_t$, which also equals π_t^e, appears in equation (10). The remaining parts of the equilibrium solution are, for actual inflation,

$$(17) \qquad \pi_t \approx \hat{\pi}_t + \frac{1}{(1+\alpha)}(\mu_t^R + v_t + \varepsilon_t),$$

and for the unemployment rate,

$$(18) \qquad U_t \approx \lambda U^n_{t-1} + (1-\lambda)\overline{U^n} + (\frac{1}{1+\alpha})\varepsilon_t - (\frac{\alpha}{1+\alpha})(\mu^R_t + v_t).$$

The new influences on monetary growth in equation (16) involve the effects on inflation from anticipated output growth and changes in expected inflation. The monetary control, $\tilde{\mu}_t$, is set so as to offset these forces in order to generate a prescribed mean value for the inflation rate, $\hat{\pi}_t$. For example, since $(\mu^R_{t-1} + v_{t-1})$ temporarily raised last period's output (equation (18)), there is an expectation of lower than otherwise growth in output from date t-1 to date t. Therefore, $\tilde{\mu}_t$ is reduced in order to maintain the value of $\hat{\pi}_t$. The model predicts that past shocks to money or velocity will be offset in future periods.

A high value for $(U^n_{t-2} - \overline{U^n})$ leads, through the persistence that is governed by the λ-parameter, to the expectation of high output growth for period t (as well as for period t-1). Accordingly, $\tilde{\mu}_t$ is raised--this channel produces a positive reaction of monetary growth to lagged unemployment. This type of countercyclical reaction would not be matched by the inflation rate.

Last period's supply shock, ε_{t-1}, enters into equation (16) with an apparently ambiguous sign. This effect would be positive on $\tilde{\mu}_t$--thereby paralleling the influence of $(U^n_{t-2} - \overline{U^n})$--if we had assumed that the unemployment effects of inflation shocks persisted over time in the same manner as did the effects of real shocks, ε_t. We neglected the persisting influences of inflation shocks solely for convenience (see below).

Changes in expected inflation, $\hat{\pi}_t - \hat{\pi}_{t-1}$, raise velocity. The negative response of $\tilde{\mu}_t$ maintains $\hat{\pi}_t$ at the prescribed level. Equation (10) implies that $\hat{\pi}_t - \hat{\pi}_{t-1}$ depends positively on last period's supply shock, ε_{t-1}, and negatively on $(U_{t-2} - \overline{U^n})$.

Equation (17) indicates that unexpected inflation arises from a combination of monetary, velocity and supply shocks, $\mu_t^R + v_t + \varepsilon_t$. Equation (18) yields the familiar conclusion from expectational-Phillips-curve models that shocks to money and velocity, $\mu_t^R + v_t$, produce reductions in the unemployment rate. The effect on unemployment of the supply shock, ε_t, is reduced below unity because of the positive response of unexpected inflation.

3. Some other Extensions

The model could be modified to allow effects from inflation shocks to persist over time--that is, equation (1) could be modified to allow U_t to depend on current and lagged values of $(\pi - \pi^e)$. This extension complicates the policymaker's first-order condition in equation (8) to include effects on a distributed lead of prospective future values of unemployment and inflation. The ultimate equilibrium is altered in that expected future values of U and π appear as influences on $\hat{\pi}_t$ in equation (10).

The magnitude of change in the inflation rate could be included as an additional argument of the cost function in equation (3). For example, the term, $c(\pi_t - \pi_{t-1})^2$, where $c > 0$, could be added to the expression for Z_t. This element might capture the costs for the economy to adapt to a different inflationary environment. The policymaker's choice of π_t then becomes a dynamic problem. The model would describe a transition path between a given initial inflation rate and a steady-state (mean) inflation rate. The overall nature of the results would not change from that discussed earlier.

4. Revenue from Money Creation

A substantial literature (e.g. Bailey, 1956, Auernheimer, 1974, Calvo, 1978) considers the outcomes when the government attempts to maximize the (present value of) revenue from paper money creation. This problem is reasonably straightforward if the government can precommit its course of future monetary actions. The solution is the one described by Auernheimer (1974), where the usual monopoly formula arises. However, when choices of monetary growth cannot be precommitted and the private sector forms expectations rationally, taking account of the government's revenue objective, Calvo (1978) has shown that a dynamic inconsistency arises. Given inflationary expectations at each date, the government can generate more revenue if it chooses a higher than anticipated rate of monetary expansion. Since the private sector is assumed to understand the government's objective, they will anticipate this outcome. Therefore, the prior expectations on money growth and inflation are revised accordingly. But, the government can then choose a higher rate of monetary expansion, and so on. Without prior restraints, the government's period-by-period optimization entails a higher-than expected--possibly infinite--rate of monetary growth. There is no equilibrium because the systematic surprises implied by this behavior are inconsistent with rationality on the part of money holders.

