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CONCEPTUAL ISSUES AND
PRACTICAL CONSIDERATIONS

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ABSTRACT

The design of rules for central bank policy has been a subject of increasing interest to many monetary economists. The purpose of this essay is first to present an analytical structure in which a policymaker is presumed to formulate a rule based on the solution to an optimal control problem, and then to examine a number of issues that are germane to the current debate on the nature of such rules. These issues include the implication for policymaking of the slope of the output-inflation variability frontier, the importance of various types of uncertainty, the consequences of a zero nominal interest rate floor, and the possible reasons for interest rate smoothing.

Although this essay is intended to raise, rather than resolve, key questions concerning policy rules, it does offer fairly compelling evidence on one point. This concerns the potential consequences of the move by many central banks toward some form of price-level or inflation targeting. In adopting this approach, central banks are implicitly changing the relative importance of output and inflation variability in their objective function. The robustness of the policy rule, however, may depend on the shape of the output-inflation variability trade-off. The data indicate that this trade-off is extremely steep: small decreases in inflation variability are associated with very large increases in output variability. This finding suggests that pure inflation targeting may have very undesirable side effects.

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1 Introduction

Central bank policymakers are not primarily random number generators.[1] Reading both the financial press and the work of academics, however, one might get the opposite impression. Reporters (and the readers of their stories) seem to attach considerable importance to each Federal Open Market Committee policy decision. Academic work on the impact of central bank policy gives a similar impression, as empirical identification yields a series of white noise innovations that are labeled "policy shocks."[2] But central bankers expend substantial energy attempting to tailor their actions to current economic conditions. In other words, policymakers are reacting to the environment, not injecting noise.

But what is central bank policy anyway? As a problem in operations research, the answer seems trivial. Policy is, or should be, the solution to a stochastic, dynamic optimal control problem. Using a control variable (an interest rate) and knowledge of the evolution of the state (aggregate output and the price level), the policymaker minimizes a loss function (for example, the weighted sum of future variance of output and prices). This approach yields what most people would call a *policy rule*, that is, a rule for adjusting the control variable as a function of previous values of the state variable and of the control variable itself. In other words, the study of policy should focus on the systematic portion of policymakers' actions.

In this essay, I discuss a number of conceptual and practical issues associated with the procedure just described. What is the appropriate loss function? Where should it come from? What is the control variable? What is a policy target? Is there any justification for the adoption of what is typically called an intermediate target? What is the slope of the inflation-output variability frontier, and how should this affect policy decisions? How does uncertainty influence the policy rule? What are the consequences for the optimal policy of the zero nominal interest rate floor? And how might we justify interest rate smoothing? For the most part, I will simply explore these questions rather than offer any definite answers.

The remainder of the essay addresses these issues in four sections. I begin in Section 2 with a discussion of the task facing policymakers, giving particular attention to the nature of the loss function that is to be minimized and the precise definition of policy. Section 3 provides a discussion of some of the conceptual and practical issues faced in the implementation of such a procedure, and Section 4

[1]Here I paraphrase a comment made by Bennett McCallum at a conference on monetary policy in January 1993.

[2]A naive reading of the recent work of Christiano, Eichenbaum, and Evans (1994a, 1994b) surely could lead to such an interpretation.

presents arguments for the adoption of policy rules. Section 5 summarizes the lessons for policy formulation with an emphasis on general issues of central bank independence, accountability, and policy transparency.

2 An Analytical Framework for Policy Formulation

What is central bank policy? As I suggested in the introduction, policy can be thought of as the solution to an optimal control problem. A truly complete description of the policymaker's problem begins with an intertemporal general equilibrium model based on a social welfare function (tastes), production functions (technology), and market imperfections that cause nominal shocks to have real effects (nominal rigidities). The goal would be welfare maximization.

I do not propose to delineate the fully specified problem. Instead, I begin with a commonly used quadratic loss function that might be a second-order approximation to the objective function in this more detailed problem.[3] Consider the following general form for the loss function the policymaker seeks to minimize:

$$\mathcal{L} = E_t \left\{ \sum_{i=0}^{h} \beta^i \left\{ \alpha [p_{t+i} - p^*_{t+i}]^2 + (1-\alpha)[y_{t+i} - y^*_{t+i}]^2 \right\} \right) , \qquad (1)$$

where p_t is the (log) aggregate price level, y_t is the (log) aggregate output, p^* and y^* are the desired levels for p and y, β is the discount factor, h is the horizon, α is the relative weight given to squared price and output deviations from their desired paths, and E_t is the expectation conditional on information at time t.[4] The loss function provides the policymaker with information about preferences over different paths for the variance of output and prices.

A complete formulation of $\mathcal{L}$ requires description of p^* and y^*. I will focus on the desired price path, ignoring issues concerning y^*.[5] Here we encounter the following question: Should the objective be a price-level path or an inflation rate? The first of these, *level targeting*, would dictate that

$$p^*_t = p^*_{t-1} + \pi^* \ = \pi^* t \ . \qquad (2)$$

[3]Throughout the discussion in this section, I will assume that the there is no dynamic consistency problem, and so policymakers can credibly commit to whatever rule they choose. Section 4 comments further on this issue.

