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Some Implications of Endogenous Stabilization Policy

JUST AS EVERYBODY TALKS ABOUT the weather, every economist talks about endogenous stabilization policy, but nobody ever does anything about it. In recent years, the authors of numerous econometric studies of fiscal and monetary policy have warned that the policy variables that they treat as exogenous should perhaps be treated as endogenous if the stabilization authorities were pursuing an active countercyclical policy during the period in question. Typically, the warning is the last word on the subject; and so far as we know, no efforts have been made to investigate the kinds of difficulties this omission may cause.

The idea that the typical stabilization policy variables—federal government purchases of goods and services, income tax rates, the monetary base (or unborrowed reserves), the Federal Reserve's discount rate, and so on—should perhaps be treated as endogenous in econometric studies raises a host of issues for the estimation and use of macro models. In this paper we hope to say something to three groups who are interested in the econometric approach to monetary and fiscal policies.

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For the first—a single, unified, stabilization authority—we have mostly good news. We find that, if it follows the conventional structural approach to econometric model building and estimation, and uses the solved reduced form to compute multipliers, the resulting estimates will probably not err much even if stabilization policies have in the past been formulated endogenously. If, however, the authority should adopt the so-called reduced-form method of estimating multipliers—as exemplified by the work of Andersen and Jordan[1]—it may get a very distorted picture indeed.

Our second ideal type is an independent stabilization authority—say, a monetary authority that works in relative isolation from its fiscal counterpart. It, of course, faces the same estimation problems as the single policy maker. But, given any estimated model, it may have additional difficulty in computing multipliers correctly if the other authority is reacting endogenously to economic developments. Such an authority may find it very important to estimate the "reaction function" of the other and take this into account in policy making. Failing to do this, it may seriously overstate the strength of its own policy instruments.

Finally, we address the outside economist who wishes to analyze the operation and effectiveness of historical stabilization policies. He has to worry about the same estimation biases. But, more important, if, during the period he is studying, the stabilization authorities were reacting endogenously to the course of the economy, it may be crucial for him to estimate any systematic reaction patterns that existed and append these equations to his econometric model. Otherwise, he may get a very misleading picture of the way fiscal and monetary policies have worked in the past.

Framework of the Analysis

From all three points of view, each of these questions can be illustrated best by reference to a trivial macroeconomic model. This model should not be interpreted literally, but rather as representative of any structural model in which there are control instruments for each of two stabilization authorities.

1. Leonall C. Andersen and Jerry L. Jordan, "Monetary and Fiscal Actions: A Test of Their Relative Importance in Economic Stabilization," *Federal Reserve Bank of St. Louis Review*, Vol. 50 (November 1968), pp. 11–24.

Suppose that national income were determined by a single stochastic behavior equation relating consumption (C) to income (Y), with u representing the stochastic element,

$$C_t = a + bY_t + u_t, \tag{1}$$

and an equilibrium condition stating that income must equal the sum of consumption, investment (I), and government (G) demands:

$$Y_t = C_t + I_t + G_t. \tag{2}$$

Assume further that government purchases of goods and services, G_t, are controlled directly by the fiscal authority, and that investment expenditures, I_t, are controlled directly by the monetary authority. The problems considered in this paper arise if the policy instruments, while exogenous in the economic sense—that is, determined outside the framework of equations (1) and (2)—are nevertheless systematically related to some endogenous variables in the model. The issues can be divided into two classes: problems in estimating econometric models, and problems in using these estimates to compute policy multipliers.

PROBLEMS IN ESTIMATING ECONOMETRIC MODELS

If an investigator's ultimate concern lies with policy multipliers, he might take one of two approaches to estimation. First, he might estimate the marginal propensity to consume, b in equation (1), by some standard simultaneous-equations technique, and use this estimate to construct a multiplier. This is the conventional structural approach that, in more complex models, involves obtaining multipliers from the solved reduced form. Second, he might solve (1) and (2) for what would typically be called the reduced form of this system:

$$Y_t = \frac{a}{1-b} + \frac{G_t}{1-b} + \frac{I_t}{1-b} + \frac{u_t}{1-b}, \tag{3}$$

estimate this by ordinary least squares, and use the estimated coefficients of G_t and I_t as his fiscal- and monetary-policy multipliers, respectively. This is the reduced-form technique of Andersen and Jordan and others.

Both methods will yield satisfactory results if the policy variables are exogenous in the statistical sense, that is, uncorrelated with the error term, u_t. However, if policy is formulated endogenously there are a variety of reasons why G_t and I_t might be correlated with u_t.[2] Consequently, (3) would not be a true reduced-form equation, and attempts to estimate it by ordinary least squares would yield inconsistent results. In other words, the econometrician would commit a specification error by treating G_t and I_t as exogenous when they were in fact endogenous. From here on, therefore, we shall refer to equations like (3) as "partial reduced forms," to distinguish them from true reduced forms.

This point made, a question arises as to the meaning and usefulness of reduced-form equations. We explore some of the difficulties in interpreting these kinds of results in the sections below. In the next section we seek to answer the following question: If both the monetary and fiscal authorities formulated policy endogenously, what kind of results would be obtained by an investigator who used ordinary least squares to estimate the partial reduced form? For the representative class of simple reaction functions that we consider, it turns out that fairly definite analytical answers can be established. In particular, interpreting the estimated partial reduced-form coefficients as policy multipliers can be extremely misleading. Typically, an authority that is conducting an effective stabilization program will appear to have a very small (and statistically insignificant) multiplier in simple reduced-form experiments, and, conversely, an ineffective authority will get a large (and statistically significant) multiplier. What these results point up is that *if we knew the true multipliers*, we could use the estimated reduced forms to assess the relative performances of the monetary and fiscal authorities as stabilizers. Alternatively, *if we knew the behavior patterns of the two authorities*, we could use these estimates to compare the sizes of the fiscal and monetary multipliers. If we know neither of these a priori, the coefficients of a partial reduced-form equation hopelessly entangle the astuteness of the authorities with the relative sizes of the multipliers.

Below we use Monte Carlo techniques to explore a variety of ways of doing reduced-form estimation in a hypothetical economy that resembles the United States in 1954–66, except that it has fiscal and monetary reaction functions that we have invented. These experiments can be viewed as "realistic" illustrations of the pitfalls that we discuss in the next section. Our basic conclusion is that reduced-form estimation is at best a highly inefficient and at worst a severely biased method of estimating policy multipliers.

2. We examine some possible sources of such correlation in the next section. For the moment, we simply assume that it exists.

But even the more conventional structural estimation procedures can run into trouble when policy is endogenous. Two distinct but related problems arise here. Consider what would be done by an economist seeking to estimate a structural econometric model to assess multipliers, who omitted from his specification equations explaining monetary and fiscal policy. Assuming that the authorities were in fact reacting endogenously during the period in question, he would commit two sorts of errors in treating the policy tools as exogenous. First, if using two-stage least squares, he would presumably utilize all the policy variables as instrumental variables in the first stage. Second, where structural equations include some policy tools directly, he would incorrectly treat the endogenous policy variable as exogenous. In both cases, misclassification of one or more variables would lead to inconsistent estimates.

The possible simultaneous-equations biases that arise from ignoring reaction functions in estimating *structural* econometric models are treated below. They turn out to be the least serious of the problems caused by reaction functions, at least in our Monte Carlo experiments. The reasons are simple, and probably apply to a wide class of econometric models. First, in most practical applications the list of predetermined variables is quite long, so incorrectly appending some endogenous policy variables to it may change the two-stage least squares estimates very little. Second, policy variables appear explicitly in very few structural relations, so their misclassification as exogenous may have serious effects on only a handful of equations in a very large model. In fact, in the simple model used in our simulation experiments, even the one equation that was seriously affected by the misclassification *in principle* proved not to be seriously affected *in practice*. Furthermore, as will be explained in the next section, there may be plausible reaction patterns that do not imply estimation biases, even in theory.

PROBLEMS IN USING ECONOMETRIC MODELS

Once we have estimated our model, and seek to utilize it to compute policy multipliers, reaction functions lead to further complexities. And while estimation problems are common to all users, unified policy makers, uncoordinated policy makers, and outside economists may all want to use a given model in different ways.

To illustrate the various multiplier concepts, suppose that structural estimation biases are negligible, so that the estimates of a and b in equation (1), obtained under the false assumption that G and I are exogenous, are nevertheless approximately correct. Assume further that, during the period in question, the policy makers followed reaction functions of the following general type:

$$G_t = G_t^* - g(Y_t - Y_t^*) + v_t \tag{4}$$

$$I_t = I_t^* - m(Y_t - Y_t^*) + e_t, \tag{5}$$

where G^*, I^*, and Y^* are the target values of the variables, g and m are reaction coefficients, and v and e are additive disturbances. What these behavioral rules say is that each authority has some long-run desired path for its policy instrument, but is willing to deviate from it in response to deviations of national income from its target level. Equations (4) and (5) are specific examples of how the policy instruments (G_t and I_t) can become negatively correlated with the disturbance term of the partial reduced form.