This dilemma disappears if the inflation rate enters the government's objective function as a cost element. For example, suppose that the policymaker's objective entails minimization of costs, as given by

$$Z_t = Z(R_t, \pi_t), \tag{19}$$

where R_t is period t's real revenue from money creation. It is assumed that $\partial Z/\partial R_t < 0$ and $\partial Z/\partial \pi_t > 0$--that is, rises in revenue are viewed as a benefit item. These preferences could reflect society's desire to raise a given total revenue at minimal deadweight loss. A larger value for R_t implies less revenue raised by other methods of (distorting) taxation.

Real revenue from money creation is generated by a function of the form,

$$(20) \qquad R_t = R(\pi_t^e, \pi_t - \pi_t^e).$$

For simplicity, we do not distinguish between the inflation rate and the monetary growth rate in this formulation. The first argument of the R-function describes the effect on real revenue of fully anticipated inflation and monetary growth--$\partial R_t/\partial \pi_t^e > 0$ applies in the range where real money demanded is less than unit elastic with respect to the expected inflation rate.[12] The second term indicates the effects of unanticipated inflation--$\partial R_t/\partial(\pi_t - \pi_t^e) > 0$ applies because real cash balances, which are the base of the inflation tax, are fixed by π_t^e.

For a once-and-for-all choice of inflation rules, where π_t and π_t^e are effectively chosen together, the policymaker's solution would again be straightforward. The actual and expected inflation rate--call it π_t^*--would be lower than that chosen by Auernheimer's monopolist, because of the direct positive effect of π_t on Z_t.

Without precommitment and with π_t^e treated as given for each period, the policymaker recognizes that R_t can be raised by generating inflation in excess of expectations. The setting, π_t^*, is no longer an equilibrium because of this possibility. Rather, the policymaker will choose $\pi_t > \pi_t^*$. Under rational expectations this outcome would be anticipated, so that π_t and π_t^e are both higher--that is, the $(\pi_t - \pi_t^e)$ term in the R-function of equation (20) equals zero in equilibrium. An equilibrium obtains when π_t is sufficiently high that the policymaker no longer finds it worthwhile, at the given value of π_t^e, to generate more revenue by setting $\pi_t > \pi_t^e$. At this point the direct marginal cost of inflation, $\partial Z/\partial \pi_t$, balances the gain from added revenue that would be produced by a hypothetical increment in unexpected inflation, $|\partial Z/\partial R_t| \cdot [\partial R_t/\partial(\pi_t - \pi_t^e)] > 0$.[13] Note that, with $\pi_t = \pi_t^e$ obtaining as part of the equilibrium, the policymaker does not actually generate revenue via unanticipated inflation. However, the potential for this sort of revenue enters into the determination of the equilibrium inflation rate.

The nature of this equilibrium corresponds to that in the previous example where the unemployment rate substituted for revenue, R_t, in the policymaker's objective function. In both cases the driving element is the impact of unexpected inflation, which is negative on U_t and positive on R_t.

5. Government Bonds

Besides the direct revenue from money creation, inflation has additional dynamic effects on government receipts. We consider here the example of nominally-denominated, interest-bearing public debt. The nominal interest rate paid on government bonds incorporates inflationary expectations, π_t^e, over the pertinent horizon for the debt. Given these expectations, increases in actual inflation and rises in nominal interest rates, which would reflect upward revisions to π^e, generate capital losses to holders of nominal bonds. The government enjoys a corresponding capital gain. As with other forms of ex post capital levies, this type of revenue mechanism entails no economic distortions. (The distortions arise because the possibility of this type of taxation is recognized, ex ante.) As before, the policymaker's objective could involve the raising of revenue at minimal overall deadweight loss. This objective implies that unexpected inflation, $\pi_t - \pi_t^e$, would appear as a benefit term, because of its negative effect on the real value of existing government debt.