[4]In some formulations the loss function includes an additional term in the change in the control variable. That is, changes in interest rates are assumed to be explicitly costly. Inclusion of such a term here adds very little to the analysis.

[5]Specifying a process for y^* would be difficult because there is no agreement on a number of crucial issues. For example, should y^* have a random walk component or be a deterministic trend? Is the growth rate in y^* affected by the volatility of y?

That is, the optimal price level this period is the optimal level last period plus some optimal change (which may be zero). The alternative, *rate targeting*, is

$$p_t^* = p_{t-1} + \pi^* \ , \tag{3}$$

where the current target price level is just the last period's *realized* price level plus the optimal change.

The difference between price-level and inflation rate targeting is the path for the variance of prices. Level targeting implies more volatile short-horizon prices and less volatile long-horizon prices than does rate targeting. To see this, simply note that (3) implies that

$$p_t^* = \pi^* t + \sum_{i=0}^{\infty} (p_{t-i} - p_{t-i}^*) \ ,$$

which can be a random walk.

It is possible to nest these two objectives into a more general formulation. Consider a parameter δ representing the relative weight given to price-level and inflation targeting. Then

$$p_t^* = \delta(\pi^* t) + (1-\delta)(p_{t-1} + \pi^*) \ . \tag{4}$$

In (4) the percentage of the variance in p explained by its random walk component will be related to δ.

The description of the loss function is now complete. It is a function of the parameter vector $\theta = \{\alpha, \beta, \delta, h, \pi^*\}$. The values of each of these will depend on the underlying economic structure, that is, tastes and technology. The preference over different paths for inflation and output variability, as embodied in the loss function, depends on the fundamental reason that these things are costly. The same is true of the desired steady level of inflation, π^*.

The policymaker's problem cannot be solved without knowledge of the dynamics of the state variables y_t and p_t as functions of the policy control variable and the stochastic forcing process driving the economy. These relations, which are taken as constraints in the optimization problem, describe the structure of the economy. For the purposes of the current discussion, I will assume that the central bank policy is carried out in terms of an interest rate, r_t,[6] and that the innovations to the economy come from an n-variate process $\{\epsilon_t\}$, with expectation zero and

[6]The use of an interest rate is not necessary. The control variable could be any quantity that is directly governed by the central bank. For example, the monetary base or some measure of reserves could be used as the control.

variance-covariance matrix Σ. The reduced form for the evolution of the output and prices can then be written as

$$\begin{bmatrix} y_t \\ p_t \end{bmatrix} = A(L) \begin{bmatrix} \epsilon_t \\ r_t \end{bmatrix} , \tag{5}$$

where $A(L)$ is an $(n+1)$x2 matrix of (possibly infinite-order) lag polynomials in the lag operator L.[7] The coefficients in $A(L)$ describe a reduced form of the economy. For the moment, I will ignore the fact that $A(L)$ is likely to change when the policy rule changes.[8]

We can now characterize the policymaker's problem as choosing a path for r_t that minimizes the loss (1), with (4) substituted in for p^*, subject to (5). The result is a policy rule, which I will write as

$$r_t = \phi(L)\epsilon_t , \tag{6}$$

where $\phi(L)$ is a (possibly infinite-order) lag polynomial.[9] This path for interest rates as a function of the innovations to the economy (which could be written as differences in the observable quantities) is the policy rule. Importantly, $\phi(L)$ is a function of the parameters θ, as well as the coefficients in $A(L)$ and the covariance matrix of ϵ, Σ.

I would like to emphasize that the preferences over paths for the variability of output and prices, as well as the optimal steady inflation rate π^*, are *inputs* into the policymaker's problem.[10] In practice, I expect that these inputs are dictated by some legislative or executive body in the government. Given this objective and a model for the evolution of the state variables (the economy), the policymaker chooses a rule that governs the path of the control (the interest rate).[11]

[7] Equation (5) is the vector moving-average form. The more common vector autoregressive (VAR) form is equivalent.

[8] This point is emphasized, for example, in Cecchetti (1995).

[9] The linear-quadratic structure of the problem described here will give rise to a linear policy rule. In general, this would not be the case. For example, if the loss function were nonlinear, or there were some additional constraints on the policymaker's behavior not considered here, then the policy rule would be nonlinear as well.

[10] Svensson (1996a) compares inflation and price-level targeting, arguing that one yields better performance than another depending on various properties of the economy. Such an exercise relies on a particular view of the costs of inflation that is not explicitly embodied in the loss function (1).

[11] Ball (1997) takes a different approach, focusing on the implications for the loss of adopting ad hoc rules that are not derived directly from the loss function. For example, after determining the minimized value of the loss $\mathcal{L}$, he then asks how close one can get by adopting a set of arbitrary rules that do not arise from the optimal control problem itself.

