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ABSTRACT

Much recent monetary policy analysis has featured stochastic simulations with small structural macroeconomic models that include: a spending vs. saving ('IS') sector; a price-adjustment sector; and an interest rate policy rule. The first two are frequently specified so as to reflect optimizing behavior; policy may or may not be specified as optimizing depending on the study's objectives. Some leading issues concern modifications to simple quantitative optimizing models that are needed to generate realistic degrees of persistence in inflation and output-gap variables. A major policy issue is whether it is desirable for monetary policy to respond strongly to the output gap. The paper argues that the latter is unobservable and considers the implications of using a trend-type measure while the true concept is of a type more in keeping with basic theory. In such circumstances, highly undesirable consequences are likely to ensue if policy responds strongly to the measured gap.

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Recent years have seen a marked convergence, among academic and central bank researchers, on a general framework for conducting analysis of monetary policy. There is more of a convergence in terms of method, however, than specific models, for crucial features of the framework are flexible enough to accommodate quite divergent views regarding the workings of the economy. In this paper, I will review the framework, describe some leading disputes concerning model specification, and discuss one particular policy issue—mentioned in the title—that is of great practical importance.

1. Agreement on Framework

The method or approach on which there is substantial agreement can be described as follows: the researcher specifies a quantitative macro model that is intended to be structural (invariant to policy changes) and consistent with both theory and data. Then, by stochastic simulation or analytical means, he determines how crucial variables (such as inflation and the output gap) behave on average under various alternative policy rules. Usually, rational expectations (RE) is assumed in both stages. Evaluation of the different outcomes can be accomplished by means of an optimal control exercise, or by reference to an explicit loss function, or left to the judgement (i.e., loss function) of the implied policy-maker. To an extent, this approach has been used for decades, but the tendency to be more explicit, to show respect for both theory and evidence, to utilize RE, and to stress performance under alternative maintained rules is much stronger than in the past.

There is also considerable agreement about the general, broad structure of the macroeconomic model to be used.[1] It can be outlined in terms of a simplified three-sector representation in which R_t is a one-period interest rate while p_t and y_t are logs of the price level and output, with $\bar{y}_t$ the natural-rate value of y_t:

(1) $$y_t = b_o + b_1(R_t - E_t\Delta p_{t+1}) + E_t y_{t+1} + v_t$$

(2) $$\Delta p_t = \beta E_t \Delta p_{t+1} + \alpha(y_t - \bar{y}_t) + u_t$$

(3) $$R_t = (1-\mu_3)[r + \Delta p_t + \mu_1(\Delta p_t - \pi^*) + \mu_2(y_t - \bar{y}_t)] + \mu_3 R_{t-1} + e_t.$$

Here (1) represents an optimizing IS-type relation or set of relations, (2) a price adjustment relation or set of relations, and (3) a monetary policy rule for period-by-period (quarters) setting of the policy instrument R_t. Also, $E_t z_{t+j}$ is the expectation of z_{t+j} conditional on information available in t, while v_t, u_t, and e_t are exogenous shocks, v_t reflecting tastes and fiscal policy. If capital and therefore $\bar{y}_t$ are treated as exogenous, as in the simplest versions, then (1)-(3) determine time paths for y_t, Δp_t, and R_t.[2] If investment is treated endogenously, then capital and $\bar{y}_t$ are endogenous and additional relations must be included in the sector here represented by (1). With no money stock terms in (1), there is no need to include a money demand equation even though one may be implied by the optimizing analysis.

It should be noted briefly that the private behavior portions of the model are often justified by full-blown dynamic optimizing

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[1] See, e.g., Richard Clarida, Jordi Gali, and Mark Gertler (1999) and papers in the volume edited by John Taylor (1999).

[2] Also included are relevant transversality conditions.

analysis in a general equilibrium setting. Thus it would be incorrect to suggest, as in Neil Wallace (2000, p. 933), that the body of research under discussion "build[s] models one equation at a time and justif[ies] each equation with a separate story." That all of the private sector relations can be obtained from one unified analysis is demonstrated in several papers going back to Robert King and Alexander Wolman (1996) and Tack Yun (1996).

