Timeless Perspective vs. Discretionary Monetary Policy

in Forward-Looking Models

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1. Introduction

Recent analysis by Clarida, Galí, and Gertler (1999), Jensen (2002), Svensson and Woodford (1999), Walsh (2002), and especially Woodford (1999a, 1999b, 2000) has been highly productive in advancing the profession's understanding of optimal monetary policy. Specifically, these papers emphasize the importance for policy purposes of the distinction between macroeconomic models (of private behavior) that are "forward looking"—i.e., have equations that include expectations of future values of endogenous variables—and those that are not. This distinction—applied to the structural form of the model—is of great theoretical significance, since models derived from optimizing analysis almost invariably include expectations of future variables. A major point of the cited literature is that there is, in forward-looking models, an inefficiency that results from *discretionary* policymaking, relative to that of a well-designed policy *rule*, that obtains in addition to the familiar inflationary bias. (The inflationary bias has been extensively discussed in a huge literature that typically uses non-forward-looking models.) This point, which is implicit in earlier work by Currie and Levine (1993), among others, has been valuably emphasized in the cited papers, especially Woodford (1999b).

There are many associated issues, nevertheless, that remain to be considered. One of these is the *quantitative* extent to which a policy rule of the type in question provides improved outcomes relative to (optimal) discretionary behavior. That magnitude depends, of course, on the specification of the model that is utilized—its parameter values and general aspects of the specification—and an exploration of these features is clearly warranted. A related topic, moreover, concerns the distinction proposed by Svensson (1997, 1999) between "targeting rules" and "instrument rules." Is there in fact a major difference? Or can

targeting-rule outcomes be closely approximated by instrument-rule procedures? Third, in the context of optimal policy-rule analysis, issues concerning operationality—stressed by McCallum and Nelson (1999)—arise naturally. Is the superiority of rule-based over discretionary policymaking enhanced or diminished by realistic specification of information available to the policymaker? Finally, how important is this newly-recognized source of discretionary suboptimality in comparison with the more familiar inflationary bias?

Each of the foregoing issues will be explored in what follows. In addition, we begin with an exposition of the basic analysis that emphasizes Woodford's concept of a "timeless perspective" and its relationship to previous concepts of rule-based policymaking.

2. Basic analysis

As an illustrative framework, let us begin with the near-canonical forward-looking macroeconomic model that is utilized by Woodford (1999b, 2000) and also is a special case of the models in Clarida, Galí, and Gertler (CGG) (1999) and Jensen (2002).[1] This simplest version features only a forward-looking price adjustment or aggregate supply relation of the Calvo-Rotemberg type, augmented with shocks that keep the current natural-rate level of output from being economically efficient.[2] Denoting inflation in period t by π_t and the output gap by y_t, this relation is the New Keynesian Phillips curve (NKPC):

$$\pi_t = \alpha y_t + \beta E_t \pi_{t+1} + u_t, \tag{1}$$

where $\alpha > 0$, $0 < \beta < 1$, and u_t is the shock term. For simplicity, we initially assume that the process generating u_t is white noise. The model that we (and the cited authors) have in mind

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[1] The latter two papers permit first-order autoregressive processes for the shock variables, which make their systems somewhat richer than that considered by Woodford, and also consider model variants that include lagged inflation and output-gap terms.

[2] For some discussion of the nature of the u_t shock in (1) below, see Woodford (1999b, 2000), CGG (1999, pp. 1566−67), Erceg, Henderson, and Levin (2000), and Giannoni (2000). Our notation differs slightly from that of any of the cited authors.

actually also includes an optimizing IS-type demand relationship of the form

$$y_t = E_t y_{t+1} + b_1(R_t - E_t\pi_{t+1}) + v_t, \qquad b_1 < 0 \qquad (2)$$

where R_t is the central bank's interest rate instrument and v_t is a preference or government

spending shock.[3] But we shall at first pretend that the central bank (CB) can directly control

π_t as an instrument—an assumption that is very common in the literature and is innocuous in

the present context.[4] In Section 4 we will extend the analysis in a manner that involves

inclusion of (2) and use of an interest rate instrument.

The central bank's objective function at time t is taken to be of the form

$$Minimize\ E_t\ \Sigma_{j=0}^{\infty}\ \beta^j\ (\pi_{t+j}^2 + \omega y_{t+j}^2), \qquad \omega > 0 \qquad (3)$$

which Woodford (1999a) has shown to be consistent with individual optimality in terms of

agents' preferences under certain reasonable conditions.[5] Consequently, the CB's problem at

some point in time, here taken (without loss of generality) to be $t = 1$, can be expressed as

minimization of the Lagrangian expression

$$L_1 = E_1\ [(\pi_1^2 + \omega y_1^2) + \beta(\pi_2^2 + \omega y_2^2) + ... \qquad (4)$$

$$+ \lambda_1(\alpha y_1 + \beta\pi_2 + u_1 - \pi_1) + \beta\lambda_2(\alpha y_2 + \beta\pi_3 + u_2 - \pi_2) + ...]$$

with respect to $\pi_1, \pi_2, ...,$ and $y_1, y_2, ...$[6] As shown by Woodford (1999b) and CGG (1999),

under policy *commitment* the optimizing conditions include

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[3] Since we have written (2) in terms of the output gap—a somewhat undesirable practice since the IS
relationship fundamentally pertains to aggregate demand, not the output gap—the v_t term also includes the
expected change in the log of the natural rate of output.
[4] If the relation (2) is included as an additional constraint, with optimization then conducted with respect to R_t as
well as y_t and π_t, the Lagrange multiplier attached to this constraint equals zero for all t.
[5] The model that Woodford uses to derive this welfare function has no u_t disturbance in the Phillips curve (1).
Giannoni (2000) provides a rationalization for the u_t term that would continue to imply the objective (3).
[6] In (4), the terms $E_t\pi_{t+1}$ from (1) can be written without E_t operators since $E_1 E_t\pi_{t+1} = E_1\pi_{t+1}$, by the law of
iterated expectations.