3 Conceptual Issues and Practical Considerations

The framework of Section 2 helps clarify a number of issues inherent in the formulation of central bank policy. In this section, I will consider five such issues. I begin by exploring the nature of a target, with a particular focus on inflation targeting and nominal income targeting. Included is a discussion of the usefulness of what are commonly termed "intermediate targets." Why might we wish to focus attention on something other than either the interest rate (the instrument) or output and prices (the goals)?

In Subsection 3.2, I discuss the practical problems posed by the apparent steepness of the output-inflation variability trade-off and consider how it might influence decisions. This is followed in Subsection 3.3 with a general discussion of how uncertainty affects policymaking. I discuss the likely sources of uncertainty and how they might be incorporated in decision making. Next, I discuss how the nonlinearity created by the fact that the nominal interest rate cannot fall below zero influences the policy rule. And finally, I explore the issue of interest rate smoothing. While I am able to address directly a number of the issues raised, I often leave most of the questions unanswered.

3.1 What Is a Target?

Given the optimal control view of the policymaker's problem, how can we interpret the current debate over the proper choice of a policy target, or the advisability of targeting in general? Commonly mentioned targets — for example, inflation and nominal income — are not control variables for the central bank, and so how might we approach this question? I will explore two ways of addressing the issue of targets. The first is purely technical, and the second has to do with the way in which policymakers might portray their intention to the public. Technically, the first-order conditions (or Euler equations) to the optimal control problem may be interpreted as producing a type of targeting regime. To see this, consider the case examined in detail by Svensson (1996b). He considers pure inflation rate targeting, $\delta = 0$, and a loss that is independent of output variation, $\alpha = 1$. The first-order condition of this problem implies setting the path for expected inflation, $E_t\pi_{t+i}$, as close to the optimal value, π^*, as possible. Svensson refers to this as "inflation forecast targeting."[12] More generally, any dynamic control problem implies a relationship among endogenous variables that holds along an optimal

[12]Svensson (1997) notes that if $\alpha \neq 1$, and so weight is given to output variability in the loss function, then this can be interpreted as a form of inflation forecast targeting in which the path of the forecast moves gradually back to the optimal level.

path — the equivalent to the statement that the expected intertemporal marginal rate of substitution in consumption equals the risk-free (real) interest rate.

Nominal income targeting does not naturally arise from the loss function (1). The reason is straightforward. Nominal income targeting would be an attempt to keep $(p_t + y_t)$ close to $(p_t^* + y_t^*)$. This suggests a loss function with terms of the form $[(p_t + y_t) - (p_t^* + y_t^*)]^2$. That is, the policymaker would be instructed to be averse to squared deviations of *nominal* income from its optimal path. If we expand this expression, it is easy to see that it includes a covariance term of the form $[(p_t - p_t^*)(y_t - y_t^*)]$ that does not appear in (1).[13]

Ball's (1997) analysis suggests another justification for targets. The argument is that the optimal control procedure I describe is too difficult to explain to the population at large (and possibly their elected representatives as well), and so will not lead to policy that is transparent enough to ensure the proper level of accountability.[14] But a pure inflation targeting rule is easy to explain and, more important, easy to understand and monitor. As a result, if the solution to the complex problem can be approximated by a simple rule, there may be substantial virtue in adopting the approximate solution.

Svensson's (1997) distinction between a *target rule* and an *instrument rule* is also useful here. As he defines it, an instrument rule is a relationship between the control variable and the observable state — equivalent to (6). So, an instrument rule is a statement that the federal funds rate will be raised or lowered by a specific amount following a forecast error in real output of a certain size. By contrast, the statement that the policymaker adjusts the instrument such that inflation and/or output will follow a certain specified path is a target rule. This is not a policy per se, but really just a statement about a relationship that is implied by the optimization.

It is worth digressing briefly to comment on where intermediate targets fit into this scheme. Over the last half-century or so, many monetary economists have advocated targeting various monetary aggregates. Consider the example of M2.[15] Researchers do not claim to care about M2 for its own sake, nor do they claim that central banks can control it exactly. Therefore, M2 is neither a direct objective nor an instrument. Instead, it is somewhere in between — an *intermediate* target — and the target path would again be akin to the first-order conditions of the optimal control problem.

I find it difficult to make an argument for intermediate targets. To see why,

[13]It is this covariance that is responsible for the poor performance of nominal income targeting noted by Ball (1997).

[14]See Section 4 for a further discussion.