As in earlier analyses, the rational expectations equilibrium involves an inflation rate (actual and expected) and a corresponding nominal interest rate that are sufficiently high to deter the policymaker from systematically exploiting the ex post power of generating departures of π_t from π_t^e. The equilibrium inflation rate and nominal interest rate are determined so as to equate the marginal cost of inflation to the marginal benefit from reducing the real value of government debt through unanticipated inflation. Note that zero revenue from unexpected capital losses on bonds results in this equilibrium, but the potential for generating this type of ex post levy enters into the determination of π_t.[14] Indexation of bonds would remove the government's ex post power to create this type of surprise capital loss and would thereby affect the equilibrium growth rate of money and prices. In effect, institutionalized inflation correction is a form of long-term commitment that is analogous to the once-and-for-all selection of a monetary rule. From the present perspective, the implementation of indexing on public debt would reduce the equilibrium inflation rate. However, if the cost attached to inflation--that is, the b-coefficient in the cost function from equation (3)--were reduced by the existence of indexed bonds, then an opposite force would arise.

6. Reputational Equilibria

A different form of equilibrium may emerge in which the policymaker foregoes short-term gains for the sake of maintaining a long-term "reputation." Consider again the initial setting where costs depend on unemployment and inflation, as in equation (3). The "rules equilibrium" generates $U_t = U_t^n$ and $\pi_t = 0$, while the non-cooperative, period-by-period solution yields the inferior outcome, $U_t = U_t^n$ and $\pi_t = \hat{\pi}_t > 0$.

Another possible form of solution, which has been discussed in the related game-theory literature (e.g. in Friedman, 1971), takes the following form. Private agents anticipate the cooperative result,[15] $\pi_t = 0$, unless they have seen something else. Once observing a different value for inflation, agents henceforth expect the non-cooperative policy, $\pi_t = \hat{\pi}_t$.[16] Confronted by this behavior, the policymaker has two options: first, $\pi_1 = \hat{\pi}_1$ can be chosen in period one. In conjunction with the initial expectation, $\pi_1^e = 0$, the choice of $\pi_1 = \hat{\pi}_1$ generates a favorable first-period tradeoff between low unemployment, $U_1 < U_1^n$, and high inflation. For the first period this outcome is preferred to the rules solution, where $U_1 = U_1^n$ and $\pi_1 = 0$. In subsequent periods individuals would set $\pi_t^e = \hat{\pi}_t$ and the policymaker selects $\pi_t = \hat{\pi}_t$ as the best possible response, given these expectations. Therefore, the non-cooperative equilibrium, $U_t = U_t^n$ and $\pi_t = \hat{\pi}_t$, arises from period 2 onward.

The policymaker's second option is to set $\pi_t = 0$ in each period. Since $\pi_t^e = 0$ is sustained under this policy, the cooperative solution, $U_t = U_t^n$ and $\pi_t = 0$, obtains in all periods. Under this option the policymaker foregoes the hypothetical short-run gain in order to sustain "credibility" and thereby enjoy the benefits of future cooperative outcomes.

From the policymaker's viewpoint the central new feature is the linkage between current policy choices and subsequent inflationary expectations. In particular, the policymaker knows that $\pi_t^e = 0$ will apply only if $\pi_{t-i} = 0$ has been set for all $i > 0$--that is, at all previous dates. Whether the reputational equilibrium will arise depends on the policymaker's weighing of the benefits from the two possible modes of behavior. The first option would be preferred if the hypothetical one-period benefit from low unemployment outweighs the present value of the losses from higher inflation in future periods.[17]

There are many features that can cause the reputational equilibrium to break down. First, any known, finite horizon for the game rules out these types of equilibria. The cooperative solution is clearly non-sustainable in the final period--working backward, period-by-period, this breakdown can be shown to be transmitted to all earlier periods.[18] However, if the game ends only probabilistically, the reputational equilibrium might be sustainable. A higher probability of termination effectively raises the discount rate that is applicable to outcomes in future periods. This higher discount rate lowers the benefits from long-term reputation (low inflation) relative to those from short-run gains (low unemployment). Accordingly, while a finite expected horizon for the game does not make the reputational equilibrium impossible, it does make it more difficult to maintain.

Second, at least the simple form of cooperation is lost if option one becomes preferable to option two during any period. In the present example, a runup in the natural unemployment rate could make the hypothetical short-run benefit from reduced unemployment exceed the present value of losses from higher future inflation.