$$2\omega y_t + \alpha\lambda_t = 0, \qquad\qquad t = 1, 2, \ldots \qquad\qquad\qquad (5a)$$

$$2\pi_t + \lambda_{t-1} - \lambda_t = 0, \qquad\qquad t = 2, 3, \ldots \qquad\qquad\qquad (5b)$$

$$2\pi_1 - \lambda_1 = 0. \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (5c)$$

Here equations (1), (5a), (5b), and (5c) apparently determine optimal values of π_t, y_t, and λ_t

for period $t = 1$ and planned values as of $t = 1$ for periods $t = 2, 3, \ldots$ But these choices entail

dynamic inconsistency, since the CB could re-solve the problem in time period 2 and would

then choose $2\pi_2 - \lambda_2 = 0$ instead of the condition $2\pi_2 + \lambda_1 - \lambda_2 = 0$ that is suggested by (5b).

Thus the standard commitment solution, in which the CB implements (5a),(5b), and (5c),[7]

views the CB as selecting values in $t = 2, 3, \ldots$ that it currently considers undesirable from

the perspective of its own decision-making process. Since such a pattern of behavior seems

highly implausible, this type of commitment solution does not provide an attractive

equilibrium concept.

There is another equilibrium concept, however, involving a different type of

commitment, that is much more attractive—as Woodford (1999b) argues convincingly.

Instead of using (1), (5a), and (5b) together with the start-up condition (5c) to determine

paths of π_t, y_t, and λ_t for $t = 1, 2, \ldots$, the CB can use (1), (5a), and (5b) without any start-up

condition by applying (5b) in all periods. This approach, which Woodford terms the

"timeless perspective," involves ignoring the conditions that prevail at the regime's

inception—say, by imagining that the decision to apply (5a) and (5b) had been made in the

distant past. In this case, there is no dynamic inconsistency in terms of the CB's own

decision-making process. Specifically, if there is no change in the CB's model, then the

values of π_2 and y_2 chosen by this process in period 2 agree with the values planned in period 1.

An alternative description of this mode of policy behavior can be obtained by specifying that the analyst's concern is with macroeconomic performance within and across regimes, not with transitions from one regime to another. In this case, the analysis supposes that the policy regime being analysed has been in effect long enough that initial conditions, which obtained at the time of its inception, have become irrelevant. This is the conception adopted by Lucas (1980, p. 205), Lucas and Sargent (1981, p. xxxvii), Taylor (1979, p. 1278), and others. Our contention is that this is the most appropriate presumption for monetary policy analysis. To us it seems implausible that private agents could immediately begin forming expectations consistent with any new policy regime, following a regime change, as is assumed by some alternative specifications. The basic rational expectations approach requires that a policy regime has been in effect long enough for private agents to understand it and believe in its continuation.

It is perhaps worth mentioning that this timeless-perspective type of policy behavior agrees basically with what has been viewed by most analysts, since publication of the Barro and Gordon (1983) exposition of the Kydland and Prescott (1977) insights, as "policymaking according to a rule." The various quotes in Woodford (1999b) taken from McCallum (1999a) illustrate that agreement,[8] as does Woodford's placement of his analysis in a section of his (1999b) paper entitled "Rule-Based Policymaking." The modification that King and Wolman (1999, pp. 374–375) make to the commitment case, in their study of optimal monetary policy, also corresponds to adoption of a timeless perspective.[9] It is also worth emphasizing that many studies of optimal monetary policy in forward-looking models have

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[7] When period $t+j$ comes around, the CB can by assumption observe y_{t+j} and π_{t+j}, so it can implement (5a)-(5b) exactly.
[8] See, for example, Woodford's (1999b) footnote 22.

considered policies which are labelled "commitment," but which (since these policies ignore the period 1 first order condition and use only the remaining portion of the commitment conditions) should really be regarded as reflecting timeless perspective policy. Recent examples in this last category of studies including CGG (1999), Batini and Nelson (2001), and Smets (2000).

For comparison, we need to derive the counterpart of conditions (5) provided by "discretionary" policymaking, i.e., a process that presumes period-by-period reoptimization involving each period's start-up conditions. In this case the derivatives with respect to the terms in the Lagrangian expression (4) that correspond to $E_t\pi_{t+1}$ in (1) are all equal to zero.[10] Thus the counterpart of (5b) becomes

$$2\pi_t - \lambda_t = 0 \qquad\qquad t = 1, 2, \ldots \qquad\qquad (6)$$

which is similar to the first-period condition (5c) in the commitment optimization but now applies to each period. Note that discretion can be characterised by the absence of the lagged Lagrange multiplier in the CB's first order condition, as stressed by Woodford (1999a).

In addition, let us express the policy-optimality conditions with the Lagrange mutipliers λ_t substituted out. Then for the discretionary optimum we obtain from (6) and (5a) the following:

$$\pi_t = -(\omega/\alpha)y_t. \qquad\qquad (7)$$

By contrast, the timeless-perspective, rule-based condition implied by (5b) and (5a) is

$$\pi_t = -(\omega/\alpha)\,(y_t - y_{t-1}). \qquad\qquad (8)$$

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[9] King and Wolman's modification is patterned after an analogous procedure in Kydland and Prescott's (1980) study of optimal tax policy.