[15]For a recent discussion of M2 targeting, see Feldstein and Stock (1994).

consider the case in which the policymaker controls an interest rate and cares about the price level ($\delta = 1$). To control the objective, the policymaker must know how prices respond to changes in the exogenous environment (the response of p_t to ϵ_t) and how the objective responds to changes in the instrument. But how does an intermediate target such as M2 help? Clearly, if the relationship between interest rates and M2 and that between M2 and prices are both stable and precisely estimable, then there is no advantage to looking at the two relationships separately. There may be some instances in which estimating the impact of interest rates on M2 and the impact of M2 on prices separately gives a more reliable estimate of the product of the two, but such instances would surely be rare. If M2 helps forecast prices, then it will be included in the model. But there is substantial evidence, some of which is in Cecchetti (1995), that reduced-form inflation forecasting relationships are very unstable even if they include M2, or any other potential intermediate target.[16]

As a result, the only case I can see for intermediate targeting is that it contributes to policy transparency. To quote Svensson (1996b), the ideal intermediate target "is highly correlated with the goal, easier to control than the goal, easier to observe by both the central bank and the public than the goal, and transparent so that central bank communication with the public and public understanding and public prediction of monetary policy are facilitated" (pp. 14-15). Monetary aggregates seem particularly poorly suited to such a task.

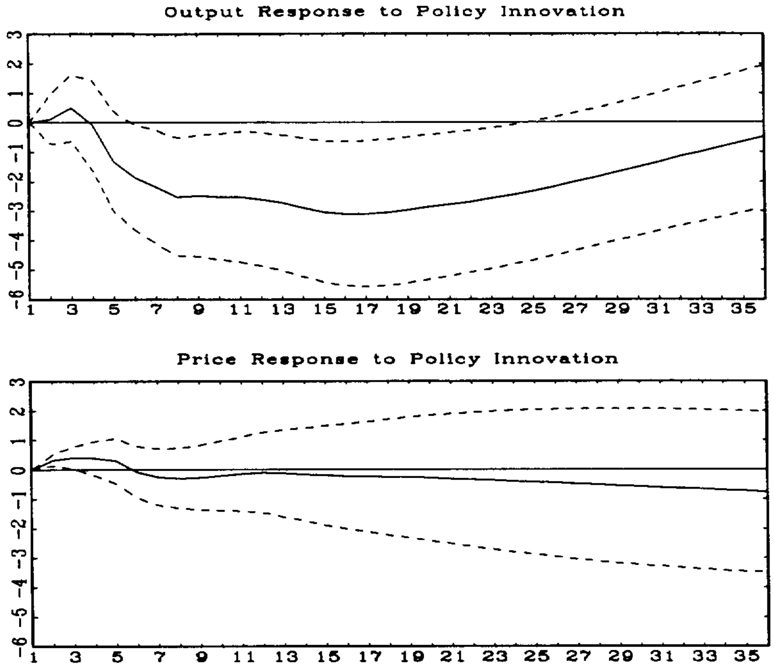
3.2 The Output-Inflation Variability Trade-off

A number of practical issues arise in formulating policy rules. One of the most important concerns the output-inflation variability trade-off that policymakers actually face. To measure this trade-off, I turn to some empirical estimates developed in my earlier work, Cecchetti (1996). There, I present an estimate of the impact of central bank policy on output and prices. In effect, these are the lag polynomials in (5) associated with r_t.[17] Figure 1 plots these *impulse response functions*, or the dynamic reactions of prices and output to innovations (ϵ_t's), on the same vertical scale. The most important point to note is that the impact of policy innovations

[16]This differs from the procedures of the Deutsche Bundesbank. As Mishkin and Posen (1997) note, since 1988 the German central bank has targeted growth in M3 in the belief that the demand for German M3 is stable.

[17]The methods used to produce these results are described in detail in that earlier work. Briefly, I estimate a four-variable vector autoregression including aggregate prices, commodity prices, industrial production, and the federal funds rate, using monthly data from 1984:01 to 1995:11. Central bank policy innovations are identified and used to estimate the impulse response functions under the assumption that no other variable beyond policy itself responds to policy shocks immediately.

Figure 1. Response of Output and Prices to Policy Innovations
(With Two Standard Deviation Bands)



on output is both large and immediate. By contrast, policy affects prices only very slowly, and by much more modest amounts. Furthermore, the precision of the estimates is quite poor.

With the aid of a very simple model, these estimates can be used to give some sense of the shape and slope of the output-inflation variability trade-off. Consider the simple case in which $h = 0$ (and so δ and β are irrelevant), $\pi^* = 0$, $y^* = 0$, and $A(L)$ is such that

$$y_t = \gamma r_t + e_t, \quad \gamma < 0 \tag{7}$$

and

$$p_t = -r_t + u_t\ , \tag{8}$$

where, e_t and u_t are uncorrelated i.i.d. random variables with $E(e_t^2) = 1$ (a normalization) and $E(u_t^2) = \sigma_u^2$.[18] The parameter γ is a measure of the impact of policy innovations on output relative to their impact on prices. The example is meant to represent the medium-horizon impact of policy on the variables of

[18]The fact that e and u are assumed to be uncorrelated is a simplification that has no substantive consequences.