The policy rule may or may not reflect optimizing behavior by the central bank (CB), depending on the purpose of the analysis. If the object is to find the optimal policy for the particular model under consideration, then (3) will be replaced by the implied rule for R_t that results from optimization with respect to the CB's objective function—which itself may or may not be explicitly based on the utility function of private agents. But it is not true that all worthwhile analysis presumes optimization by the CB; positive analysis of the effects of different hypothetical rules represents an alternative approach that some analysts find more useful.[3]

2. Disagreement on Specifics

Let us now consider some of the leading issues concerning behavior represented by (1), (2), and (3). In doing so it will be helpful to have a particular quantitative example at hand so that the effects of different specifications can be illustrated. Suppose then that the model's parameters are $b_1 = -0.4$, $\beta=0.99$, $\alpha=0.03$, $\mu_1=0.5$, $\mu_2=0.5$, $\mu_3=0.8$. (The latter reflects a realistic degree of interest rate smoothing.) Also, v_t, u_t, e_t, and $\bar{y}_t$ are AR(1) proc-

[3] No actual CB has as yet publicly disclosed an explicit objective function, presumably because none has been adopted.

esses with AR parameters 0.0, 0.0, 0.0, and 0.95, respectively, and innovation standard deviations of 0.03, 0.002, 0.0017, and 0.007. Then we can examine the model's impulse response functions to learn about its properties. These are shown for unit realizations of e_t, v_t, u_t, and η_t (innovation in $\bar{y}_t$) as the dashed curves in Figure 1.

With regard to the "IS" relation (1), note that only one of the impulse response functions (IRFs) shows much inertia in the series for y_t. In this model, as a consequence, neither y_t nor the output gap, $\tilde{y}_t = y_t - \bar{y}_t$, features persistence in the implied auto-covariance functions. Since high persistence is present in the data, this reflects a weakness of the model, as emphasized by Fuhrer (2000) and others.[4] That weakness can be remedied to a considerable extent, while still representing optimizing behavior, by adoption of a household utility function in which current-period utility depends upon C_t/C_{t-1}^h, rather than just C_t, where the latter is per-capita consumption. With Fuhrer's estimated value of h=0.8, much more persistence is generated (as will be shown below).

Another IS-related dispute concerns the value of b_1 (or its counterpart if we take h>0). Thus Julio Rotemberg and Michael Woodford (1999) use –6 whereas McCallum and Edward Nelson (1999) suggest –0.2. My present belief is that –0.4 is more appropriate than either; this supposes that –0.2 is about right for consumption alone but needs to be increased to reflect the investment spending

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[4] These include Glenn Rudebusch and Lars Svensson (1999), who prefer to use a small model not justified by optimizing analysis but featuring a good fit to the U.S. time series data.

that is not explicit in the simplified structure (1)-(3).

More controversial still is the price adjustment specification. With the basic relation (2) and a white noise u_t, the IRFs for Δp_t show very little inertia, as shown by the dashed curves in Figure 1.[5] Again the absence of persistence follows, and again it is counterfactual. There are two common routes for introducing persistence. One is to respecify the price adjustment equation as

$$(2') \qquad \Delta p_t = (1-\phi)E_t\Delta p_{t+1} + \phi\Delta p_{t-1} + \alpha(y_t-\bar{y}_t) + u_t.$$

Here the value ϕ=0.5 is suggested by the approach of Fuhrer and Moore (1995), but some argue for a higher value of ϕ. With ϕ=0.5, and also using the h=0.8 case with habit formation in consumption, the results are as shown by the solid curves in Figure 1. These seem much more consistent with empirical reality. As yet, however, no one has produced a convincing optimizing rationale for (2').

It has been suggested that one could retain (2) but specify that u_t is serially correlated, e.g., $u_t=\rho u_{t-1}+\varepsilon_t$ (with ε_t white noise) with ρ=0.8. That change could result in realistic persistence in inflation, but would not affect the first three IRFs in Figure 1. Also, it is again the case that the theoretical rationale is quite weak. Indeed, it is not clear just what phenomena u_t is supposed to represent, even when assumed to be white noise.

McCallum and Nelson (1999) implicitly object to both (2) and (2') on the grounds that neither satisfies the strict version of the natural rate hypothesis. They propose instead the P-bar model,

[5] With μ_3=0, there would be no persistence at all; the responses in Figure 1 would be merely one-period (one-quarter) spikes.

which does satisfy the NRH and implies much persistence for y_t and $\tilde{y}_t$. It does not generate adequate inflation persistence, however, and leads to a few counter-intuitive responses to certain shocks.