[10] The reason is somewhat more complex than in the Barro-Gordon (1983) model, which is not forward looking: see Woodford (1999b, pp. 308–309) or CGG (1999, p. 1672).

The latter expression is equivalent to (8) or (7) in Woodford (1999b) and to (4.18) of CGG (1999). It is of some interest to note that in the special case $\omega = \alpha$, and with constant potential GDP growth, the TP rule (8) calls for nominal income growth targeting. This point is related to the findings reported by Jensen (2002) and Walsh (2002).

Quite recently, it has been recognized that use of (8) in all periods, as proposed by CGG (1999) and Woodford (1999b), is not fully optimal within the class of time-invariant policy rules. Specifically, there is a slightly different rule that generates superior results on average, i.e., that yields a smaller unconditional expectation of the conditional expectation in (3).[11] Quantitatively, however, the differences are very small, and in any event this recognition does not negate interest in comparisons between the Woodford-CGG timeless-perspective results and those based on discretionary behavior.

To determine how inflation and the output gap behave in the timeless-perspective equilibrium, we obtain the rational expectations (RE) solution to the model consisting of the policy rule (8) and the private behavioral relation (1). In particular, we look for the minimal state variable (MSV) solution that excludes bubbles and sunspots, as discussed by McCallum (1999b). Thus we conjecture that π_t and y_t are related to the clearly-relevant state variables y_{t-1} and u_t as follows:

$$\pi_t = \phi_{11} y_{t-1} + \phi_{12} u_t \tag{9a}$$

$$y_t = \phi_{21} y_{t-1} + \phi_{22} u_t. \tag{9b}$$

Then $E_t \pi_{t+1} = \phi_{11}(\phi_{21} y_{t-1} + \phi_{22} u_t)$ and substitution into (1) and (8) yields the undetermined-coefficient relationships:

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[11] See Jensen and McCallum (2002), Jensen (2001), and Blake (2001). These papers indicate that optimality requires that (8) be altered to $\pi_t = -(\omega/\alpha)(y_t - \beta y_{t-1})$.

$$\phi_{11} = \alpha\phi_{21} + \beta\phi_{11}\phi_{21} \tag{10a}$$

$$\phi_{12} = \alpha\phi_{22} + \beta\phi_{11}\phi_{22} + 1 \tag{10b}$$

$$\phi_{11} = (\omega/\alpha)(1 - \phi_{21}) \tag{10c}$$

$$\phi_{21} = -(\omega/\alpha)\phi_{22}. \tag{10d}$$

From (10a) and (10c), we find that ϕ_{21} satisfies

$$\beta\phi_{21}{}^2 - \gamma\phi_{21} + 1 = 0 \tag{11}$$

where $\gamma = (1 + \beta + \alpha^2/\omega)$. The relevant root, according to both the stability and MSV criteria,

is

$$\phi_{21} = [\gamma - (\gamma^2 - 4\beta)^{0.5}]/2\beta, \tag{12}$$

which satisfies $0 < \phi_{21} < 1$. Following CGG (1999), let us use the symbol $\delta = \phi_{21}$. Then the

values for ϕ_{11}, ϕ_{12}, and ϕ_{22} can be found to be $\phi_{11} = (\omega/\alpha)(1 - \delta)$, $\phi_{12} = 1/(\gamma - \beta\delta)$, $\phi_{22} =$

$-(\alpha/\omega)/(\gamma - \beta\delta)$ and the solutions are

$$\pi_t = (\omega/\alpha)(1 - \delta)y_{t-1} + (\gamma - \beta\delta)^{-1}u_t \tag{13}$$

and

$$y_t = \delta y_{t-1} - [(\alpha/\omega)/(\gamma - \beta\delta)]u_t. \tag{14}$$

These can be shown, with some tedious algebra, to agree with solution expressions reported

by CGG (1999, e.g. (8.1)).

Finally, to find the MSV equilibrium under discretionary optimal policy, we use (7)

rather than (8) as the policy rule. In a system consisting of (1) and (7), there are no clearly-

relevant state variables other than u_t, so we conjecture a solution of the form

$$\pi_t = \phi_1 u_t \tag{15}$$

$$y_t = \phi_2 u_t. \tag{16}$$

Then $E_t\pi_{t+1} = 0$ and the values of ϕ_1 and ϕ_2 are found to be $\omega/(\omega+\alpha^2)$ and $-\alpha/(\omega+\alpha^2)$.

Neither Woodford (1999b) nor CGG (1999) includes an analysis of the relative losses—the unconditional expectations of the objective function—under the two modes of policy-making. Indeed, they do not actually put forth any claim that the timeless-perspective losses are generally smaller than those from discretionary policymaking.[12] We do not here attempt any general algebraic analysis, but proceed by examining the issue quantitatively by use of calibrated models with specific parameter values varied over fairly wide but realistic intervals. Such an analysis will be included in the next section.[13]

3. Quantitative analysis

Our agenda now is to specify values for the model's parameters α, β, and ω, find the RE solutions described above, and report for a chosen value of the variance of u_t—and chosen autocorrelation properties, if desired—the average values of the loss function. The average values of the intertemporal loss function (3) are proportional to the mean of the instantaneous loss function—its unconditional expectation—which is what we report.[14] (Thus the unconditional expectation of (3) equals the reported values multiplied by $1 + \beta + \beta^2 + \dots = (1 - \beta)^{-1}$.) In what follows, these values are calculated using asymptotic formulae for the moments of the variables in the model (e.g., Hamilton (1994, p. 265)).[15] We use our modification of the QZ algorithm of Klein (2000) to obtain the MSV solution.