Third, in a context of partial information, agents may have difficulty verifying the underlying monetary policy (such as the value of $\tilde{\mu}_t$ in the example discussed above in Section 2). Some form of stochastic decision rule would have to be implemented. Policymakers would have a corresponding incentive to cheat--such situations would be characterized by claims that inflation and/or monetary growth was not caused by past governmental actions. Similarly, policymakers would desire to proclaim the end of a previous regime that involved excessive inflation in order to restore matters to the "first period" in which $\pi_1^e = 0$ was based on trust, rather than on performance.

The essential problem is the lack of an objective link between current actions, π_t, and future expectations, π_{t+i}^e. An enforced rule ties actual and anticipated values together. In this sense the reputational equilibrium amounts to a fragile approximation to the rules equilibrium. Despite the apparent difficulties with sustaining reputational equilibria, casual observation suggests that reputational forces, unreinforced by formal rules, can generate satisfactory outcomes in some areas. Further investigation seems warranted into the factors that allow reputational equilibria to be sustained.

7. Rules versus Discretion Once Again

The presence or absence of precommitment coincides with the meaningful distinction between rules and discretion. It is useful to eliminate two common, but irrelevant, distinctions between rules and discretion that have arisen in previous literature:

1) Policy is described by a once-and-for-all choice of reaction function, $h(I_{t-1})$, but discretion allows I_{t-1} to encompass a larger set of arguments

than does a (simple) rule. This viewpoint makes rules look like a silly constraint on the options of the policymaker. From this perspective, rules are defensible only if the policymaker is incompetent or nontrustworthy, in the sense of using an inappropriate objective.

2) Ignorance about the workings of the economy favors a simple rule for policy. While this outcome is possible, the conclusion is not general. It is readily imaginable that uncertainty about variables or about model structure would magnify the number of factors to which feedback was justified.

The meaningful dimension of a rule is its capacity to precommit the manner in which future policy choices will be determined. In many private arrangements, as with governmental policies, efficiency requires the potential for advance commitments--that is, for contractural obligations. Kydland and Prescott (1977) describe numerous public policy areas in which formal or implicit ex ante constraints on future actions are important, including patents, flood plain projects, and energy investments. Other areas include repudiation of national debt and taxation of capital income generally. Actual methods for framing government policies seem to be successful to different degrees in each case.

In the unemployment/inflation example the outcome is sub-optimal relative to that generated by a policy rule, if the costs of erecting and enforcing the rules are disregarded. The "optimal" solution, $\pi_t = 0$ and $U_t = U_t^n$, is then attainable through a (costlessly-operating) mechanism that restricts future governmental actions on inflation. Under a discretionary regime, the policymaker faces an unemployment/inflation tradeoff at each date and performs accordingly. The policymaker does as well for the public as possible within an environment where precommitments--that is, long-term contracts with the public--are precluded. Rather than rules being less flexible than discretion, the situation is reversed. Discretion amounts to disallowing a set of long-term arrangements between the policymaker and the public. Purely discretionary policies are the sub-set of rules that involve no guarantees about the government's future behavior.[19]

8. Monetary Institutions and Policy Choice

The spirit of this paper is to characterize monetary growth and inflation as reflections of optimal public policy within a given institutional setup. Under a discretionary regime, the policymaker performs optimally subject to an assumed inability to precommit future actions. The framework assumes rationality in terms of the day-to-day actions that are carried out repeatedly within the given institutional mode. The intention here is to model the regular behavior of a monetary authority, such as the Federal Reserve. Excessive inflation, apparently unrewarding countercyclical policy response, and reactions of monetary growth and inflation to other exogenous influences can be viewed as products of rational calculation under a regime where long-term commitments are precluded.

The model stresses the importance of monetary institutions, which determine the underlying rules of the game. A purely discretionary environment contrasts with regimes, such as a gold standard or a paper money constitution, in which monetary growth and inflation are determined via choices among alternative rules. The rule-of-law or equivalent commitments about future government behavior are important for inflation, just as they are for other areas that are influenced by possibly shifting public policies.

We are less comfortable about specifying frutiful approaches for framing positive theories of monetary institutions.[20] If we had retained the optimality criterion that we utilized for analyzing day-to-day monetary actions, and if we had assumed that the costs of implementing and enforcing monetary rules were small, then discretionary monetary policy would not be observed. Within the natural-rate setting of our model, a positive theory might predict the selection of a rule (or its equivalent)--and the establishment of an accompanying enforcement apparatus--that would guarantee low and relatively stable rates of inflation. But, we have abstracted completely from the evolution of economic theory and its place as a research and development tool for designing policy institutions. Thus, we simply do not address the source of technological change in the "production" of policy.