A model builder who ignored the reaction functions would presumably use his estimated b to compute policy multipliers:

$$\frac{dY}{dG} = \frac{1}{1-b}, \quad \frac{dY}{dI} = \frac{1}{1-b}, \tag{6}$$

as in the partial reduced form. But, if the reaction functions were considered part of the model, he would presumably solve the system of equations (1), (2), (4), (5) simultaneously to find the true reduced-form equation for national income:

$$Y_t = \frac{a + G_t^* + I_t^* + (g+m)\,Y_t^* + u_t + v_t + e_t}{1 - b + g + m}. \tag{7}$$

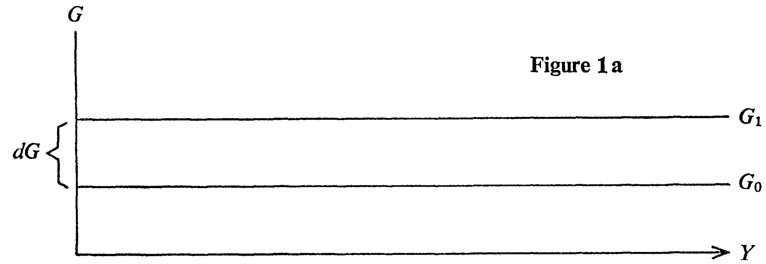
From this expression, it appears natural to compute multipliers such as

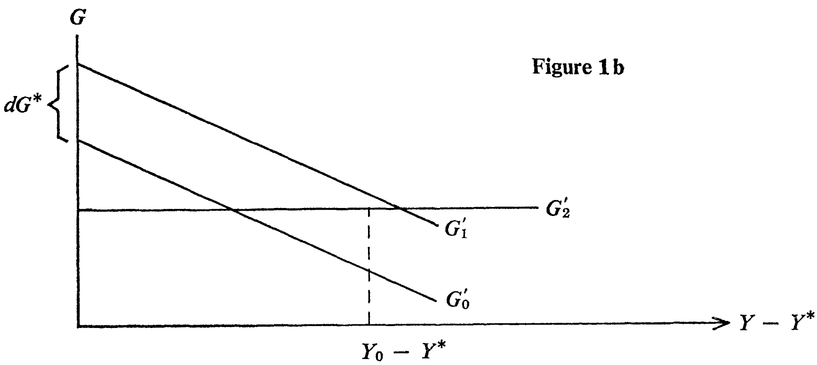
$$\frac{dY}{dG^*} = \frac{1}{1-b+g+m}, \quad \frac{dY}{dI^*} = \frac{1}{1-b+g+m}. \tag{8}$$

These formulas show, of course, the usual effects of automatic stabilizers. The differences between (6) and (8) are precisely analogous to the difference between the simple Keynesian multiplier in the absence of an income tax, $1/(1-b)$, and that same multiplier in the presence of an income tax at marginal rate t, $1/[1-b(1-t)]$.

The issue of which sort of multipliers are relevant for which sort of questions can be clarified with the aid of Figure 1 below, which uses government spending multipliers for illustrative purposes. Figure 1a depicts the situa-

Figure 1. Alternative Notions of Fiscal Multipliers





tion in a world with no reaction functions. Because the volume of government purchases is independent of GNP, no ambiguity attaches to the term "government spending multiplier." If autonomous government spending shifts upward from G_0 to G_1, the fiscal policy multiplier is simply dY/dG as in equation (6).

However, when reaction functions exist, a "shift in fiscal policy" has several plausible meanings. Two of these are illustrated in Figure 1b. There schedule G_0' depicts the initial reaction function; government spending is a declining function of output, as in equation (4). One possible interpretation of fiscal expansion—the one adopted in equation (8) and elsewhere in this study—is an upward shift in the reaction function from G_0' to G_1' in Figure 1b, that is, an increase in the intercept, G^*. This leads us to compute multipliers like dY/dG^*. The analogy to the standard treatment of tax multipliers should be obvious. In models that include a tax function like $T = T_0 + tY$, it has become a commonplace to compute multipliers like dY/dT_0 instead of the ill-defined dY/dT. Our use of dY/dG^* instead of

dY/dG when G is dependent on Y is meant to conform to this practice. It serves to answer the following counterfactual question: What would have been the impact on GNP if the allocation branch of the government decided to increase government spending by \$1 billion, and the stabilization branch adopted a "business as usual" attitude?

However, under a second interpretation of fiscal stimulus, multipliers like dY/dG are more interesting. They would be relevant if the authorities ordered an increase in government purchases and simultaneously suspended the reaction functions, that is, shifted from schedule G_0' to schedule G_2' in Figure 1b (where $Y_0 - Y^*$ is the current GNP gap). On this interpretation of fiscal actions, whereby the government increases spending by $dG = dG^*$ and then closes down the stabilization branch, multiplier equations such as (6) would prevail. And this may be the more plausible behavior pattern in many cases. After all, our previous characterization of fiscal policy (a switch from G_0' to G_1' in Figure 1b) implies that the government first raises expenditures in order to stimulate income, and then reduces them if income actually rises.

Which interpretation of fiscal policy actions is the "correct" one depends on who is doing the multiplier calculation. From the viewpoint of a single policy-making authority charged with stabilizing national income, multipliers such as (6) would probably matter most; that is, it would be interested only in the conventional structural equations of a model, not in the reaction functions, since it is not bound by its own previous behavior. A unified stabilization authority need care about historical reaction functions only to the extent that structural estimates of the rest of the model might be biased if they are ignored; and these structural estimation biases may not be too important in practice.

Alternatively, two stabilization authorities cooperating perfectly might not choose to suspend their reaction functions but instead might maintain their basic reaction patterns, as in (4) and (5), changing only the intercepts. This would make multipliers like (8) operational, but both sets of policy makers would *know* the reaction coefficients, g and m, and would not have to worry about estimating them econometrically. In such a regime the Fed does not simply inform the administration of the monetary policy it intends to implement if things turn out as they now expect, but actually reveals its course under every conceivable contingency, that is, gives it equation (5). Symmetrically, the administration reveals equation (4) to the Fed, and they jointly decide on G_t^* and I_t^* (and presumably also on g and m).

However, we do not believe that the U.S. institutional framework fits this paradigm. Although the fiscal and monetary authorities undeniably maintain close contacts and attempt to coordinate their actions, recent U.S. economic history provides instances when they acted at cross purposes. When there are two more or less independent stabilization authorities, reaction functions become vitally important even to the policy makers. If, for example, the Fed fails to take cognizance of the fiscal reaction function, it will hold an inflated view of the potency of monetary policy. In terms of the contrasting multipliers in (6) and (8), the Fed in this sort of a world should build the fiscal reaction function into its multiplier:

$$\frac{dY}{dI} = \frac{1}{1 - b + g}. \tag{8'}$$

The estimate of g might come from the administration or from the Fed's own best guess based on econometric or other evidence.

Policy multipliers are also of interest to outside economists studying the past use and effectiveness of stabilization policies. Obviously, if the data they work with were generated in a regime that included reaction functions like (4) and (5), they would want to compute multipliers like (8) rather than (6).

In a word, the purpose of multiplier calculations dictates the kind to be made. Since multipliers such as (8) may be relevant, the question centers on the analytical harm done by computing other multipliers, like (6). Because the answer depends on the nature of both the model and the reaction functions, we use Monte Carlo techniques in a simple econometric model of the United States to investigate the issue and find that, for sensible-looking reaction functions, the differences in the multipliers might be very large indeed.

Thus, for the outside economist, the only "right" way to estimate policy multipliers econometrically is to include in his model reaction functions for the fiscal authorities and for the Federal Reserve System.[3] Otherwise, the

3. These observations are hardly original with us. See, for example, the comments by Rudolf R. Rhomberg and by H. T. Shapiro in *Journal of Money, Credit and Banking*, Vol. 3 (May 1971), pp. 546–49 and 550–54, respectively. The same points are stressed, and some of the results of the next section are anticipated, by Alan S. Blinder and Robert M. Solow in their forthcoming survey of fiscal policy. In fact, the notion that endogenous policy responses could vitiate the usefulness of reduced-form studies is as old as the oldest such study. See John Kareken and Robert M. Solow, "Lags in Monetary Policy," in E. Cary Brown and others, *Stabilization Policies*, Prepared for the Commission on Money and Credit (Prentice-Hall, 1963), pp. 14–96.

models may continue to overstate multipliers, in the sense of (8), whatever the improvements in specification or estimation techniques. To date, few economists have shown any inclination to travel this road. We conclude this study by briefly outlining some of the pitfalls in estimating reaction functions, and summarizing most of the small literature on empirical reaction functions.

Problems in Estimating Reduced-form Equations

Andersen and Jordan revived the challenge originally posed by Friedman and Meiselman,[4] and advanced a widely discussed "new" method of estimating policy multipliers. Instead of devising a complex structural model, which is bound to err in some respects, why not estimate the reduced form of the model directly, that is, derive the multipliers by regressing income on certain "obvious" exogenous variables. The Andersen-Jordan list of exogenous variables contains only one fiscal policy variable (or possibly two) and a monetary policy variable. But even if the specification allowed for many exogenous variables, the resulting multiplier estimates might, in our view, be difficult to interpret. The model builder might well discern the "true" policy instrument, which the stabilization authority "really" controls, and yet may be using a variable that is endogenous rather than exogenous. Even if the partial reduced-form specification,

$$Y_t = k + \alpha F_t + \beta M_t + \epsilon_t \tag{9}$$

(where Y is an income aggregate, F is a fiscal variable, M is a monetary variable, and ϵ is a disturbance term), includes all the relevant exogenous variables and specifies them impeccably,[5] it may still be untrue that

$$E(M\epsilon) = E(F\epsilon) = 0,$$

where E represents the expected value operator. In this case, ordinary least squares estimation of (9) may give strange results.

4. Milton Friedman and David Meiselman, "The Relative Stability of Monetary Velocity and the Investment Multiplier in the United States, 1897–1958," in *Stabilization Policies*, pp. 165–268.

5. This should not be interpreted as minimizing the difficulties involved in proper specification of the reduced form. An extensive literature has focused on such problems, and we have nothing to add to it. On the effects of omitting relevant variables, see Edward M. Gramlich, "The Usefulness of Monetary and Fiscal Policy as Discretionary Stabilization Tools," *Journal of Money, Credit and Banking*, Vol. 3 (May 1971), pp.

SOME FORMAL STABILIZATION RULES

On the other hand, in some cases where policy *does* respond to economic events, ordinary least squares estimation of (9) will be valid because ϵ is uncorrelated with F and M.