interest. In this simple linear case, the policy rule will be

$$r_t = ae_t + bu_t \ . \tag{9}$$

Equation (9) implies that

$$\sigma_y^2 = (\gamma a + 1)^2 + (\gamma b)^2 \sigma_u^2 \tag{10}$$

and

$$\sigma_p^2 = a^2 + (1-b)^2 \sigma_u^2 \ . \tag{11}$$

Minimizing the loss function $\mathcal{L} = \alpha\sigma_p^2 + (1-\alpha)\sigma_y^2$ yields

$$a = -\frac{\gamma(1-\alpha)}{\alpha + \gamma^2(1-\alpha)} \tag{12}$$

and

$$b = \frac{\alpha}{\alpha + \gamma^2(1-\alpha)} \ . \tag{13}$$

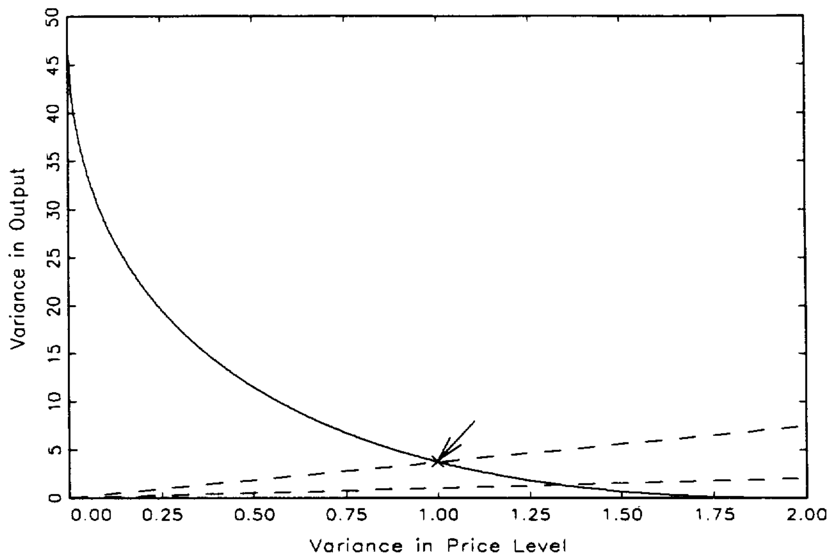
Substituting these into the variance expressions (10) and (11) yields σ_p^2 and σ_y^2 as functions of α, γ, and σ_u^2.

Using the monthly data from Cecchetti (1996), I can now compute an approximate output-inflation variability frontier. From Figure 1, I estimate that γ is approximately -5. Once I determine σ_u^2, varying α allows construction of the frontier. Setting σ_u^2 such that the frontier passes through the value in the data (the ratio of output to price variability is approximately 3.72) and normalizing the variance of the detrended log price level in the data to be equal to one gives Figure 2. The arrow and the "X" mark the data.

The figure includes two dashed lines. The lower one is a 45^o line, at which $\alpha = 0.5$, while the upper line passes through the value from the data. As one rotates the ray from the origin in the counterclockwise direction, α falls. The historical value suggests that policymakers were operating as if α were approximately 0.21.

Importantly, Figure 2 shows that the trade-off is extremely steep. Reducing inflation variability entirely by setting $\alpha = 1$ creates an extremely high level of real variability. In fact, moving from the historically observed point where the ratio of output to inflation variability is 3.72, setting σ_p^2 to zero would increase the variability of output by a factor of nearly 13! By contrast, reducing real variability from 3.72 to 0 increases price variability from 1.0 to 1.92. This finding is not a consequence of the simplicity of the example, but rather of the fact that γ is so large. It is straightforward to show that the maximum value of σ_y^2, at $\alpha = 1$, is γ^2 times the maximum value of σ_y^2, at $\alpha = 0$, minus one. That is to say, the point of

Figure 2. The Inflation-Output Variability Trade-off



intersection of the line in Figure 2 with the x- and y-axes is solely determined by the size of the ratio of the impact of policy innovations on output to their impact on prices.[19]

This result has important implications for the current policy debate. As many central banks move toward some form of price-level or inflation targeting, they are implicitly changing the relative importance of output and inflation variability in their objective function, raising α toward one. From a purely pragmatic point of view, someone who cares about the aggregate price path loses little by allowing α to be less than one, but the reverse is emphatically not true. Someone who cares about output variability is made substantially worse off by moving to a price-level target. As a result, when considering policies based on prices alone, policymakers must ask whether they really care so little about output and other real quantities.

3.3 Uncertainty

How does uncertainty affect policy? Of the numerous types of uncertainty that might influence central bank policy decision making, two forms are examined here: Uncertainty about the likely impact of policy changes, and uncertainty about one's model of the economy.[20] The first of these has two parts, one that is straightforward

[19]Cecchetti (1996) considers a substantially more complex case with the same results.

[20]There will also be uncertainty over the current state of the economy that arises from lags in the data. This has an impact similar to that of parameter uncertainty considered below.

to handle and another that is not. Intractable difficulties arise when one has to worry about shifts in regime. In particular, the underlying economic relationships, which policymakers had previously been able to exploit, may change. Such changes could be brought about by policy itself. It is this point, first noted by Lucas (1976), that has driven many macroeconomists to work on dynamic general equilibrium models with well-articulated microeconomic foundations. But these efforts are still at too early a stage to be of practical use.