Presumably, the substantial setup costs that are associated with erecting monetary or other institutions mean that changes in regime will be observed only infrequently. The relatively small experience with alternatives suggests--unlike for the case of regular operations within a given regime--the potential for substantial, persisting errors. Although we would be uncomfortable attempting to forecast a systematic direction of error in future institutional choices, we might be willing to label a particular past choice--such as the movement away from the remnants of the gold standard and fixed exchange rates--as a mistake.

The distinction between institutional choice and operating decisions within a given regime relates also to the economist's role as a policy adviser. In our model the economist has no useful day-to-day advice to offer to the monetary authority.[21] If monetary institutions were set optimally, then the economist's counsel would also not enter at this level. The most likely general role for policy advice consists of identifying and designing improvements in present policy institutions. In the monetary area the major issue concerns arrangements that are preferable replacements for the present discretionary setup. It is important to identify mechanisms--such as commodity standards and legal restrictions on the behavior of paper money--that would effectively (and cheaply) precommit the course of money and prices. This topic appears to be the central issue in controlling inflation.

Footnotes

[1]The model that we consider is sufficiently simple to allow for unanimity about desirable governmental actions.

[2]Many people respond with a willingness to view public policy as irrational. Despite the obvious attractions of this viewpoint, it does leave one without a theory of systematic governmental behavior. An earlier attempted reconciliation with rationality (Barro, 1977, p. 104) was based on public finance considerations associated with cyclical changes in the revenue obtained from printing money. This avenue appears to be quantitatively insufficient to explain the facts about countercyclical monetary response. However, the revenue motive for money creation would be important in some extreme cases. For example, see Hercowitz (1981) for an analysis of monetary behavior and government spending during the German hyperinflation.

[3]The prior expectation of inflation for period t could be distinguished from the expectation that is conditioned on partial information about current prices. This distinction arises in models, such as Lucas (1972, 1973) and Barro (1976), in which people operate in localized markets with incomplete information about contemporaneous nominal aggregates. In this setting the Phillips-curve slope coefficient, α, turns out to depend on the relative variances for general and market-specific shocks.

[4]The target unemployment rate is $U_t^* = kU_t^n < U_t^n$. The formulation implies also that $\partial U_t^*/\partial U_t^n < 1$. The last condition, which is important for some of the conclusions, is more difficult to justify.

[5]In the present setting the policymaker has no incentive to randomize policy choices--therefore, the reaction function will end up being purely deterministic. Some uncontrollable random parts of monetary growth are considered later.

[6]Because there are many private agents, they neglect any effect of their methods for formulating π_t^e on the policymaker's choice of π_t.

[7]Note that no equilibrium exists if the policymaker gives no direct weight to inflation--that is, if $b = 0$ holds. More generally, it is necessary that the marginal cost of raising π_t be positive at a point where $\pi_t = \pi_t^e$.

[8]$\pi_t^* = \overline{\pi_t}$ would emerge if Z_t in equation (3) depended on $(\pi_t - \overline{\pi_t})^2$. The result in equation (11) corresponds to Kydland and Prescott's "optimal" solution (1977, p. 480). They contrast this outcome from policy rules with a "time-consistent," but less desirable result, which corresponds to our equation (10).

[9]Consider the more general case where $Z_t = Z(U_t - kU_t^n, \pi_t)$ and $U_t = U_t^n - f(\pi_t - \pi_t^e)$. The first-order condition entails $f' = (\partial Z/\partial\pi_t)/[\partial Z/\partial(U_t - kU_t^n)]$. This expression will be evaluated in equilibrium at $\pi_t = \pi_t^e$ and $U_t = U_t^n$. An equilibrium will be found if $\partial Z/\partial\pi_t$ rises sufficiently with π_t (as in the quadratic case considered in the text) or if f' declines sufficiently with π_t ($f'' = 0$ was assumed in the example). (This discussion ignores any cross-effect of π_t on $\partial Z/\partial(U_t - kU_t^n)$.) The condition $f'' < 0$ would tend to be satisfied, because $(\pi_t - \pi_t^e)$ is likely to enter multiplicatively with the level of real cash balances in influencing U_t. (The product of $(\pi_t - \pi_t^e)$ and $(M/P)_t$ determines the capital loss or gain on money holdings in commodity units that is induced by surprises in the inflation rate.) Further, $(M/P)_t$ would be declining in π_t^e. In other words the reduction in U_t that is bought by a unit rise in $(\pi_t - \pi_t^e)$ is likely to diminish as π_t and π_t^e rise. If this element is added to the model, it is no longer essential that inflation involve increasing marginal costs--$\partial^2 Z/\partial\pi_t^2 > 0$.