A variety of so-called "optimal" stabilization policies fall into this category, including, perhaps most importantly, the one-period *certainty-equivalence* strategy of Theil.[6] For example, suppose the partial reduced form is

$$Y_t = aP_t + bZ_t + u_t, \tag{10}$$

where

Y_t = the target variable
P_t = the policy instrument
Z_t = an exogenous variable whose future values are not known with certainty
u_t = a random disturbance uncorrelated with Z_t,

and a and b are known and fixed. The optimal stabilization policy, according to the certainty-equivalence rule, is simply to proceed as if Z_t will take on the value $E(Z_t)$, and u_t will take on the value $E(u_t) = 0$ *with certainty*; that is, the policy reaction function would be

$$P_t = \frac{Y_t^* - bE(Z_t)}{a}, \tag{11}$$

where Y^* is the target value of Y. P_t will then be uncorrelated with u_t. We shall call equation (11) a *Theil reaction function.* Now suppose that an

506–32; Levis A. Kochin, "Judging Stabilization Policies" (paper presented at the winter meeting of the Econometric Society, Toronto, December 1972; processed). On the effects of misspecifying the policy instruments, see Gramlich, "Usefulness of Monetary and Fiscal Policy," and E. Gerald Corrigan, "The Measurement and Importance of Fiscal Policy Changes," *Federal Reserve Bank of New York Monthly Review*, Vol. 52 (June 1970), pp. 133–45. The paper by Gramlich, in particular, suggests that an improved reduced-form specification can yield multiplier estimates that are much closer to those derived from large-scale econometric models. The only study known to us that considers the possible biases caused by endogenous stabilization policy is Roger N. Waud, "Monetary Control, Monetary Indicators, and Reverse Causation: An Empirical Investigation" (paper presented at the winter meeting of the Econometric Society, Toronto, December 1972; processed).

6. Henri Theil, *Economic Forecasts and Policy* (2nd ed., Amsterdam: North-Holland, 1961), or *Optimal Decision Rules for Government and Industry* (Rand McNally, 1964).

outside economist who does not know a and b proceeds to estimate (10). From the exogeneity of P_t we have the following:

> *Proposition 1:* A stabilization policy that follows a *Theil reaction function* poses no problems for reduced-form (or, for that matter, structural) estimation.

The recent analysis of optimal monetary policy by Poole, for example, explores several Theil-type reaction functions. If the Fed had adhered strictly to one or the other of these rules, it would be perfectly valid to treat their control variable (be it unborrowed reserves, the monetary base, the money stock, or the Treasury bill rate) as exogenous for econometric purposes.[7]

Several years ago, Brainard proposed a significant amendment to the Theil analysis of optimal stabilization policy. He noted that while uncertainty about Z_t, u_t, and even b ought not to affect the conduct of stabilization policy, uncertainty about a, the policy multiplier, should.[8] The reason is that the *uncertainty* over Y_t will depend (among other things) on the *level* at which P_t is set. In terms of equation (10), the *Brainard reaction function* would be

$$P = \frac{\bar{a}[Y^* - E(bZ)] - \rho\, \sigma_a \sigma_{bZ+u}}{\bar{a}^2 + \sigma_a^2}, \tag{12}$$

where

$\bar{a}$ = the expected value of a

σ_a^2 = the variance of $\bar{a}$

σ_{bZ+u} = the standard deviation of the composite variable $(bZ + u)$

ρ = the simple correlation between a and $(bZ + u)$.

It follows that multiplier uncertainty in no way alters the conclusion that $E(P_t u_t) = 0$. While the optimal setting of stabilization policy depends on the *variance* of u and on its *covariances* with a and b, it is independent of the *realized value* of u_t. Therefore,

7. William Poole, "Optimal Choice of Monetary Policy Instruments in a Simple Stochastic Macro Model," *Quarterly Journal of Economics*, Vol. 84 (May 1970), pp. 197–216. Poole also considers a combination policy in which the control variable, the money stock, is made a function of current-period interest rates. As he notes, this leads to the type of simultaneity difficulties we treat below.

8. William C. Brainard, "Uncertainty and the Effectiveness of Policy," in American Economic Association, *Papers and Proceedings of the Seventy-ninth Annual Meeting, 1966* (*American Economic Review*, Vol. 57, May 1967), pp. 411–25. The case considered here is Brainard's random coefficients model.

> *Proposition 2:* A stabilization policy that follows a *Brainard reaction function* poses no problems for reduced-form (or, for that matter, structural) estimation. This is true even if the disturbance term is correlated with the multipliers.

In recent years, Theil's framework has been extended into an explicitly dynamic, intertemporal context.[9] These studies use the techniques of dynamic programming or control theory to derive optimal rules—or reaction functions—for the conduct of stabilization policy. These reaction functions are essentially linear feedback rules whereby this period's setting of the policy instruments depends on the *current* targets and exogenous variables, but only on *lagged* values of the endogenous variables. Thus they imply no *contemporaneous* correlation between the policy instruments and the error terms.

> *Proposition 3:* A stabilization policy that follows any of a variety of *linear feedback rules* of the kind that can be derived from dynamic utility maximization poses no problems for reduced-form (or, for that matter, structural) estimation.

SOME INTUITIVE STABILIZATION RULES

Of course, real-world policy makers do not follow any such formal rule. Sometimes they perform much worse than the rules would indicate—as when partisan politics throws the fiscal authorities off course. But sometimes they can outperform the allegedly "optimal" rules.

One reason this may be possible is that the decision period for stabilization policy—especially for monetary policy—is often shorter than the quarterly data period upon which econometric models are usually based. In formal models, each policy instrument is, in effect, held constant throughout each quarter; but, in practice, an authority need not be bound for an entire quarter by any initial decision. Data are constantly arriving, for example, at the Federal Reserve Board that may suggest the need for revision in the initial forecasts made by the Fed's economists and hence for prompt adjustment in policy instruments. In the present context, the continuous process of receiving new information and revising the settings of the stabi-

9. See, for example, Gregory C. Chow, "How Much Could be Gained by Optimal Stochastic Control Policies?" *Annals of Economic and Social Measurement,* Vol. 1 (October 1972), pp. 391–406.

lization tools can be viewed as imparting some *contemporaneous* correlation between the policy variables and the disturbance terms; that is to say, in actual practice it may be possible to gear policy to offset the disturbance term, and thus to outperform any formal lagged feedback rule. Thus, if a policy maker followed an optimal stabilization rule, this *month's* policy (say) might remain independent of this *month's* error term, but this *quarter's* policy could become correlated with this *quarter's* error.

In the context of a simple income determination model such as (9), these notions could be represented by reaction functions in which the current values of the stabilization tools are functions of some current endogenous variables, as in equations (4) and (5) above. Such a model could consist of

$$Y_t = k + \alpha F_t + \beta M_t + \epsilon_t \tag{9}$$

$$F_t = F_t^* - f(Y_t - Y_t^*) + v_t \tag{4'}$$

$$M_t = M_t^* - m(Y_t - Y_t^*) + e_t. \tag{5'}$$

The true reduced form of this model implies a linear relationship between each policy variable and the current disturbance term, ϵ_t. Specifically, the reduced-form equations for F_t and M_t are

$$\begin{cases} F_t = -\dfrac{fK}{h} + Q_{1t} + \dfrac{h - f\alpha}{h} v_t - \dfrac{f\beta}{h} e_t - \dfrac{f}{h}\epsilon_t \\ M_t = -\dfrac{mK}{h} + Q_{2t} - \dfrac{m\alpha}{h} v_t + \dfrac{h - m\beta}{h} e_t - \dfrac{m}{h}\epsilon_t, \end{cases} \tag{13}$$

where

$$h = 1 + f\alpha + m\beta$$

$$Q_{1t} = \frac{h - f\alpha}{h} F_t^* - \frac{f\beta}{h} M_t^* + \frac{f}{h} Y_t^*$$

$$Q_{2t} = -\frac{m\alpha}{h} F_t^* + \frac{h - m\beta}{h} M_t^* + \frac{m}{h} Y_t^*.$$

Alternatively, if the authorities react to movements of the endogenous variables only with a lag, but the error in the partial reduced form (ϵ_t) is autocorrelated, the econometric effects would be the same: a linear relationship between F_t (or M_t) and ϵ_t.

To simplify the computations, we shall ignore the constant terms in equations like (13) and characterize a wide variety of such reaction functions by directly assuming that both fiscal and monetary policies are a linear function of the partial reduced-form disturbance, ϵ_t, plus some random noise. For every result in this section, an analogous but far more cumbersome result can be derived from reaction functions like (4′) and (5′).

In order to attach some meaning to the various parameters, we shall speak *as if* the monetary and fiscal authorities attempted to forecast the disturbance term—however imperfectly—and manipulated their policy tools so as to offset it. But this simple paradigm should not be interpreted literally; instead, it stands for any circumstance in which the behavior of two uncoordinated policy makers[10] results in a linear relationship between ϵ and the policy instruments.

Our simple story thus initially consists of the partial reduced-form equation (9)[11] plus these stylized reaction functions:

$$F = -\frac{\epsilon_F}{\alpha}; \qquad M = -\frac{\epsilon_M}{\beta}, \tag{14}$$

where ϵ_F and ϵ_M are, respectively, the forecasts of ϵ made by the fiscal and monetary authorities. We assume further that

$$\epsilon_F = \epsilon + u_F, \qquad \epsilon_M = \epsilon + u_M, \tag{15}$$

where the forecast errors, u_F and u_M, are independent of ϵ[12] but may well be correlated with each other; we call this correlation between the forecast errors ρ. Finally, we designate the variance of u_F as $\gamma^2\sigma_\epsilon^2$, where σ_ϵ^2 is the variance of ϵ, and the variance of u_M as $\delta^2\sigma_\epsilon^2$. The parameter ρ indicates the extent to which the two authorities utilize similar forecasts. The parameters γ^2 and δ^2 indicate the astuteness of each authority in forecasting, showing the size of the variance of its forecast error relative to the variance of ϵ. A low γ indicates that the government's forecasts have a high degree of precision and a low δ indicates the same thing for the Fed.

10. We assume initially that each ignores the other. This is somewhat reminiscent of a pair of Cournot duopolists. We later take up some possible interrelations of monetary and fiscal policy.

11. We assume that (9) does not omit any relevant variables. For a related analysis based on the existence of bias arising from omitted variables, in addition to the kinds of reaction-function bias we shall discuss, see Kochin, "Judging Stabilization Policies."