A leading dispute concerning policy is whether it is desirable for the CB to respond strongly to the output gap, $\tilde{y}_t$. To set the stage, adopt (2') and h=0.8 and consider the standard deviations (SDs) of Δp_t, $\tilde{y}_t$, and R_t in Table 1. Since constant terms are ignored in the simulations, these SDs reflect root-mean-square targeting misses for Δp_t and y_t. In Table 1, it is assumed that the CB responds to the variables $E_{t-1}\Delta p_{t+1}-\pi^*$ and $\tilde{y}_t$. As the response to $\tilde{y}_t$ is strengthened (μ_2 is increased), the variability of $\tilde{y}_t$ is reduced, as can be seen readily from each row. The variability of $\Delta p_t-\pi^*$ is, however, increased for large values of μ_2. In this sense there is a tradeoff between inflation and output-gap variability. Interestingly, such a tradeoff does not exist if there is no shock term u_t in equation (2'). If Table 1 were redone with $\sigma_u=0$, the entries for $\mu_1=0.5$ and $\mu_2=50$ would be 0.47, 0.83, and 11.23. So one issue needing resolution is the existence and nature of the u_t shock term.

3. Policy Rule Operationality

We now turn to the dispute concerning the role of the output gap in the CB's policy rule. One point concerns the availability of data. Whereas many analysts proceed under the presumption that the CB can observe and respond to Δp_t and $\tilde{y}_t$ when setting R_t, McCallum and Nelson (1999) and Athanasios Orphanides (2000) have disagreed strongly. An obvious first step in the direction of realism is to replace $\tilde{y}_t$ in (3) with $E_{t-1}\tilde{y}_t$. To see whether this replacement has much effect on the CB's ability to conduct a successful stabilization policy, consider next the SDs reported in Table 2. Here we see that for large values of μ_2 the effectiveness of the rule, in terms of the SD of $\tilde{y}_t$, is reduced. The reduction is not large, however, and for small values of μ_2 there is almost none.

A second point of concern is, therefore, of 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. Rather than reflecting merely a lack of current information, the problem in this case is largely conceptual—that is, 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 "natural rate," other terms involve the words "potential," "trend," "capacity," "NAIRU," "market-clearing," and "flexible-price." There are perhaps fewer distinct concepts than terms, but there are at least three fundamentally different ones: trend, NAIRU, and flexible-price. And of course there are many ways of measuring trend output that are quite different in their effects. Crucially, since reliance on any particular concept will persist over time, differences will not have 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 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 approach empirically, but there is a brief one in McCallum and Nelson (M-N) (1999). It begins with the assumption that output is produced according to a production function linearly relating y_t 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 <u>given</u> in *t* whether or not prices are flexible, the difference $y_t - \bar{y}_t$ (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 M-N assumed that $\bar{n}_t$ (per period, per person) is a constant. Numerically, M-N 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, and scaled the measure so that the average value of $n_t - \bar{n}_t$ would equal zero. The necessity of that last step is undesirable, but on the positive side there was no need to remove any trend from the resulting $n_t - \bar{n}_t$ series. Then using 0.7 as the elasticity of output with respect to labor, M-N constructed a series for the output gap $\tilde{y}_t$. This series, with the corresponding output series, gives a series for $\bar{y}_t$. It has approximately the time series properties assumed above for that variable.

An important point is that non-zero realizations of the technology shock a_t affect the M-N measure of $\bar{y}_t$ one-for-one whereas many detrending procedures 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 now is whether this conceptual discrepancy is of quantitative importance—i.e., whether use of a mistaken concept would induce a large extent of suboptimality into policy rules that rely upon measures of the output gap.

To approach this question I now suppose that the M-N measure of the gap is correct but the CB incorrectly uses the measure based on linear detrending. I pretend that the CB has accurate knowledge of the true trend, which is overly optimistic, so the error as implemented is only that the CB neglects the influence of a_t on $\bar{y}_t$.

Results are reported in Table 3. The SD values shown there differ from those in Table 2 only because of the postulated mismeasurement of $\bar{y}_t$. It is clear that the consequences of the conceptual error are quite substantial for large values of μ_2.[6] Also, large values for both μ_1 and μ_2 entail excessive R_t variability, which requires either a high target inflation rate or frequent problems of R_t approaching its zero lower bound. Thus these results support the view that it is undesirable to respond strongly to the output gap.