It is straightforward to consider the sampling error from estimation of the reaction of prices and output to changes in the policy instrument. In the simple example here, this is just the variance of the estimated γ, which I will call $\sigma^2_{\hat{\gamma}}$. Brainard (1967) originally noted that this type of uncertainty leads to caution in that policy rules imply smaller reactions.[21] In this simple example, inclusion of $\sigma^2_{\hat{\gamma}}$ implies that the policy parameters a and b become

$$a = -\frac{\gamma(1-\alpha)}{\alpha + (\gamma^2 + \sigma^2_{\hat{\gamma}})(1-\alpha)} \tag{14}$$

and

$$b = \frac{\alpha}{\alpha + (\gamma^2 + \sigma^2_{\hat{\gamma}})(1-\alpha)} . \tag{15}$$

Clearly, these imply smaller reactions to a given size shock.

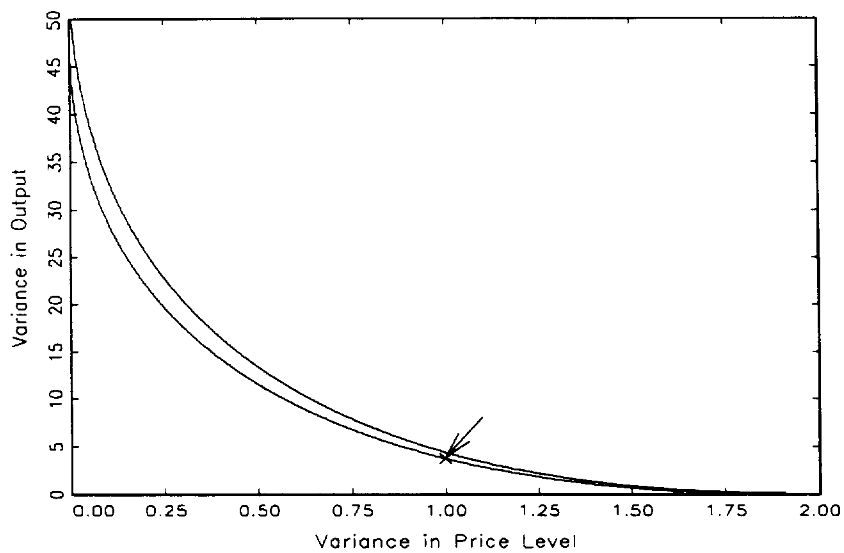
In a more realistic model, such as the one implied by Figure 1, accounting for parameter uncertainty can be very difficult. Is it likely to be worth the trouble? To get some sense of its impact, I have constructed an example in which γ is assumed to have variance equal to four (standard error equal to two). The results are plotted in Figure 3. My impression is that the impact is minimal, as the variability frontier barely moves.

What about model uncertainty? McCallum (1997) argues convincingly that since there is little agreement over the true structural economic model, a policy rule should be robust to the possibility that numerous models are correct. In the context of the framework of Section 2, identifying such a rule would mean exploring the implications of various $A(L)$'s, each of which corresponds to a different model. The object would be to look for a rule that would perform well for a wide range of choices. One method for handling model uncertainty would be to treat it as variance in the estimate of the parameters in $A(L)$. This approach would be a generalization of the procedure used.[22] Unfortunately, I am forced to conclude that

[21] Blinder (1997) notes that in a multivariate model, things are not so simple, and the size and sign of covariances will determine whether policymakers exhibit more cautious or less cautious behavior.

[22] A simple possibility would be to multiply the estimated covariance matrix of the estimated $A(L)$

Figure 3. Impact of Uncertainty on the Variability Trade-off



we know very little about how to solve this problem and that it is a worthwhile subject for future research.

3.4 The Zero Nominal Interest Rate Floor

What average inflation level should the policymaker target? There are two parts to this question. First, what is the optimal level of inflation, π^*? Second, should policy allow the average realized level of π to deviate from this?

I argued above that π^* should be dictated to the central bank by social welfare considerations. Here, there has been quite a bit of work. Most recently, Akerlof, Dickens, and Perry (1996) and Groshen and Schweitzer (1997) consider whether small positive levels of aggregate inflation can facilitate real adjustments in the presence of an aversion to nominal wage declines, suggesting π^* might be positive. But Feldstein (1996) contends that the tax distortions created by inflation reduce the level of output permanently, an argument that suggests π^* may even be negative.[23] Overall, we await further research for the definitive resolution of this issue.

There is one dominant argument for why policymakers might choose to allow average inflation to deviate systematically from the optimal level. The argument,

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by a positive constant.