Furthermore, in what follows, we are implicitly thinking of a world where Y_t is the *change* in GNP, k is the (constant) desired change, and F_t and M_t are the *changes* in fiscal and monetary policies. Thus in the absence of any policy moves, Y_t would be $k + \epsilon_t$.

12. William Poole has pointed out to us that this may not be a desirable property for forecasts to have. In the appendix, we show how the analysis would have to be altered if u_F and u_M were uncorrelated with ϵ_F and ϵ_M.

What would happen, under such a regime, if (9) were estimated by ordinary least squares?[13] Using (14), (15), and the standard formulas for the estimated regression coefficients in (9), it is shown in the appendix that

$$(16)\qquad \begin{aligned} R^{\alpha} &= 1 + \frac{\delta(\rho\gamma - \delta)}{\Delta} \\ R^{\beta} &= 1 + \frac{\gamma(\rho\delta - \gamma)}{\Delta}, \end{aligned}$$

where

$$\Delta \equiv \gamma^2 + \delta^2 - 2\rho\gamma\delta + \gamma^2\delta^2(1 - \rho^2) > 0,$$

and where the symbol R^{α} denotes the ratio of the estimate of α to the true value of α, with corresponding notation for β.[14]

It is impossible for both biases to be positive simultaneously. For $\hat{\alpha}$ is biased upward if and only if $\rho\gamma > \delta$. But with ρ positive (and, if it is not, neither bias is positive), this implies $\rho^2\gamma > \rho\delta$. But since $\rho^2 \leq 1$, this establishes that $\hat{\beta}$ is biased toward zero.

The simplest case, and one that graphically highlights the basic principles, occurs when the forecast errors are uncorrelated ($\rho = 0$). In this case the *percentage* biases become $-\delta^2/\Delta$ for the fiscal policy multiplier and $-\gamma^2/\Delta$ for the monetary policy multiplier. That is, *both policy multipliers are biased toward zero, and the policy maker who does the better forecasting job gets the more serious bias.* Thus one way of interpreting the Andersen-Jordan results is as a suggestion that the fiscal authority is a superior forecaster and the Fed is an inferior one.[15]

If the correlation between the forecasting errors is negative, precisely the same conclusions emerge from (16). Both biases will be negative, and $\hat{\alpha}$ will be the more seriously biased coefficient if and only if $\delta^2 > \gamma^2$. In plain En-

13. Throughout this section we shall refer to the parameters α and β in (9) as "multipliers." The previous discussion makes clear that they are multipliers that ignore reaction functions (like (6) above) rather than multipliers that take reaction functions into account (like (8) above).

14. The wording in the text is heuristic rather than rigorous. The actual definition of R^{α}, as is made clear in the appendix, is

$$R^{\alpha} = plim\ \hat{\alpha}/\alpha,$$

where $\hat{\alpha}$ is the least squares estimator of α and *plim* stands for probability limit. Hence, what we refer to in the text as bias really is asymptotic bias. Equations (16) are actually special cases of much more general formulas that are worked out in the appendix.

15. We are not inclined to draw this conclusion. As will be clear shortly, the Andersen-Jordan results have many alternative explanations.

glish, the bias will be more serious for the fiscal multiplier if and only if the Fed is the worse forecaster.

In fact, these same conclusions hold even if ρ is positive, provided only that $\rho\gamma - \delta < 0$ and $\rho\delta - \gamma < 0$. Combining these two inequalities gives the crucial condition:

$$\frac{1}{\rho} > \frac{\delta}{\gamma} > \rho. \tag{17}$$

If this is satisfied, the basic result that both multipliers are biased toward zero, with the "smarter" authority biased more, holds even if the correlation is positive. If ρ is relatively small, (17) is almost certain to hold unless δ and γ are very disparate. Similarly, if $\delta \sim \gamma$, (17) is bound to hold even if ρ is rather large.

Thus, upward bias can emerge in one of the multipliers only if one authority is very much more astute than the other while the forecast errors have a substantial positive correlation. If the Fed is cleverer, so that δ/γ is a very small number, upward bias may appear in the fiscal policy multiplier. Conversely, an excellent forecasting record on the part of the Council of Economic Advisers might lead to an overestimate of the monetary policy multiplier. These conclusions are summarized in Table 1.

Two extreme cases of bias are of interest since ordinary least squares estimation of (9) performed by the St. Louis Fed assigns a coefficient of ap-

Table 1. Biases in Multipliers for Fiscal Policy (α) and Monetary Policy (β)

	Relative quality of forecasters		
Relation of forecast errors	*Fiscal authority much better*	*Equally good*	*Monetary authority much better*
Positively correlated	α biased down β biased up α biased more	α biased down β biased down % biases equal	α biased up β biased down β biased more
Uncorrelated	α biased down β biased down α biased more	α biased down β biased down % biases equal	α biased down β biased down β biased more
Negatively correlated	α biased down β biased down α biased more	α biased down β biased down % biases equal	α biased down β biased down β biased more

Source: Developed from equations (9) and (14)–(17) discussed in text. The results cited for the case of positively correlated forecast errors assume equation (17) holds.

proximately zero to fiscal policy. Suppose first that one of the authorities possessed a crystal ball, so that either γ or δ was zero. In that case, as equations (16) demonstrate, the all-knowing authority would receive an estimated coefficient of exactly zero while the estimated coefficient of the other authority would be precisely the true multiplier. Alternatively, if one of the authorities were worthless as a forecaster, the multiplier of the bad forecaster would be unbiased while the other multiplier would be biased toward zero.

Under some conditions, an estimated multiplier can even have the incorrect sign. The condition for the sign of the fiscal multiplier to be incorrect is that $R^\alpha < 0$, which by (16) reduces to:

$$\gamma^2 \delta^2(1 - \rho^2) < \gamma(\rho\delta - \gamma)$$

or

$$\frac{\gamma^2\delta^2(1 - \rho^2)}{\Delta} < R^\beta - 1,$$

which would hold if the money multiplier had a large enough upward bias and ρ were sufficiently high.

In fact, this analysis can go somewhat further. The standard errors of each estimated coefficient in (9) are worked out in the appendix. From these results and equation (16), it is possible to compute—for any triplet of γ, δ, and ρ values—both the expected coefficient estimates (as fractions of the true coefficients) and the expected t-ratios that would be obtained from ordinary least squares reduced-form estimation from an infinite sample.[16] Table 2 compiles some selected results, and Figure 2 portrays this same information graphically.

In this table, $r_M \equiv (1 + \delta^2)^{-\frac{1}{2}}$ is our measure of the forecasting accuracy of the Federal Reserve (with $r_M = 0$ indicating complete inaccuracy, and $r_M = 1$ indicating perfect accuracy), and r_F is the like measure for the fiscal authority.[17] Under each r value, the corresponding γ or δ value is also given. The entries in the table are the values for R^α (with unity indicating the absence of bias) along with the expected t-ratios in parentheses. Because (16) is symmetrical, the tables can be used to read off R^β simply by interchanging the roles of r_M and r_F.

For example, if $\rho = 0$, $r_M = 0.1$, and $r_F = 0.5$, the fiscal multiplier, α, would be biased down by about 25 percent and the t-ratio in large samples would be about 1.74. By contrast, the monetary multiplier, β, would have

16. Assuming that (9) is the true model of the real world, which it certainly is not!

17. r_M is the correlation between ϵ and ϵ_M, and r_F is defined analogously.

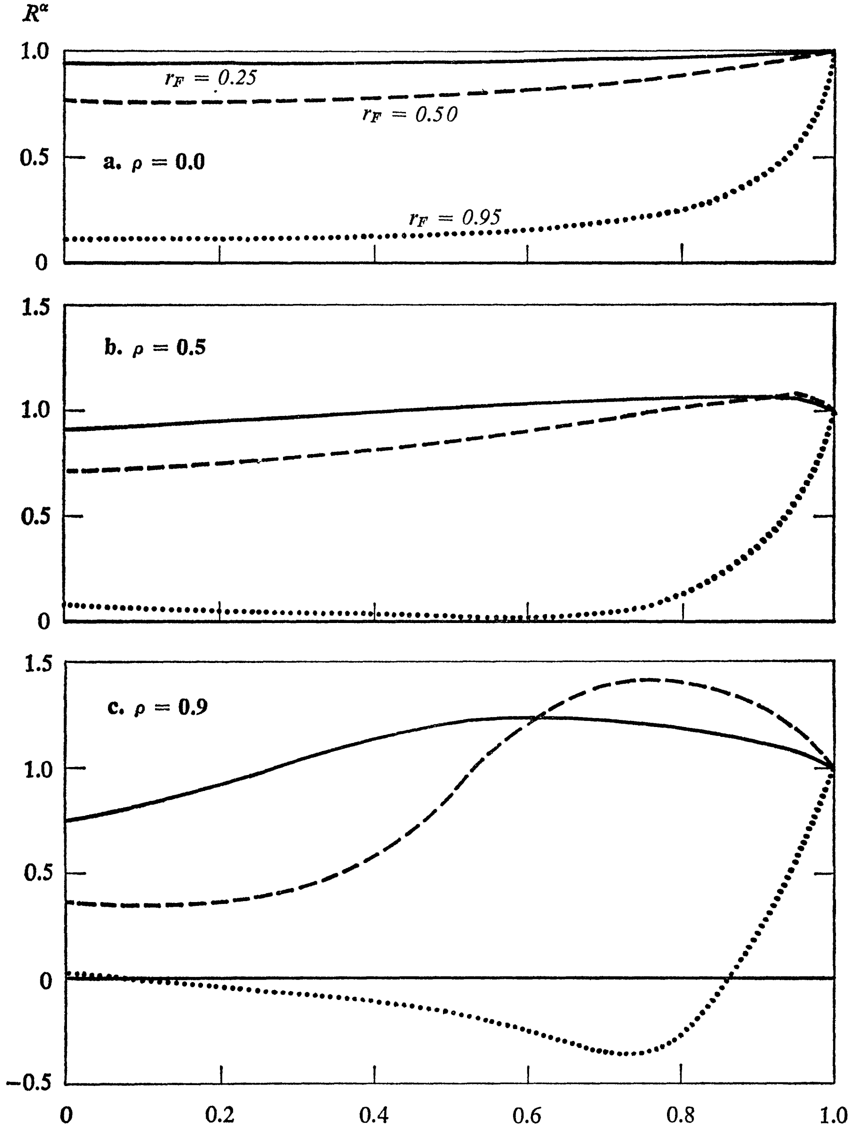
Table 2. Ratios of Estimated to Actual Fiscal Multipliers for Selected Levels of Correlation between Forecast Errors and Various Degrees of Astuteness of Fiscal and Monetary Authorities[a]