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[12] The recent results of Blake (2001) indicate that such a claim would be incorrect, although the contrary cases involve unusually low values of α/ω and β.

[13] A few quantitative results have previously been reported by Vestin (1999), Giannoni (2000), Woodford (1999a), and Walsh (2002), but without the type of systematic exploration provided here.

[14] Here we follow the example of King and Wolman (1999), Rotemberg and Woodford (1999), Rudebusch and Svensson (1999), and Walsh (2002) in our use of the unconditional expectation of (3) as the policy criterion.

[15] These values have been checked by comparison with averages of the same statistics across 100 stochastic simulations (200 periods).

Table 1 reports values of the loss function for a range of α and ω values, with β kept at 0.99 throughout. For α, we would suggest that actual values probably lie between 0.01 and 0.05; see, e.g., the estimates in Galí and Gertler (1999). For the central-bank preference parameter ω our range of 0.001 to 0.1 includes values that place almost all weight on inflation variability and ones that give much weight to output gap variability. Since we are using quarter-year time periods, equal weights in terms of annualized inflation (as in the original Taylor rule) imply $\omega = (1/4)^2 = 0.0625$. The standard deviation of the white-noise u_t shocks is taken to be 0.005, our variables being measured in fractional (rather than percentage) units.[16] Thus the annualized standard deviation is about 2.0 percent, slightly less than is realistic for the U.S. economy. In each entry of Table 1 there are two numbers; the first is the average (i.e., unconditional expectation) loss for the timeless-perspective (TP) solution and the second is for the discretionary (DIS) solution. From the table it can be seen that the TP policy produces smaller losses than the DIS policy for all examined values of α and ω. The quantitative extent of the difference is about 15–20 percent for most values in the table, but falls to a magnitude as low as 2 percent.

To consider whether these results are robust, let us modify the model somewhat. In particular, we now assume that the u_t shock process is serially correlated according to a first-order autoregressive specification with an autoregression parameter value of 0.8. This change will result in solution processes for inflation and the output gap that feature considerable persistence, much more like actual data than those generated by the basic model with white noise u_t shocks. We retain a value of 0.005 for the standard deviation of u_t by reducing the innovation variance by a factor of $[1/(1-0.8^2)] = 2.778$. Results are shown in

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[16] The value chosen for this standard deviation directly influences the values of calculated losses, but does not

Table 1

Losses with TP and DIS policy behavior, basic NKPC

(Reported values are losses times 10^5, TP/DIS)

Value of α	Value of ω			
	0.001	0.01	0.0625	0.10
0.10	0.21/0.23	0.96/1.25	1.69/2.16	1.84/2.27
0.05	0.59/0.71	1.54/2.00	2.07/2.40	2.15/2.44
0.01	1.84/2.27	2.28/2.48	2.43/2.50	2.45/2.50

Table 2

Losses with TP and DIS policy behavior, NKPC with $\rho_u = 0.8$

(Reported values are losses times 10^5, TP/DIS)

Value of α	Value of ω			
	0.001	0.01	0.0625	0.10
0.10	0.24/0.26	1.98/3.43	7.89/21.4	10.6/29.9
0.05	0.89/1.19	5.82/14.9	17.3/42.3	21.4/47.2
0.01	10.6/29.9	29.9/53.1	45.2/57.0	48.2/57.3

influence the relative magnitudes of the losses under timeless-perspective and discretionary policies.

Table 2. There it will be seen that there is a greater percentage difference than before in the TP and DIS outcomes for most α and ω values. The ratios of DIS to TP losses, that is, are somewhat larger than in the case with white noise shocks. This is not too surprising, for the fundamental advantage of the TP rule is that it takes correct account of private sector expectations, and therefore of intertemporal aspects of the situation, which are more pronounced when serial correlation of the shocks is included.

An alternative specification that also tends to generate persistence in inflation, and has been prominent in recent research, is provided by replacement of price-adjustment relation (1) with the following:

$$\pi_t = \alpha y_t + \beta\theta E_t\pi_{t+1} + \beta(1-\theta)\pi_{t-1} + u_t. \qquad\qquad 0 < \theta < 1 \qquad\qquad (17)$$

Relations of this general type have been promoted by Fuhrer (1997) among others, and are considered by CGG (1999), Jensen (2002), and Walsh (2002). To find the TP policy rule with (17) replacing (1), we proceed as in Section 2 and obtain the following first-order conditions in place of (5):[17]

$$2\omega y_t + \alpha\lambda_t = 0 \qquad\qquad t = 1, 2, \ldots \qquad\qquad (18a)$$

$$2\pi_t + \theta\lambda_{t-1} - \lambda_t + \beta^2(1-\theta)E_t\lambda_{t+1} = 0 \qquad\qquad t = 2, 3, \ldots \qquad\qquad (18b)$$

$$2\pi_1 - \lambda_1 + \beta^2(1-\theta)\lambda_2 = 0. \qquad\qquad (18c)$$

Adopting the Woodford-CGG timeless perspective approach, by substituting out the λ_t multipliers between (18a) and (18b), yields the optimality condition

$$\pi_t = (\omega/\alpha)[\theta y_{t-1} - y_t + \beta^2(1-\theta)E_t y_{t+1}] \qquad\qquad t = 1, 2, \ldots \qquad\qquad (19)$$

Here $E_t y_{t+1}$ appears instead of y_{t+1}, since the latter is not known at t.