[23]The problem of inflation bias is also relevant here, because measured inflation may systematically exceed true inflation. For example, Shapiro and Wilcox (1996) argue that the U.S. consumer price index may overstate inflation by 1 percentage point on average. Such a conclusion suggests that even if π^* is zero, the central bank should attempt to keep measured CPI inflation above zero.

raised in Summers (1991), concerns the case in which π^* is zero, and focuses on the fact that the nominal interest rate cannot fall below zero. In fact, any choice of π^* bounds the real interest rate. Summers goes on to note that in the historical record, the real interest rate (at least ex post) has often been negative. But if central bank policymakers successfully target zero inflation, then the fact that the nominal interest rate cannot be negative means that the real interest rate must always be positive as well. In essence, this restricts the ability of the policymaker to respond to certain shocks. The control problem as it is described above does not explicitly consider the fact that r_t is bounded at zero. As a result, there will be realizations of ϵ_t in which the policy rule (6) would imply negative values for the nominal interest rate. One interpretation of Summers's point is that the desirability of negative nominal interest rates in some instances should be taken into account, with the result that mean inflation may deviate from the optimal level in order to allow for a complete response to some larger set of shocks.

To see the point, consider the simple model of Section 3.2. Then, the restriction that $r_t \geq 0$ implies that the loss is minimized for target inflation equal to approximately $0.276\sigma_u$. That is, average inflation will be approximately one-quarter the standard deviation of the shocks to the price level. More complex forms of the model will have similar properties. In general, the greater the likelihood of a shock driving the desired nominal interest rate below zero, and the higher the loss associated with not being able to react to such a shock, the higher will be the average level of inflation that minimizes the policymaker's loss function.

A similar result would arise when the loss function is asymmetrical. It has been argued that there are potential costs associated with deflation rather than just realized inflation that is less than expected. These arise largely because the zero nominal interest rate floor implies that deflation beyond a certain level increases the real interest rate (ex ante and ex post), resulting in a lower steady-state capital stock.[24] This suggests that realized prices below target may be more costly than equivalent realizations above the target. This would naturally create a positive bias in the policy rule that would result in average inflation exceeding π^*.

To gauge the extent of this problem, Table 1 reports the frequency with which the ex post real interest rate has been below zero and below -1.0 percent. Note that the problem is clearly most severe for the United States and France. But for other countries it is relatively modest. In fact, assuming that inflation includes an upward bias of roughly 1 percentage point, the realized real interest rates were negative less than 20 percent of the time in all countries except the United States.

[24] See the discussion in Cecchetti (1997).

Table 1. Frequency of Negative Ex Post Real Interest Rate

Country	Initial Observation	Less Than Zero	Less Than −1.0
France	1970.01	68%	82%
Japan	1978.11	82%	96%
Germany	1970.01	94%	99%
Italy	1979.11	94%	95%
United Kingdom	1974.06	77%	80%
United States	1970.01	69%	78%

Notes: Table reports the percentage of observations of the ex post real rate on three-month treasury securities, or equivalent, that are less than zero and less than −1.0 percent. Data are monthly.

3.5 Interest Rate Smoothing

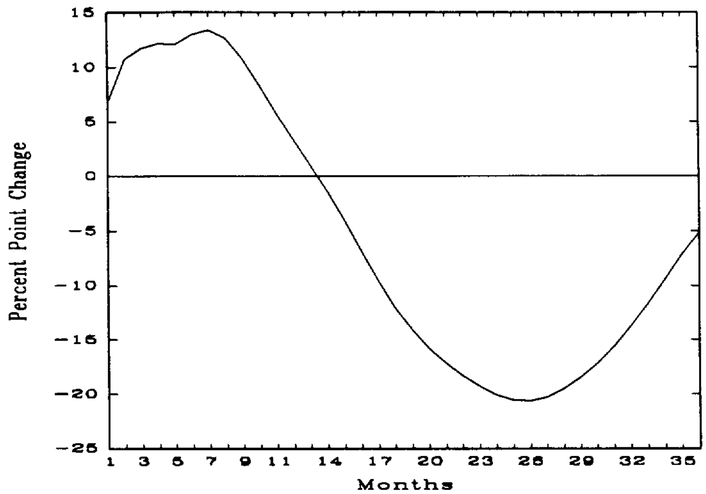
Another important practical concern in the conduct of central bank policy is whether it is optimal to smooth the changes in the policy instrument. There are two issues here. First is the question of whether, following a shock, the optimal response is to have interest rates move immediately up (or down) and then return monotonically to the steady-state level. Second is the separate consideration of whether, given that the policymaker intends to change interest rates by some amount, the entire change should occur all at once.

The policy reaction function immediately yields the answer to the first question. Here the presumption must be that $\phi(L)$ is not monotone. To see this, consider Figure 4, which plots the optimal reaction of interest rates to an innovation in the aggregate price level implied by the impulse response functions plotted in Figure 1 (for the case where $h = 36$ and $\alpha = 1$).[25] The path is hump-shaped. That is, the optimal response to an innovation is to raise interest rates immediately, continue to raise them gradually, and then lower them slowly. This pattern could be further exaggerated if the loss function included an explicit cost to changing interest rates — a term of the form $k(r_t - r_{t-1})^2$.