Forecast accuracy of fiscal authority, r_F	*Forecast accuracy of monetary authority,* r_M				
	0 ($\delta = \infty$)	*0.1* ($\delta = 9.95$)	*0.5* ($\delta = 1.73$)	*0.95* ($\delta = 0.33$)	*1.0* ($\delta = 0$)
			a. $\rho = 0$		
0	1	1	1	1	1
($\gamma = \infty$)	(...)	(...)	(...)	(...)	(...)
0.1	0.990	0.990	0.992	0.999	1
($\gamma = 9.95$)	(9.95)	(10.00)	(11.49)	(31.87)	(...)
0.5	0.750	0.752	0.800	0.969	1
($\gamma = 1.73$)	(1.73)	(1.74)	(2.00)	(5.55)	(...)
0.95	0.097	0.098	0.126	0.526	1
($\gamma = 0.33$)	(0.33)	(0.33)	(0.38)	(1.05)	(...)
1.0	0.0	0.0	0.0	0.0	(...)
($\gamma = 0$)	(...)	(...)	(...)	(...)	(...)
			b. $\rho = 0.5$		
0	1	1	1	1	1
($\gamma = \infty$)	(...)	(...)	(...)	(...)	(...)
0.1	0.987	0.993	1.018	1.015	1
($\gamma = 9.95$)	(8.62)	(8.63)	(10.49)	(35.35)	(...)
0.5	0.692	0.706	0.846	1.063	1
($\gamma = 1.73$)	(1.50)	(1.46)	(1.59)	(5.70)	(...)
0.95	0.075	0.063	0.024	0.537	1
($\gamma = 0.33$)	(0.29)	(0.23)	(0.07)	(0.64)	(...)
1.0	0	0	0	0	(...)
($\gamma = 0$)	(...)	(...)	(...)	(...)	(...)
			c. $\rho = 0.9$		
0	1	1	1	1	1
($\gamma = \infty$)	(...)	(...)	(...)	(...)	(...)
0.1	0.950	0.995	1.098	1.030	1
($\gamma = 9.95$)	(4.34)	(4.34)	(9.31)	(65.37)	(...)
0.5	0.363	0.345	0.870	1.189	1
($\gamma = 1.73$)	(0.76)	(0.59)	(0.77)	(9.76)	(...)
0.95	0.020	−0.008	−0.160	0.547	1
($\gamma = 0.33$)	(0.14)	(−0.06)	(−0.69)	(0.26)	(...)
1.0	0	0	0	0	0
($\gamma = 0$)	(...)	(...)	(...)	(...)	(...)

Source: Derived from equations (16) discussed in the text and (A-6) in the appendix. The numbers in parentheses are t-ratios.

a. ρ = correlation of forecast errors; γ and δ = astuteness of fiscal and monetary authorities, respectively. The entries in the table are the values for the fiscal multiplier ratios R^{α} (see equations (16)). The corresponding values for the monetary multiplier ratios R^{β} are read by interchanging the roles of r_M and r_F. For example, in reading R^{α} from the a section of the table, when $r_M = 0.1$ and $r_F = 0.5$, the value is 0.752; correspondingly, for R^{β}, when $r_M = 0.5$ and $r_F = 0.1$, the value is 0.992.

Figure 2. Ratios of Estimated to Actual Fiscal Multipliers for Selected Levels of Correlation between Forecast Errors and Various Degrees of Astuteness of Fiscal and Monetary Authorities[a]



Source: Same as Table 2.

a. ρ = correlation of forecast errors; r_F and r_M = astuteness of fiscal and monetary authorities, respectively.

only a negligible downward bias (less than 1 percent) and a t-ratio of 11.5. With the fiscal authority nearly clairvoyant and thus r_F equal to 0.95, the estimate of α would be only about one-tenth of the true α (with a t-ratio of 0.33), while the estimate of β would be essentially unbiased (with an expected t-statistic of about 32). Indeed, as Table 2 suggests, the t-ratio for the money multiplier becomes arbitrarily large as the forecasting ability of the fiscal authority improves, and vice versa.

Table 2 exhibits several examples of estimated coefficients with the wrong sign. Although these tables do not show it, the incorrectly signed coefficient can even appear statistically significant by the conventional (but inappropriate) t-test.

Though many other interpretations are possible, Table 2b offers one case that is quite consistent with the version of the St. Louis equation reported by Andersen and Carlson. When $r_F = 0.95$ (that is, the fiscal authority is nearly clairvoyant) and $r_M = 0.5$ (the monetary authority is a fair forecaster), this table says that the estimated fiscal multiplier should be only about 2½ percent of its true value, while the monetary multiplier should be overestimated by about 6 percent. The Andersen-Carlson findings of a multiplier of about 5½ for the money stock and 0.05 for government purchases could arise in such a milieu if the true multipliers were about 5¼ for money and 2 for government spending, not an implausible pair of values.[18]

Figure 2 corresponds to Table 2. Each panel plots the behavior of R^α, the ratio of the estimated to the actual fiscal multiplier, as the forecasting ability of the Fed (as measured by r_M) improves. In the first panel, where the forecasting errors are uncorrelated, everything is straightforward. The bias is more serious the better forecasters the fiscal authorities are, and less serious the better the monetary authorities are. The second panel, where $\rho = 0.5$, tells almost the same story, but does show some instances where condition (17) is violated so that the multiplier estimate is actually biased upward ($R^\alpha > 1$). It also points out the possibility (for very high r_M) that the fiscal authorities might look better (that is, have a higher R^α) by forecasting better (that is, by raising r_F from 0.25 to 0.50). As we already know,

18. See Leonall C. Andersen and Keith M. Carlson, "A Monetarist Model for Economic Stabilization," *Federal Reserve Bank of St. Louis Review*, Vol. 52 (April 1970), p. 11. The t-ratios reported by Andersen and Carlson—8.1 for monetary policy and 0.17 for fiscal policy—are also roughly consistent with the data in Table 2b. This is not the only (nor even the best) set of parameters that would "explain" their results. Other possible interpretations are given below.

such unconventional results occur much more frequently when ρ is very high. The third panel, which corresponds to $\rho = 0.9$, depicts a wide variety of parameter values that result in upward bias ($R^{\alpha} > 1$), or a better performance by the fiscal authority the more accurately it forecasts, or both. This figure also exhibits instances of estimated multipliers with the wrong sign.

While the general tendency seems to be for downward bias in estimating the fiscal multiplier to become more serious as the administration's forecasts improve (r_F rises), as the Fed's forecasts deteriorate (r_M falls), and as the correlation between the two forecasts rises, Figure 2 and Table 2 reveal a bewildering variety of possibilities. And, unfortunately, very few can be ruled out until much more is known about the reaction functions of the authorities. Without such knowledge, it is impossible to interpret the results of reduced-form estimates.

These results can be summarized in the following statement:[19]

> *Proposition 4:* If the stabilization authorities are imperfectly offsetting a stochastic error term, reduced-form estimates of both policy multipliers are likely to be biased toward zero, with the larger percentage bias associated with the more astute forecaster.

MULTIPLIER ERRORS OR PARTIAL ADJUSTMENT

In the analysis so far, the only thing that prevented either the Federal Reserve or the administration from doing a perfect job of stabilizing income (apart from the actions of the other) was errors in forecasting. In practice, things are not quite so tidy. Even when the authorities' forecasts hit the bull's eye, they often do not take the appropriate actions. A variety of such cases can be handled by the simple device of changing the reaction functions from (14) to:

$$F = -\frac{\epsilon_F}{a}, \qquad M = -\frac{\epsilon_M}{b}, \tag{18}$$

where a and b are equal not to the multipliers α and β, but instead to $\lambda\alpha$ and $\omega\beta$.

One interpretation of this case is that the authorities do not know the

19. Biases in the real world are more complicated than this. Our bias formulas are all predicated on the existence of a *stable* reaction function. In practice, reaction patterns are likely to change over time for political and other reasons.

true multipliers, but think that they are a and b. In this case, λ and ω are the factors by which the fiscal and monetary authorities, respectively, misestimate their own multipliers; for example, $\lambda = 1.2$ means that the administration thinks its multiplier is 20 percent higher than it actually is. As a result, of course, its actions will be only 1/1.2, or 83.3 percent, as strong as they should be. Alternatively, the fiscal authority may know its multiplier accurately, but choose to offset only 83.3 percent of any random disturbance, as a result of cowardice, bureaucratic inertia, innate conservatism, or just plain pig-headedness. Another interpretation is that an attempt to close only a fraction of the gap between actual and desired GNP could be an optimal response in the face of multiplier uncertainty of the kind analyzed by Brainard.[20] Finally, a partial response could arise because the administration realizes that the Fed will also be trying to offset part of the stochastic disturbance, and does not want the total stabilization policy package to be too strong. Symmetrically, a λ value less than unity could indicate an underestimated multiplier, or the overzealous reactions of a panic-prone fine tuner, or a belief on the part of the fiscal authority that the Fed would act in a procyclical manner. A final case, which may be of interest in view of the historical pattern of U.S. stabilization policy, is where λ or ω, or both, is negative. That is, the administration or the Fed follows a procyclical course, exacerbating random disturbances.[21] All of these possiblities can be handled by utilizing reaction functions (18) rather than (14) to develop expressions for the bias similar to (16). It turns out that

$$(19)\qquad \begin{cases} R^{\alpha} = 1 + \dfrac{\lambda\delta(\rho\gamma - \delta)}{\Delta} \\ R^{\beta} = 1 + \dfrac{\omega\gamma(\rho\delta - \gamma)}{\Delta}. \end{cases}$$

Thus, incorrect estimation of multipliers by the authorities (alone or in combination with too weak or too strong stabilization actions) requires only minor modification of the conclusions summarized in Table 1 above. In particular, all of the previous findings about the *signs* of the biases remain valid when λ or ω are not unity, so long as they are positive. The scalars λ and ω affect only the absolute magnitudes of the percentage biases

20. See equation (12) above with $\rho = 0$.

21. For example, whenever the Fed has allowed bank reserves to move in a procyclical manner because it desired to stabilize interest rates, ω was negative.