[6] If the AR parameter for $\bar{y}_t$ is larger than 0.95, as M-N (1999) estimate, the consequences are even more serious.

Table 1--Standard Deviations of Δp_t, $\tilde{y}_t$, and R_t with $\tilde{y}_t$ in Rule

Value of μ_1	μ_2 = 0.0	μ_2 = 0.5	μ_2 = 5.0	μ_2 = 50.0
0.5	2.66 1.99 1.86	2.60 1.88 1.98	2.82 1.45 3.55	4.17 0.83 11.77
5.0	1.80 1.75 2.54	1.79 1.69 2.60	1.89 1.45 3.71	2.78 0.85 11.40
50.0	1.31 1.63 5.88	1.29 1.64 5.82	1.34 1.52 6.12	1.66 1.01 11.95

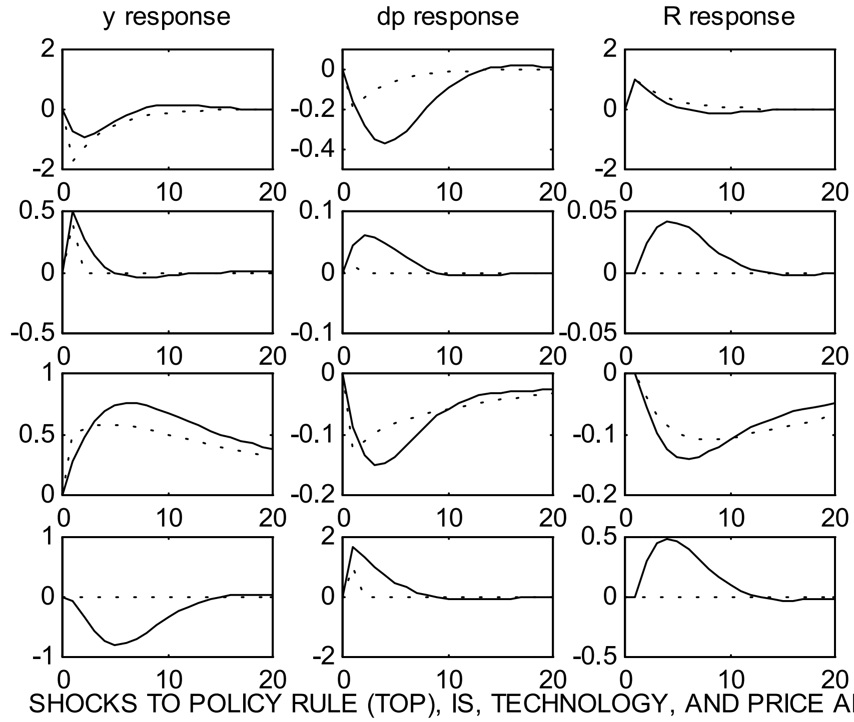
Table 2--Standard Deviations of Δp_t, $\tilde{y}_t$, and R_t with $E_{t-1}\tilde{y}_t$ in Rule

Value of μ_1	μ_2 = 0.0	μ_2 = 0.5	μ_2 = 5.0	μ_2 = 50.0
0.5	2.68 1.99 1.85	2.69 1.96 1.98	2.98 1.65 2.89	4.45 1.23 6.64
5.0	1.77 1.74 2.48	1.82 1.70 2.56	1.92 1.58 2.98	2.75 1.24 5.94
50.0	1.29 1.65 5.77	1.29 1.65 5.78	1.34 1.59 5.85	1.63 1.30 6.83

Table 3--Standard Deviations of Δp_t, $\tilde{y}_t$, and R_t with $E_{t-1}y_t$ in Rule

Value of μ_1	μ_2 = 0.0	μ_2 = 0.5	μ_2 = 5.0	μ_2 = 50.0
0.5	2.71 2.03 1.90	3.45 2.02 2.73	12.89 2.32 12.19	57.99 2.32 58.35
5.0	1.80 1.73 2.53	1.84 1.73 2.62	2.68 1.65 3.57	12.33 1.65 13.39
50.0	1.29 1.65 5.77	1.30 1.63 5.81	1.37 1.61 5.87	2.44 1.39 7.02

Figure 1—Impulse Response Functions for Two Models



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