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[17] In general, changing the Phillips curve specification means that the loss function (3) can no longer be obtained directly from an approximation of household utility. For example, Steinsson (2000) shows that a Phillips curve like equation (17) implies that the period loss function is no longer time-separable. Following

For the case of discretionary optimization, interestingly, there are two possible

concepts. First, one might conceive of the CB as implementing (18a) and (18c) in period 1

and *planning* to implement (18a) and (18b) in each subsequent period. When period 2

arrives, however, the CB re-solves its problem and again implements (18a) and (18c), now

updated to period 2. Indeed, in this case the CB re-solves and implements this solution in

each period. With Lagrange multipliers substituted out, the relevant optimality condition is

$$\pi_t = -(\omega/\alpha)[y_t - \beta^2(1-\theta)E_t y_{t+1}], \qquad\qquad (20)$$

where again it is recognized that y_{t+1} is not known in period t. The second concept, used by

CGG (1999, p. 1692) and Jensen (2002), does not involve the dynamic inconsistency that is

clearly implied by the first. Instead of planning to implement (18b) in future periods, the CB

recognizes in period 1 that in period 2 it will behave just as it does in period 1. In

minimizing (3), accordingly, $E_1\pi_2$ in the constraint (17) for period 1 will be replaced with

$\rho_1\pi_1$, where ρ_1 is a parameter of the equilibrium solution expression $\pi_t = \rho_1\pi_{t-1} + \rho_2 u_t$. In the

present case with white noise u_t, accordingly, the relevant optimality condition with this

conception of discretionary behavior is

$$\pi_t = -(\omega/\alpha)[(1-\beta\theta\rho_1)y_t - \beta^2(1-\theta)E_t y_{t+1}]. \qquad\qquad (21)$$

Thus there is a smaller responsiveness of inflation (and larger responsiveness of output) to

shocks than would be present if policy behavior were as implied by (20). Since (21)

evidently reflects a more standard version of discretion than (20), it will be used in what

follows.[18]

CGG and Jensen, we neglect this nonseparability and continue to use (3) as our welfare criterion.

[18] We proceed computationally by assuming a value for ρ_1, solving the model conditional on that value, determining the value implied by the solution, and iterating. For an alternative, dynamic programming approach to the problem, see Steinsson (2000).

Table 3

Losses with TP and DIS policy behavior, model including (17)

(Reported values are losses times 10^5, TP/DIS)

Value of α	Value of ω			
	0.001	0.01	0.0625	0.10
0.10	0.22/0.23	1.36/1.48	3.70/4.34	4.56/5.45
0.05	0.72/0.75	2.99/3.44	6.60/8.17	7.83/9.85
0.01	4.56/5.45	10.6/13.7	17.7/22.6	19.7/24.6

Results are reported in Table 3 for the case in which (17) describes price adjustment behavior, with $\theta = 0.5$, when u_t is white noise. Here the ratio of DIS losses to TP losses is somewhat larger than in Table 1 for the lower right-hand cells but smaller elsewhere. In all cases covered by our α and ω values, the TP losses are smaller than the DIS losses.

4. Target rules and instrument rules

Implementation of the optimality conditions of the previous section would correspond to adoption of what Svensson (1997, 1999) terms "targeting rules," as distinct from "instrument rules." In these papers, as well as others, Svensson has argued that consideration of targeting rules is preferable for actual central banks and accordingly for analysts. McCallum (1999a) and McCallum and Nelson (1999) have, by contrast, suggested that instrument rules are more interesting from a normative point of view. It could also be argued that they are more relevant empirically, i.e., that the actual inflation-targeting regimes currently in place in New Zealand, Canada, the United Kingdom, and elsewhere are more satisfactorily represented by formal analytical models with instrument rules than with target

rules.[19] An important part of this argument is that no actual CB has revealed what its loss function is—e.g., what its value of ω is in expression (3). Of course an argument of this nature can never be conclusive, but we would point out that Woodford (1999b, pp. 287–299) has presented a sophisticated discussion that is predominantly supportive of this position.

A strictly analytical claim made by McCallum (1999a, p. 1493, fn. 17) is that an instrument rule can typically be written so as to imply instrument responses that would tend to bring about the satisfaction of any (feasible) specified target rule. In the context of the present analysis, for example, one could include the optimizing IS relation (2) as part of the model and then specify an instrument rule for R_t that is designed to implement an optimality condition such as (8). In this case the rule could be written as

$$R_t = (1-\mu_2)\{\bar{r} + \pi_t + \mu_1[\pi_t + (\omega/\alpha)(y_t - y_{t-1})]\} + \mu_2 R_{t-1}, \tag{22}$$

which with $\mu_1 > 0$, $\mu_2 \geq 0$ is similar to an extended[20] version of the Taylor (1993) rule, but with $\pi_t + (\omega/\alpha)(y_t - y_{t-1})$ rather than $\pi_t + y_t$ as the target variable, i.e., the variable that the rule seeks to keep close to some desired value. If the economy is one in which current aggregate demand can be influenced by R_t, then as μ_1 is increased, the variability of the term in square brackets in (21) tends to be decreased, yielding an approximation to the satisfaction of optimality condition (8).[21]

To determine whether it is in fact the case that increasing μ_1 values would lead to approximate satisfaction of (8)—and likewise of the discretionary optimality condition (7)—consider the figures reported in Table 4. There $\alpha = 0.05$ and $\mu_2 = 0$ are retained throughout,

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[19] See, for example, the discussions of the respective central bank practices given by Archer (2000), Freedman (2000), and King (1999).

[20] I.e., a version with an R_{t-1} term included to reflect interest rate smoothing.