—not their direction; but they can reverse our previous findings about which bias was the more serious. Thus:

> *Proposition 5:* Overestimating one's multiplier or reacting too weakly to random fluctuations in macroeconomic activity will result in a *larger* (in absolute value) bias than would "correct" reactions. Conversely, underestimating the multiplier or reacting too vigorously to random shocks will tend to mitigate the bias.

If, however, either authority should behave in a procyclical manner, its bias would be reversed, as is clear from (19). For example, if both original biases in (16) were negative, but if the Fed were reacting perversely to random disturbances ($\omega < 0$), the estimate of the money multiplier would now be biased upward.

> *Proposition 6:* If the stabilization authorities are behaving in a *procyclical* manner, reduced-form estimates of policy multipliers are likely to be biased *upward*, with the larger bias associated with the authority that is (a) pursuing the less vigorous procyclical policy, and (b) forecasting more accurately.

Table 3 gives some sample computations of the expected results from ordinary least squares regressions on (9) when λ and ω are not equal to unity. As before, the table displays the fiscal multiplier and must be transposed to supply the money multiplier.[22] The range of possibilities is, if anything, even more staggering than before. For example, in Table 3c, for $r_M = 0.5$, $r_F = 0.95$ there now appears a fiscal multiplier whose magnitude is three-quarters of the true value but is negative and significant! Table 3d underscores the point of proposition 7 that, when the fiscal authority is behaving procyclically, reduced-form studies are likely to overestimate the fiscal multiplier.

As was the case with Table 2, a number of these results are consistent with the Andersen-Carlson findings, for example, the entries in Table 3c with $r_M = 0.1$ and $r_F = 0.5$. Compared with the case above that matches the St. Louis results, the forecasts of the authorities are of poorer quality and closer to one another. In addition, both authorities overstate their multipliers by 50 percent.

22. In addition, in the present case the roles of λ and ω must be interchanged. Note that equations (19) imply that ω is irrelevant for the fiscal multiplier and λ is irrelevant for the monetary multiplier.

Table 3. Ratios of Estimated to Actual Fiscal Multipliers for Selected Levels of Correlation between Forecast Errors and Multiplier Misestimation Factors and Various Degrees of Astuteness of Fiscal and Monetary Authorities[a]

Forecast accuracy of fiscal authority, r_F	*Forecast accuracy of monetary authority,* r_M				
	0 ($\delta = \infty$)	*0.1* ($\delta = 9.95$)	*0.5* ($\delta = 1.73$)	*0.95* ($\delta = 0.33$)	*1.0* ($\delta = 0$)
			a. $\rho = 0.5$, $\lambda = 0.5$		
0	1	1	1	1	1
($\gamma = \infty$)	(...)	(...)	(...)	(...)	(...)
0.1	0.993	0.997	1.009	1.007	1
($\gamma = 9.95$)	(17.35)	(17.32)	(20.79)	(70.19)	(...)
0.5	0.846	0.853	0.923	1.032	1
($\gamma = 1.73$)	(3.67)	(3.52)	(3.46)	(11.06)	(...)
0.95	0.537	0.531	0.512	0.769	1
($\gamma = 0.33$)	(4.08)	(3.90)	(2.89)	(1.82)	(...)
1.0	0.500	0.500	0.500	0.500	(...)
($\gamma = 0$)	(...)	(...)	(...)	(...)	(...)
			b. $\rho = 0.5$, $\lambda = 1.5$		
0	1	1	1	1	1
($\gamma = \infty$)	(...)	(...)	(...)	(...)	(...)
0.1	0.980	0.990	1.027	1.022	1
($\gamma = 9.95$)	(5.71)	(5.74)	(7.06)	(23.74)	(...)
0.5	0.538	0.559	0.769	1.095	1
($\gamma = 1.73$)	(0.78)	(0.77)	(0.96)	(3.91)	(...)
0.95	−0.388	−0.406	−0.464	0.306	1
($\gamma = 0.33$)	(−0.98)	(−0.99)	(−0.87)	(0.242)	(...)
1.0	−0.500	−0.500	−0.500	−0.500	(...)
($\gamma = 0$)	(...)	(...)	(...)	(...)	(...)
			c. $\rho = 0.9$, $\lambda = 1.5$		
0	1	1	1	1	1
($\gamma = \infty$)	(...)	(...)	(...)	(...)	(...)
0.1	0.924	0.992	1.147	1.045	1
($\gamma = 9.95$)	(2.81)	(2.89)	(6.49)	(44.21)	(...)
0.5	0.045	0.017	0.805	1.283	1
($\gamma = 1.73$)	(0.062)	(0.019)	(0.474)	(7.022)	(...)
0.95	−0.470	−0.513	−0.740	0.320	1
($\gamma = 0.33$)	(−2.23)	(−2.28)	(−2.13)	(0.10)	(...)
1.0	−0.500	−0.500	−0.500	−0.500	(...)
($\gamma = 0$)	(...)	(...)	(...)	(...)	(...)
			d. $\rho = 0.5$, $\lambda = -0.5$		
0	1	1	1	1	1
($\gamma = \infty$)	(...)	(...)	(...)	(...)	(...)
0.1	1.007	1.003	0.991	0.993	1
($\gamma = 9.95$)	(17.59)	(17.42)	(20.42)	(69.21)	(...)
0.5	1.154	1.147	1.077	0.968	1
($\gamma = 1.73$)	(5.01)	(4.73)	(4.04)	(10.37)	(...)
0.95	1.463	1.469	1.488	1.237	1
($\gamma = 0.33$)	(11.12)	(10.79)	(8.40)	(2.91)	(...)
1.0	1.5	1.5	1.5	1.5	1
($\gamma = 0$)	(...)	(...)	(...)	(...)	(...)

Source: Derived from equation (19) discussed in text. The numbers in parentheses are t-ratios.
a. γ = multiplier misestimation factor; other symbols are defined as in Table 2, note *a*.

LAGGED RESPONSES

The analysis can be taken one step further by allowing for lags in reaction functions. If the authorities offset the *lagged* disturbance, ϵ_{t-1}, but do so with some error, equations (18) should be replaced by

$$F = \frac{-(\epsilon_{t-1} + u_F)}{a}, \qquad M = \frac{-(\epsilon_{t-1} + u_M)}{b}, \tag{20}$$

where, as before, a and b are the multipliers perceived by the authorities. Lags in the reaction function eliminate simultaneous-equations bias if the disturbance term is independent over time, but not if it is serially correlated. So, for the present case, we assume ϵ_t follows a simple first-order autoregressive scheme given by

$$\epsilon_t = \rho^* \epsilon_{t-1} + e_t, \tag{21}$$

where ρ^* is the serial correlation coefficient.

Following the same steps used to derive the earlier results (see the appendix) yields the biases:

$$\begin{cases} R^\alpha = 1 + \dfrac{\lambda\delta\rho^*(\rho\gamma - \delta)}{\Delta} \\[2ex] R^\beta = 1 + \dfrac{\omega\gamma\rho^*(\rho\delta - \gamma)}{\Delta}. \end{cases} \tag{22}$$

The similarity between equations (22) and (19) is striking. Therefore:

> *Proposition 7:* As contrasted with the standard case, if the authorities seek instead to offset a lagged disturbance that is autocorrelated, the percentage biases are those of the standard case multiplied by a fraction ρ^*, where ρ^* is the serial correlation coefficient.

So long as ρ^* is positive, all the qualitative results obtained for the standard case mainly apply here as well. For example, Tables 2 and 3 can be used for the present case simply by interpreting λ as $\lambda\rho^*$—that is, Table 3a could now be used for the case $\lambda = 1$, $\rho^* = 0.5$.

POLICY INTERACTIONS

A third extension of the simple reaction functions used in equation (14) would allow each of the two authorities to realize that the other is also trying to stabilize macroeconomic activity. In the absence of explicit coordination, each might forecast the actions of the other, and adjust its own policies accordingly. The two cases are precisely symmetrical, but for concreteness let us suppose that the Fed takes account of the administration's behavior, while the fiscal authority ignores the central bank. The model, then, consists of

$$Y_t = k + \alpha F_t + \beta M_t + \epsilon_t \tag{9}$$

$$F = \frac{(\epsilon_F)}{a},\ M = -\frac{(\epsilon_M + A\hat{F})}{b}, \tag{23}$$

where

$a = \lambda\alpha$, the administration's estimate of its own multiplier
$A = s\alpha$, the Fed's estimate of the fiscal multiplier
$b = \omega\beta$, the Fed's estimate of its own multiplier
ϵ_F, ϵ_M = the forecast of the disturbance term made by the administration and the Fed, respectively
$\hat{F}$ = the Fed's forecast of fiscal policy.

Expressions for the biases in this case are given in the appendix. The necessary modification for estimating the money multiplier turns out to be trivial:

> *Proposition 8:* If the monetary authority predicts fiscal policy and modifies its actions accordingly, the bias in estimating the money multiplier shrinks in size, but has the same direction. As the accuracy of the Fed's predictions of fiscal policy improves, the bias in the money multiplier increases. In the limit, when it forecasts fiscal behavior perfectly, the bias is just as large as if it did not forecast it at all.