[10]Formally, changes in the parameters a, b, α, or k--which alter $E_{t-1}\hat{\pi}_t$ for all dates t in equation (10)--have no significance for the time path of unemployment.

[11]One is tempted to say that setting $\pi_t < \hat{\pi}_t$ in equation (10) would deliver $U_t > U_t^n$. (As an analogue, a firm that ends up in equilibrium with an ordinary rate of return would end up with below-normal rates of return if it did not strive to maximize profits at all times.) However, the choice of $\pi_t < \hat{\pi}_t$ is inconsistent with the prescribed form of the policymaker's objective.

[12]This statement neglects the distinction between the expected inflation rate and the nominal interest rate as the measure of the tax rate on real cash balances.

[13]Suppose that $R_t = \pi_t L(\pi_t^e)$, where L is the downward-sloping real money-demand function, and $Z_t = -R_t + f(\pi_t)$. The equilibrium inflation rate is then determined from the condition, $L(\pi_t) = f'$. The level of real balances--which equals $\partial R/\partial \pi_t$ when π_t^e is held fixed--is equated to the marginal cost of inflation, $\partial Z/\partial \pi_t = f'$.

[14]It would be possible for unexpected inflation to arise, conditional on the realization of some stochastic variables. For example, the government might depreciate the real value of the public debt during wartime.

[15]The result is not fully cooperative because of the underlying externality that makes the natural unemployment rate "too high."

[16]The reaction can be modified so that $\pi_t^e = \hat{\pi}_t$ applies only for a finite time period. However, a shorter "punishment interval" makes it more difficult to induce the policymaker to opt for the cooperative result.

[17]The form of behavior described under the first option cannot arise in equilibrium in the present model. If this option were attractive for the policymaker, private agents would anticipate this outcome. In that case $\pi_t^e = 0$ would not be maintained. The non-cooperative solution, $U_t = U_t^n$ and $\pi_t = \hat{\pi}_t$, would then arise for all periods, including the first. However, there will always exist some intermediate values of π_t, where $0 \leq \pi_t < \hat{\pi}_t$, such that a cooperative solution based on π_t would be sustainable. Assuming an infinite horizon for the problem (see below), a sufficiently high value of π_t within this interval must make option two preferable to option one. However, the admissable range for π_t would depend on the realizations for U_t^n and other variables.

[18]Some attempts to avoid this conclusion in analogous contexts have been explored in Kreps and Wilson (1980) and Radner (1979), et. al.

[19]If the desirability of precommitments on monetary growth and inflation is accepted, there are numerous procedures within the present model that can generate outcomes that are equivalent to those produced by a once-and-for-all choice of rules. For example, discretion could be maintained, but the parameters of the policymaker's preferences could be artificially manipulated in order to generate a non-cooperative solution where $\hat{\pi}_t = 0$. This result follows if the policymaker gives infinite weight to inflation ($b = \infty$), zero weight to unemployment ($a = 0$), or regards the natural unemployment rate as optimal ($k = 1$). In the context of discretionary policy, outcomes may improve if there is a divergence in preferences between the principal (society) and its agent (the policymaker).

[20]The distinction between choices of institutions and selections of policies within a given regime parallels Buchanan and Tullock's (1962) dichotomy between decisions at the constitutional and operating levels of government. Buchanan (1962) stresses the importance of the constitutional perspective in designing a satisfactory monetary/inflation policy.

[21]Perhaps this observation accounts for the Federal Reserve's attitude toward the unsolicited advice that is provided to it by economists. The Federal Reserve appears interested mostly in "efficient" operation within a given policy regime--specifically, on what to do "right now." Although many economists offer advice of this sort, there is little reason to believe that these suggestions would improve on the Fed's period-by-period optimization. More recently, much of economists' advice to the Fed has amounted to proposals for altering the underlying "rules of the game." It is likely that the Federal Reserve is powerless to utilize these types of constitutional-like suggestions.

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