[21] Note that it is not being claimed that (22) is the only instrument rule that would serve the purpose of implementing (8), but merely that it will do so (and has been mentioned in the literature).

Table 4

Losses with interest instrument versions of TP and DIS

behavior, basic NKPC model with $\alpha = 0.05$ and $\mu_2 = 0$

(Reported values are losses times 10^5, TP/DIS)

Value of μ_1	Value of ω			
	0.001	0.01	0.0625	0.10
0.5	2.51/2.51	2.90/2.86	5.29/4.20	7.36/4.69
5.0	2.12/2.14	2.45/2.43	3.38/2.63	3.40/2.62
50.0	0.86/1.04	1.58/2.03	2.09/2.41	2.17/2.44
500.0	0.59/0.72	1.54/2.00	2.07/2.40	2.16/2.44

with various values of ω specified and μ_1 increased from the Taylor value 0.5 to extremely

large magnitudes.[22] The shock term in relation (2) includes two components, a white noise

taste component with standard deviation 0.02 and also $\bar{y}_t - E_t \bar{y}_{t+1}$, where the natural-rate

value $\bar{y}_t$ comes from an AR(1) process with AR parameter 0.95 and innovation standard

deviation of 0.007.[23] The results indicate that, at least for this example,[24] the instrument rule

approximates very closely the target-rule optimality conditions for large μ_1 values, i.e.,

strong feedback responses. With $\mu_1 \geq 50$, for example, the $\omega = 0.0625$ case gives TP and

DIS loss values of 2.09 and 2.41, essentially identical to the target-rule losses shown in Table

1. Thus instrument rules can be written to include target rules as extreme special cases, but

are more general.[25]

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[22] We are using relation (1) with a white noise shock term.
[23] This component must be included because the IS equation (2) is written in terms of the output gap.
[24] Similar results have also been obtained for the case where the shock term in (1) is AR(1) with parameter 0.8.
[25] Some readers have suggested that large values of μ_1 would induce excessive volatility of the R_t instrument,

5. Operationality

Exercises such as those of the preceding sections are interesting and even enlightening, but are far removed from the monetary policy problems facing actual central bankers. In reality, CB decision makers have only vague notions about the "true model"— i.e., the workings of the actual economy—and have highly incomplete and imperfect information regarding current values of many variables of macroeconomic importance. Recognition of these features of reality should characterize serious studies of desirable policy. Here we would like to determine how such *operationality* considerations are related to the issues regarding optimality in forward-looking models that have been considered to this point. Clearly, a complete study is beyond the scope of this paper, but some leading problems can be considered. We begin in this section by considering two particular points, ones that have been stressed in previous work by McCallum and Nelson (1999) and McCallum (1999a).

The first point of concern is the absence of knowledge by the CB of the current value of real output during a period at the time at which it is setting its interest rate instrument for that period. To be more realistic one could include the most recent period's value y_{t-1}, but a preferable approach would be to use $E_{t-1}y_t$. Accordingly, we now investigate the effects of including $E_{t-1}y_t$ in place of y_t in instrument rule simulations such as those of Section 4. In addition, we consider cases in which current inflation is not observed, so that $E_{t-1}\pi_t$ is used by the CB in place of π_t, and in which neither of these variables is observed.

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but such an outcome will not obtain if these large values keep the variability of π_t and y_t low. Our results indicate that in fact the latter case prevails.

A first set of results is shown in Table 5. There the first row repeats results from Table 4 for comparison. Then the second row gives the results with the expected current output gap included in place of the (unobserved) current value. It will be seen that the magnitude of the losses is in this case much greater than with full information, with the extent of the increase positively related to ω (i.e., to the strength of the response to the imperfectly observed gap variable). For each ω value considered, it remains true that the TP losses are smaller than the DIS losses. Then in the third row, we suppose that inflation (instead of output) is currently unobservable. In this case, the losses are essentially equal for all ω values and for both TP and DIS policies. The value of the loss function, moreover, is very nearly equal to the value of the variance of the u_t shock term.

In the fourth row, we suppose that both inflation and output are currently unobservable. In this case, the TP losses jump up drastically while the DIS losses increase but by much less. It is understandable that losses could be very large in this case, for the setup is one in which policy is in effect trying to stabilize current variables although they are not observable. In the discretionary case, the separation principle (see Svensson and Woodford, 2002) implies that the attempt is being carried out as efficiently as possible when the $t-1$ expectations are used in the rule in the absence of current observations, but this principle does not apply to the TP case. In that case, it turns out, interestingly, that inclusion of $E_{t-1}\pi_{t+1}$, $E_{t-1}y_{t+1}$, and $E_{t-1}y_t$ yields much better results. In fact the results, shown in the fifth row of Table 5, are equivalent to those given in the fourth row DIS cases.

A second set of results, pertaining to the case in which the price adjustment relation (17) replaces (1), is given in Table 6. Qualitatively, the results are not too different from

Table 5

TP and DIS losses with unobservable output

Basic model with $\alpha = 0.05$, $\mu_1 = 50$, and $\mu_2 = 0$

(Reported values are losses times 10^5, TP/DIS)

Value of ω				
	0.001	0.01	0.0625	0.10
With y_t and π_t in rule	0.86/1.04	1.58/2.03	2.09/2.41	2.17/2.44
With $E_{t-1}y_t$ and π_t in rule	0.74/0.90	3.21/3.29	12.0/17.2	16.1/27.1
With y_t and $E_{t-1}\pi_t$ in rule	2.62/2.57	2.58/2.52	2.53/2.50	2.52/2.50
With $E_{t-1}y_t$ and $E_{t-1}\pi_t$ in rule	2.77/2.64	12.5/3.00	185.6/5.10	31220/6.60
With $E_{t-1}y_{t+1}$, $E_{t-1}y_t$, and $E_{t-1}\pi_{t+1}$ in rule	2.64/2.64	3.00/3.00	5.10/5.10	6.60/6.60

those of Table 5. In particular, when neither π_t nor y_t is currently observable, the TP

performance is poor—but it can be improved by shifting forward the dates of each variable

(whose values are those expected on the basis of $t-1$ data). In fact, in this case the TP results

are superior to those based on the DIS procedure, instead of being equal as in Table 5.