What happens to the estimate of the fiscal policy multiplier is much more complicated. Proposition 9 summarizes the results:

> *Proposition 9:* If the monetary authority predicts fiscal policy and modifies its actions accordingly, the bias in estimating the fiscal multiplier becomes *more negative* than previously. It might even change sign from positive to negative. Increases in the Fed's accuracy have an uncertain effect on this bias.

These last propositions perhaps supply a more reasonable interpretation of the St. Louis Fed results. Even if the fiscal authority were the inferior forecaster, the fiscal multiplier might still have the more serious bias if (a) the administration was a more cautious stabilizer than the Fed (see proposition 5); or (b) the central bank tried to predict and take account of fiscal policy while the fiscal authority did not do likewise for monetary policy (see propositions 8 and 9). Even in the limiting case where fiscal policy is truly exogenous, such actions on the part of the Fed would lead to downward bias in the estimated fiscal policy multiplier.

A MORE GENERAL MODEL

A final extension of the analysis modifies the partial reduced-form model, equation (9), rather than the reaction functions. Clearly, monetary and fiscal policy are not the only exogenous variables that should enter any properly specified partial reduced form. Therefore equations like the St. Louis model are subject to considerable bias from omitted variables. Our analysis has deliberately abstracted from this kind of bias in order to concentrate on the biases caused by endogenous stabilization policy. But the results obtained for an economy satisfying equation (9) can be extended to more realistic situations with exogenous variables other than monetary and fiscal policy. In particular, suppose that the true reduced-form equation is

$$Y = k + \alpha F + \beta M + \mu X + \epsilon, \tag{9'}$$

where X is some exogenous variable uncorrelated with ϵ. This calls for some modification in the reaction functions. Since the level of Y would be affected by both X and ϵ, the authorities should attempt to predict both, and to offset their joint effect. That is,

$$(24) \qquad \begin{aligned} F &= -\frac{(\mu \hat{X}_F + \epsilon_F)}{\alpha} \\ M &= -\frac{(\mu \hat{X}_M + \epsilon_M)}{\beta}, \end{aligned}$$

where $\hat{X}_F$ and $\hat{X}_M$ are the forecasts of X by the fiscal and monetary authorities, respectively.

The tedious manipulations needed to analyze this case are summarized in the appendix. It turns out that none of our basic conclusions is overturned.

> *Proposition 10:* If the stabilization authorities are imperfectly offsetting both a stochastic error term and an exogenous variable, reduced-form estimates of all parameters are very likely to be biased toward zero. Of the two policy multipliers, the one asso-

ciated with the more astute forecaster (now defined in terms of both ϵ and X) will have the larger percentage bias.

As is usual in econometric analyses of specification error, it is difficult to prove that analogous results would hold in a completely general model with an arbitrary number of policy instruments and of exogenous variables. Still, this last case is sufficiently general to encourage speculation that they would. Furthermore, the preceding models of multiplier errors, partial adjustment, lagged responses with serially correlated errors, and interactions between monetary and fiscal policy generally point in the same direction; that is, if the monetary or fiscal authorities (or both) are consciously pursuing a countercyclical stabilization policy, partial reduced-form estimates of all multipliers most likely will be underestimates. By contrast, if policy is procyclical, partial reduced-form estimates will probably be too high.

In summary, for a wide class of plausible behavioral patterns on the part of the stabilization authorities, it may be fruitless to assess policy multipliers by estimating partial reduced-form equations. If such exercises are to be done at all, policy instruments should at least be treated as endogenous variables, and appropriate estimation techniques employed. We shall return to this problem below, when we offer some concrete examples of the substantial differences between endogenous and exogenous treatment of policy instruments in estimating reduced-form equations.

Estimating Structural Models: Some Simulation Results

Estimates of policy multipliers can, and in general should, be derived from a structural model rather than from a reduced-form method. To do this, one must first specify and consistently estimate all the structural equations, and then compute the solved reduced form. The next two sections deal with these problems in order.

Instead of continuing the simple analytical approach of the previous section, we thought it more illuminating to analyze the structural estimation problem in the context of a small "realistic" econometric model of the United States. To do this, we have borrowed the model developed by Moroney and Mason,[23] which has the following structure:

23. J. R. Moroney and J. M. Mason, "The Dynamic Impacts of Autonomous Expenditures and the Monetary Base on Aggregate Income," *Journal of Money, Credit and Banking*, Vol. 3 (November 1971), pp. 793–814. We chose this model because it is essentially linear, which makes it possible to calculate explicitly the reduced form.

(25a) $C_t = a_0 + a_1 Y_t + a_2 C_{t-1} + a_3 M_t + a_4 M_{t-1} + u_{1t}$

(25b) $I_t = b_0 + b_1(C_{t-1} - C_{t-2}) + b_2 Y_t + b_3 RL_{t-2} + b_4 I_{t-1} + u_{2t}$

(25c) $O_t = c_0 + c_1 Y_t + u_{3t}$

(25d) $RL_t = d_0 + d_1 RS_t + d_2 Y_t + u_{4t}$

(25e) $M = (e_0 + e_1 RS_{t-1} + e_2 RD_{t-1}) B_t + u_{5t}$

(25f) $RS = f_0 + f_1 Y_t + f_2 M_t + u_{6t}$

(25g) $Y_t = C_t + I_t + G_t + E_t - O_t,$

where

Y = GNP
C = consumption expenditures
I = gross private domestic investment
G = government purchases
E = exports
O = imports
M = money stock (currency plus demand deposits)
RS = short-term interest rate
RL = long-term interest rate
B = unborrowed reserves plus currency
RD = discount rate
u = disturbance term,

and all dollar variables are in current prices.

We gathered data for these variables, approximating the original definitions of the Moroney-Mason model, for the sample period 1953:3–1965:4. We then estimated their model by two-stage least squares, correcting for autocorrelation in each equation.[24] The estimated parameters and their standard errors appear in Table 4 in the columns labeled "true value" and "true standard error."[25]

24. The estimation technique is due to Ray C. Fair; see his "The Estimation of Simultaneous Equation Models with Lagged Endogenous Variables and First Order Serially Correlated Errors," *Econometrica*, Vol. 38 (May 1970), pp. 507–16.

25. We should note that the reported money supply equation (25e) differs from the original specification, which was linear in current values of B, RS, and RD. We altered the specification because we felt that it yielded an unreasonably low estimate of the multiplier for B or M (for example, Moroney and Mason report a multiplier of 1.8, which implies an elasticity of the money stock with respect to the base of only about 0.6). The remaining results are, reassuringly, quite close to those they obtained.

Table 4. Results of Alternative Methods of Structural Estimation

Parameter[a]	True value (1)	Mean estimate coefficients: Policy treated as exogenous (2)	Mean estimate coefficients: Policy treated as endogenous (3)	True standard error (4)	Root mean-squared error: Policy treated as exogenous (5)	Root mean-squared error: Policy treated as endogenous (6)
a_0	−32.85	−36.46	−37.92	14.55	9.79	8.70
a_1	0.131	0.188	0.182	0.045	0.106	0.077
a_2	0.751	0.659	0.664	0.059	0.082	0.066
a_3	0.479	0.455	0.508	0.272	0.079	0.093
a_4	−0.123	−0.070	−0.104	0.324	0.176	0.132
b_0	1.31	1.86	1.98	2.67	4.17	4.30
b_1	0.290	0.279	0.249	0.251	0.334	0.333
b_2	0.053	0.057	0.059	0.014	0.015	0.016
b_3	−3.11	−3.41	−3.45	0.911	0.630	0.661
b_4	0.768	0.752	0.737	0.099	0.114	0.119
c_0	−1.30	−0.96	−0.97	1.45	1.20	1.22
c_1	0.048	0.048	0.048	0.003	0.002	0.002
d_0	1.33	1.25	1.36	0.74	0.89	1.15
d_1	0.684	0.681	0.683	0.089	0.033	0.50
d_2	0.0006	0.0007	0.0006	0.002	0.002	0.002
e_0	3.04	3.02	3.03	0.062	0.092	0.092
e_1	0.026	0.026	0.026	0.018	0.005	0.005
e_2	−0.056	−0.053	−0.054	0.027	0.025	0.025
f_0	1.60	13.61	14.15	11.63	13.50	14.14
f_1	0.061	0.048	0.049	0.015	0.015	0.014
f_2	−0.257	−0.250	−0.257	0.102	0.018	0.022

Source: Estimated Moroney-Mason model from equations (25a)–(25i). See text for discussion, and J. R. Moroney and J. M. Mason, "The Dynamic Impacts of Autonomous Expenditures and the Monetary Base on Aggregate Income," *Journal of Money, Credit and Banking*, Vol. 3 (November 1971), pp. 793–814, for a description of the model. Columns 1 and 4 are based on actual data for the sample period 1953:3–1965:4. The other columns are based on fifty-two-period simulations corresponding roughly to the U.S. economy from 1954:1–1966:4.

a. The parameters are for equations (25a)–(25f).

Our basic method was to apply Monte Carlo techniques to a hypothetical economy with structure as described by equations (25), to see what sort of estimation biases might arise if the stabilization policy instruments (B and G) were (incorrectly) treated as exogenous. To do this, we had to append to the basic Moroney-Mason model two policy reaction functions:

(25h) $$B_t = B_t^* + h_0 + h_1(Y_t - Y_t^*) + h_2(RS_t - RS_{t-1}) + h_3(E_t - O_t) + u_{7t}$$

(25i) $$G_t = G_t^* + i_0 + i_1(Y_t - Y_t^*) + u_{8t},$$

where

B^* = desired long-run trend value of the monetary base
G^* = desired long-run trend value of government expenditures
Y^* = potential GNP.[26]

The following section considers these reaction functions in greater detail. For present purposes it suffices to note that (25h) asserts that the monetary authorities were concerned with the GNP gap, interest rate stability, and the trade balance, while (25i) implies that the fiscal authorities reacted solely to the gap. These equations were not estimated; rather their parameters were fixed a priori.[27]

The entire set of nine equations (25a)–(25i) was then used to generate twenty-five sets of artificial data for a fifty-two-quarter period corresponding roughly to the U.S. economy from 1954:1 to 1966:4. This was accomplished by drawing twenty-five sets of normally distributed disturbances (the u_{it}), and then solving the model repeatedly.[28] These twenty-five replications of our artificial economy were then used as input to the following estimation exercise.