The second question is more difficult. If the central bank were to decide that the interest rate should be increased by 100 basis points, should the change be in one large jump or in a series of smaller ones? If policy were sufficiently transparent that everyone knew that the interest rate would ultimately rise 100 basis points, so that the changes would be perfectly anticipated, then it is difficult to see why a series of smaller changes would be preferred over a single one. But often, I suspect, this question is asked with a different intention. In fact, the policymaker

[25]See Cecchetti (1996) for details on this computation.

Figure 4. Interest Rate Path following a Shock



will start to change interest rates not really knowing what the final results are likely to be. This would be a form of experimentation.

4 Should Central Bankers Follow Rules?

The entire discussion thus far has been directed at the construction of a rule for central bank policy. But should we try to construct a set of systematic responses to external events? There are numerous reasons to support the adoption of rules by the central bank. The first is the well-known result that with pure discretion, the dynamic inconsistency problem leads to high steady inflation, and the second concerns the importance of policy transparency.

Over fifteen years ago, Barro and Gordon (1983) noted that if a policymaker cannot credibly commit to a zero inflation policy, then even if the policymaker announces that inflation will be zero and all private decisions are based on the assumption that inflation will in fact be zero, it is in the policymaker's interest to renege and induce inflation of some positive amount. The reason for this is that at zero inflation the value of the increase in output obtained from fooling private agents and creating a transitory increase in output (along a Phillips or Lucas supply curve) more than offsets the cost of the higher inflation, and so the claim of zero inflation in the absence of commitment is not credible. In the language of optimal control, a zero inflation policy is not dynamically consistent.

Since the problem is thought to be most severe when potentially short-sighted legislators are capable of influencing central bank policy directly, the most prominent solution has been to create independent central banks. It is commonly thought, and the data confirm, that policymakers who are more independent are better able to make more credible commitments to low-inflation policy.[26]

As Alan Blinder (1997) has recently pointed out, however, there is a potential conflict between central bank independence and representative democracy. Since one of the crucial elements of a democratic society is that the powerful policymakers are accountable to the people, how can we square these two apparently disparate goals of accountability and independence?

Blinder (1997) and Bernanke and Mishkin (1997) suggest that the solution is policy transparency. They argue that if policymakers announce targets and are forced to explain their actions in relation to these preannounced goals, then there is accountability. Put another way, transparency and accountability are enhanced if the elected officials announce the loss function the central bankers are charged with minimizing, and the central bankers in turn demonstrate how they are accomplishing this goal. Researchers have suggested that the publication of the target for prices and/or output along the optimal path would serve this purpose. In fact, not only would policymakers become more accountable, but their policies would become more transparent.[27]

Arguments such as these have led to the implementation of explicit targeting regimes in a number of countries. Prominent among these countries are Australia, Canada, Finland, Israel, New Zealand, Spain, Sweden, and the United Kingdom.[28] Because of their transparency, explicit targeting regimes are easily understood. As a result, potential policy actions are less likely to create uncertainty and instability.

5 Lessons for Policy Formulation

This analysis offers a number of lessons. First, and most important, if a policymaker were to focus on inflation alone, the likely result would be a very high level of real output variation. This factor seems to weigh heavily in favor of the way in which policy targeting is currently carried out around the world.

Consider the example of the countries that have adopted explicit inflation targeting. These include Australia, Canada, Finland, Israel, New Zealand, Spain, Sweden, and the United Kingdom. The central banks in most of these countries appear to take short- to medium-run real fluctuations into account when deciding

[26] Alesina and Summers (1993) establish this empirically and raise the additional possibility that countries with independent central banks not only have lower steady inflation, but less variable output and higher growth. Cukierman, Kalaitzidakis, Summers, and Webb (1993) also investigate the impact of central bank independence on the growth rate of output.

[27] Mishkin and Posen (1997) argue that policy transparency and explicit targeting were important factors in the granting of operational independence to the Bank of England.

[28] See Haldane (1995) for a discussion.

on their policies. This is easiest to see in the banks' official statements. For example, the central banks in New Zealand, the United Kingdom, and a number of other countries announce target ranges — rather than point targets — for inflation. The Reserve Bank of Australia states that its goal is to have inflation average between 2 and 3 percent *over the business cycle*. By using this wording, trhe central bank retains the flexibility to stabilize in the face of short-run real shocks. Even countries with explicitly stated inflation targets behave as if they place some weight on output variability in their implicit loss function.

No country has adopted a zero inflation target, or even a range that is centered at zero. In fact, Haldane (1995, p. 8) reports that only New Zealand's target range includes zero at the lower end. This suggests that there continues to be substantial aversion to the possibility of deflation and some sensitivity to the dangers inherent in bumping against the zero nominal interest rate floor.

Let me conclude by emphasizing that substantial work remains to be done before we can convincingly articulate a detailed and operational rule for central bank policy. The framework I have proposed requires crucial information on which there is simply no general agreement at this date. What is most needed is a set of stable numerical estimates of the impact of policy actions on output and prices — as well as the ability to estimate the impact of exogenous shocks on the goals of policy.

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