Our second point of concern is arguably of even greater practical importance. It

involves the unobservability of the natural-rate level of output that goes into the CB's

measure of the output gap. In this case the nature of the problem is quite different, we

contend. Rather than reflecting merely a lack of current information, the problem is largely

conceptual—that is, it stems from the existence of various different concepts of the relevant

reference value (which we have been calling "natural-rate"). That there are several distinct

concepts in use is implicit in the terms used by different researchers and practitioners. In

addition to the term "potential," which is frequently used by practitioners, others involve the

words "trend," "capacity," "NAIRU," "market-clearing," and "flexible-price," besides

"natural-rate." There are perhaps fewer distinct concepts than terms, but there seem to be at

least three fundamentally different ones: trend, NAIRU, and flexible-price concepts. And of

course there are many ways of measuring trend output that are quite different in their effects.

Furthermore, since reliance on any particular concept will be maintained over time,

differences will not possess the orthogonality properties of pure "noise."

Which of the concepts is most appropriate theoretically? From the perspective of

dynamic, optimizing analysis, the answer is the third of the three just listed, the flexible-price

concept—i.e., the output level that would prevail in the absence of nominal price stickiness.

There have been very few attempts to implement this type of measure empirically, but there

is one in McCallum and Nelson (henceforth, MN) (1999), which we briefly review.

Table 6

TP and DIS losses with unobservable output

Model Including (17) with $\alpha = 0.05$, $\mu_1 = 50$, and $\mu_2 = 0$

(Reported values are losses times 10^5, TP/DIS)

	Value of ω			
	0.001	0.01	0.0625	0.10
With $E_t y_{t+1}$, y_t, and π_t in rule	1.03/1.11	3.05/3.58	6.60/8.24	7.84/9.88
With $E_{t-1} y_{t+1}$, $E_{t-1} y_t$, and π_t in rule	0.90/0.99	4.58/4.56	28.3/25.0	44.5/39.7
With $E_t y_{t+1}$, y_t, and $E_{t-1} \pi_t$ in rule	2.31/2.41	3.92/4.41	7.06/8.59	8.20/10.2
With $E_{t-1} y_{t+1}$, $E_{t-1} y_t$, and $E_{t-1} \pi_t$ in rule	2.22/2.35	4.39/4.58	25.3/11.0	51.2/14.2
With $E_{t-1} y_{t+2}$, $E_{t-1} y_{t+1}$, and $E_{t-1} \pi_{t+1}$ in rule	2.89/3.12	3.39/4.36	8.47/17.3	11.0/26.4

Note: y_{t-1} appears in all the TP rules except those of the last row, where it is replaced by $E_{t-1} y_t$.

This procedure begins with the assumption that output is produced according to a Cobb-Douglas production function relating the log of output linearly to the logs of labor and capital (n_t and k_t), a deterministic trend, and a shock term a_t reflecting the stochastic component of technological change. Then, since k_t and a_t are given in t whether or not prices are flexible, the difference between the logs of actual and flexible-price output (i.e., the output gap) will be proportional to the difference between actual and flexible-price labor input, $n_t - \bar{n}_t$. For simplicity MN (1999) assumed that the flexible-price level $\bar{n}_t$ (per period, per person) is a constant and, numerically, measured n_t for the United States, 1955.1–1996.4, as total manhours employed in non-agricultural private industry divided by the civilian labor force. This measure is scaled so that the average value of $n_t - \bar{n}_t$ equals zero. The necessity of that step is undesirable, but on the positive side there is no deterministic trend in the resulting $n_t - \bar{n}_t$ series. Then using 0.7 as the elasticity of output with respect to labor, MN constructed a series for the output gap y_t that is shown by MN (1999, p. 28) and contrasted with a measure based on simple log-linear detrending. This series, in combination with the corresponding output series, provides a series for $\bar{y}_t$.[26] It has approximately the time series properties assumed above.

An important point is that non-zero realizations of the technology shock a_t affect the MN (1999) measure of $\bar{y}_t$ one-for-one whereas many detrending procedures, used extensively by academics and to some extent by central banks, remove a_t almost entirely from each period's measure of $\bar{y}_t$. The same is true, furthermore, for many NAIRU-based procedures. So the question at hand is whether this conceptual discrepancy is of quantitative

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[26] Galí and Gertler (1999) also use labor market data, in a different but related manner, in the context of estimating the Calvo specification (equation (1) above).

importance—whether the use of a mistaken concept would induce a large extent of suboptimality into policy rules that rely upon measures of the output gap. We approach this question here by assuming that the MN (1999) measure of the gap is correct but the CB incorrectly uses the measure based on linear detrending in the context of instrument rule (22). We pretend that the CB has accurate knowledge of the true trend, which is excessively optimistic, so the conceptual error as implemented is only that the CB neglects the influence of a_t on $\overline{y}_t$.

Results are reported in Table 7. The loss values reported there can be compared with those in Table 4, in which the experiment is the same except for the postulated mis-measurement of $\overline{y}_t$. It is clear that the consequences of the conceptual error are quite substantial, except for $\omega = 0.001$, and are much larger for large values of ω. Since these values imply giving more weight to the output gap, the results are consistent with the suggestion of McCallum (1999a) and Orphanides (2000) that it is dangerous to respond strongly to measures of the output gap. Furthermore, Table 7 indicates that the TP outcomes are considerably more desirable than those resulting from DIS behavior. That result is in keeping with the spirit of the suggestions of McCallum, Orphanides, and Jensen (2002) that responding to some variable reflecting nominal income growth may be more attractive than responding to the level of the output gap.

Table 7

Losses from responding to incorrect concept for potential output

(Reported values are losses times 10^5, TP/DIS)

Value of	Value of ω			
μ_1	0.001	0.01	0.0625	0.10
0.5	4.09/4.31	4.37/6.67	6.11/18.8	7.75/24.8
5.0	2.13/2.21	2.42/3.98	4.00/16.5	4.93/22.7
50.0	0.86/1.06	1.63/3.38	3.11/16.2	4.15/22.5
500.0	0.59/0.74	1.61/3.33	3.12/16.2	4.17/22.5

6. Inflationary Bias

An issue of obvious interest is how the magnitudes of the losses shown above in Tables 1-6 compare with those implied by the discretionary inflationary bias that is discussed in the enormous literature that uses non-forward-looking models. The inflationary bias carries over to the forward-looking models, as Woodford (1999b) and CGG (1999) have pointed out, if the CB's objective function includes terms such as $\pi_t^2 + \omega(y_t - k)^2$, with $k > 0$, reflecting a desire by the CB to keep output above the natural-rate value that would obtain on average in the absence of nominal frictions (i.e., with fully flexible prices). In the model at hand, the magnitude of the bias is simply $(\omega/\alpha)k$, as can be easily verified. To get a clear

idea of the magnitudes involved, let us then suppose that $k = 0.01$, i.e., that the CB aims for a level of output that exceeds the natural-rate (i.e., flexible-price) value by one percent. Then if $\omega/\alpha = 1$, the bias would be 0.01 and its square, 0.0001, would be appropriate for comparison with the values in Tables 1, 4, and 5.[27] Those tables' entries are losses multiplied by 10^5, of course, so in this case the loss value comparable to the first-row, second-column entries of Table 1 would be 10. More generally, we have the values reported in Table 8. There it will be seen that for values of ω equal to or greater than 0.0625 the inflationary bias is more important, if relevant, than the newly-emphasized dynamic loss.

It is, of course, not clear that actual CBs behave as if k exceeds zero, i.e., behave so as to aim for an output rate higher than the flexible-price (natural rate) value. The position that intelligent CBs do *not* aim for higher output values has been advanced by Svensson (1999), King (1996), and others. To us, nevertheless, it seems possible that positive values of k might well reflect the behavior of some actual CBs, even ones with intelligent and inflation-adverse leaders, since $k > 0$ would be a feature of CB preferences that accord with a welfare criterion based on individual utility functions in the presence of some externalities or such real factors as monopolistic competition or tax distortions that imply that the flexible-price competitive equilibrium is not socially optimal (as shown by Woodford, 1999c). Of course, CBs may regard these real factors as more appropriately dealt with through devices other than monetary policy, and this, indeed, is the assumption about how real distortions are treated in many recent analyses of optimal monetary policy (including Woodford (1999c) and Aoki (2001)). In any event, knowledge of the relative importance of this bias is relevant for the strategic decisions of CBs.

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[27] In these cases, the standard deviation of u_t is, we think, fairly realistically calibrated. For the other tables, different values would have to be used.

Table 8

DIS Losses Due to Inflation Bias

Basic Model

(Reported values are losses times 10^5)

Value of α	Value of ω			
	0.001	0.01	0.0625	0.10
0.10	0.001	0.10	3.91	10.0
0.05	0.004	0.40	15.6	40.0
0.01	0.10	10.0	391	1000.0

7. Concluding Remarks

Let us conclude with a very brief summary. We began by reviewing the distinction between the timeless perspective and discretionary modes of monetary policymaking, the former representing rule-based policy as formalized by Woodford (1999b). In the context of models with forward-looking expectations, this distinction is greater than in the models that have been typical in the rules-vs.-discretion literature. Typically, that is, there is a second inefficiency from discretionary policymaking, distinct from the more familiar inflationary bias. We have made calculations of the quantitative magnitude of this second inefficiency or loss, using calibrated models of two types prominent in the current literature and a wide range of values representing the relative seriousness of inflation and output-gap variability. The magnitude of the losses is significant, and greater in some (but not all) cases than the inflationary bias from a one percent excess of the central bank's output target over the natural rate value. The losses tend to be somewhat larger in model specifications that imply inflation

rate persistence and are often (but not universally) larger with more objective-function weight on output-gap variability.

In addition, we have examined the distinction between instrument rules and targeting rules; our results indicate that targeting-rule outcomes can be closely approximated by instrument rules that respond to any failure of the targeting rule's optimality condition to hold. Using the instrument rule formulation, a brief investigation of operationality issues, involving the unobservability of current output and perhaps inflation, is reported. In addition, a set of cases involving the assumption that the wrong concept of the natural-rate or potential level of output, essential in measuring the output gap, is used by the monetary policymaker. In almost all of the various cases examined in the paper, the performance of timeless perspective policymaking is at least as good as that provided by optimal discretionary behavior. Furthermore, these optimal rules can be well approximated by simple feedback rules based on an interest rate instrument.

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