We first followed the statistical procedures that might have been employed by an econometrician who believed B_t and G_t to be exogenous—that is, we estimated the six equations (25a)–(25f) by two-stage least squares, correcting for autocorrelation, but employing both B_t and G_t as exogenous instruments. The results of this experiment are summarized in columns (2)

26. The trend values for B^* and G^* were calculated by finding, in each case, the growth rate that was consistent with the observed growth between 1954:1 and 1966:4. For Y^* we took real potential GNP as defined by the Council of Economic Advisers and multiplied it by a smoothed version of the actual implicit GNP deflator.

27. For the present section we used $h_0 = -8$, $h_1 = -0.6$, $h_2 = 1.5$, $h_3 = 0.3$, $i_0 = -2.76$, and $i_1 = -0.2$. This corresponds to an extremely activist monetary policy and a considerably less vigorous fiscal policy.

28. Each disturbance was generated so as to follow a first-order autoregressive scheme, $u_{it} = \rho_i u_{it-1} + \epsilon_{it}$, where the estimated ρ_i and variances of ϵ_i were used (ϵ_i was measured in billions of current dollars, except for equations (25d) and (25f), where it was measured in percentage points). These are as follows:

i	1	2	3	4	5	6
ρ	0.263	0.021	0.652	0.859	0.852	0.981
σ_ϵ	1.46	3.19	0.68	0.15	1.46	0.38

The reaction functions were assumed to be serially uncorrelated with standard errors of \$1 billion.

and (5) of Table 4, where column (2) contains the average of the twenty-five estimates for each coefficient and column (5) displays the root mean-squared error (RMSE). The second estimation procedure recognized that reaction functions existed.[29] Again using two-stage least squares and correcting for serial correlation, we estimated the augmented model (25a)–(25i), treating B_t and G_t as endogenous throughout. Columns (3) and (6) of Table 4 report the results of this estimation technique.

The table reveals that there is little to choose between the two methods. The mean estimates of most parameters are rather close to the true values, regardless of the estimation method. And, in the cases where biases are substantial, they are comparable for the two methods.

Of course, a single sampling experiment cannot be conclusive. For one thing, the kind of analysis conducted here is obviously dependent on how well the reaction functions fit the data and on how strong the endogenous policy responses are. If reaction functions have only meager explanatory power, B_t and G_t may be considered "almost exogenous," and estimation biases would probably be negligible. By contrast, if the specified reaction functions fit very tightly, the biases might be substantial. Hence, we deliberately made the standard errors of the reaction functions rather small and the policy responses substantial. Specifically, when we estimated (25h) on our artificial data we obtained R^2s of 0.70–0.80 for $B_t - B_t^*$; when we estimated (25i), we got R^2s for $G_t - G_t^*$ of around 0.50–0.60. Thus these reaction functions appear to fit the fictitious data rather better than empirical reaction functions typically fit actual U.S. data. Nevertheless, the structural estimation biases—somewhat to our surprise—turned out to be minuscule.

It thus appears that the big payoff from proper treatment of reaction functions is not in improved estimates of the standard structural equations. Rather, as the next section reveals, the benefits come from calculating the policy multipliers from the solved reduced form of the augmented model rather than from a model that excludes the reaction functions. This conclusion implies that the various pitfalls described in this paper are not cause for much conern to a fully coordinated set of policy makers since they presumably will be interested only in the multipliers obtained by ignoring all reaction functions.

29. We are obviously referring here to reaction functions that make G_t and B_t dependent on some *current* endogenous variables. As noted earlier, *lagged* reactions will present no estimation problems if disturbances are not autocorrelated.

Computing Multipliers from Structural Models

The first section contrasted two basically different ways of computing policy multipliers: The first ignored the existence of reaction functions—equation (6), while the second took appropriate account of them—equation (8). We shall now discuss the quantitative difference between the two types of multipliers, and how it depends on the nature of the reaction functions. We consider first the case where the structural parameters are known, and hence no estimation problems arise. In practice, of course, the true structural parameters are not known, but must be estimated, and so we explore subsequently the intertwined issues of proper use and estimation.

To evaluate the consequences of ignoring policy reaction functions, we experimented with a variety of functions following equations (25h) and (25i). These functions imply that the authorities have long-term desired trends for their policy tools, but are willing to deviate from them in response to stabilization needs.[30] The assumed targets are: for output, potential GNP, with deviations in either direction treated symmetrically; for the short-term interest rate, interest rate stability, irrespective of the level of rates; and for the balance of trade, a \$4.5 billion surplus.[31]

One can obtain as many different pairs of reaction functions as one wishes simply by varying the underlying parameters of equations (25h) and (25i). Table 5 presents the parameters for the fourteen combinations (some of which are repeated) of monetary and fiscal reaction functions used in our simulation experiments.

For each pair we dynamically simulated the Moroney-Mason model for fifty-two quarters (corresponding roughly to 1954:1–1966:4), and computed the RMSE of GNP about its target (potential GNP) and of the change in the short-term rate of interest about the target of zero. These two quantities, which appear in Table 5 under the heading "Y-SCORE" and "RS-SCORE," are convenient measures of the effectiveness of each pair of reaction functions as stabilizers; zero would, of course, represent perfection and larger "scores" mean less effectiveness.

30. This form of reaction function is generally consistent with a quadratic loss function.

31. Hence the reaction functions considered in this section will have $i_0 = 0$ and $h_0 = -4.5h_3$. The one exception is the reaction function used above and described in note 27. The constants, i_0 and h_0, clearly have no bearing on the marginal responses of the system.

Table 5. Results of Moroney-Mason Model for Alternative Monetary and Fiscal Reaction Functions

	Reaction function parameters[a]				Scores[b]		Multipliers[c]	
Row	h_1	h_2	h_3	i_1	Y-SCORE	RS-SCORE	Monetary policy dY/dB^*	Fiscal policy dY/dG^*
			Effect of standard monetary or fiscal stabilization					
1	0.0	0.0	0.0	0.0	81.6	0.259	13.48	1.66
2	0.0	0.0	0.0	−0.6	41.2	0.237	6.62	0.83
3	−0.06	1.5	0.3	0.0	41.7	0.188	6.71	0.82
			Effect of stronger fiscal stabilization (standard monetary stabilization)					
4	−0.06	1.5	0.3	0.0	41.7	0.188	6.71	0.82
5	−0.06	1.5	0.3	−0.2	35.7	0.179	5.74	0.71
6	−0.06	1.5	0.3	−0.6	27.6	0.176	4.45	0.55
7	−0.06	1.5	0.3	−1.0	22.5	0.179	3.62	0.45
			Effect of stronger monetary stabilization (standard fiscal stabilization)					
8	−0.02	1.5	0.3	−0.6	33.3	0.182	5.39	0.68
9	−0.06	1.5	0.3	−0.6	27.6	0.176	4.45	0.55
10	−0.10	1.5	0.3	−0.6	23.6	0.172	3.78	0.47
			Effect of stronger interest rate stabilization (standard fiscal stabilization)					
11	−0.06	0.5	0.3	−0.6	27.1	0.218	4.45	0.55
12	−0.06	1.5	0.3	−0.6	27.6	0.176	4.45	0.55
13	−0.06	6.0	0.3	−0.6	29.8	0.136	4.44	0.56
			Effect of stronger fiscal stabilization (weak monetary stabilization)					
14	−0.02	1.5	0.3	−0.6	33.3	0.182	5.39	0.68
15	−0.02	1.5	0.3	−1.0	26.2	0.185	4.21	0.53
16	−0.02	1.5	0.3	−2.0	17.0	0.192	2.73	0.35
17	−0.02	1.5	0.3	−3.0	12.6	0.196	2.01	0.26
			Effect of stronger monetary stabilization (weak fiscal stabilization)					
18	−0.06	1.5	0.3	−0.2	35.7	0.179	5.74	0.71
19	−0.60	1.5	0.3	−0.2	3.5	0.244	1.40	0.17

Source: Equations (25h) and (25i) and Moroney-Mason model cited in Table 4.

a. The parameters are from equations (25h) and (25i).

b. Y-SCORE is the root mean-squared error of gross national product around potential GNP; RS-SCORE is the root mean-squared error for the change in the short-term rate of interest about the target of zero.

c. As the Moroney-Mason model is slightly nonlinear, the computed multiplier paths will depend on initial conditions. In practice, the actual variability proved to be quite trivial.

Two further simulations with each set of reaction functions were run in order to calculate policy multipliers. In particular, we introduced a sustained increase of $1 billion in B^* (or G^*) and resimulated the model. The differences between this set of simulations and the corresponding initial control simulation provided us with a pair of dynamic multiplier paths. In the last two columns of Table 5 we have reported the steady-state (that is, fifty-second quarter) multipliers for both monetary and fiscal policy, labeled dY/dB^* and dY/dG^*, respectively.[32]

32. The dynamic multipliers for some other selected time periods for the reaction functions in row 19 are given in the right-hand portion of Table 7. We also computed multiplier effects on short rates but have not reported them.

The first row of Table 5 corresponds to the "degenerate" reaction functions, $B_t = B_t^*$ and $G_t = G_t^*$. In other words, the monetary base and government spending are exogenous and grow at their trend rates regardless of macroeconomic conditions. The multipliers for this case—13.48 for B and 1.66 for G—are calculated by ignoring the existence of the reaction functions (and thus correspond to equation (6) above). The multipliers in the remaining rows of Table 5 (which are analogous to equation (8) above) reveal that ignoring the reaction functions may lead to a striking overstatement of the true multipliers. In the table, this overstatement is at least by a factor of 2, and goes as high as a factor of 10.

The table indicates a systematic relationship between the character of the reaction function and the magnitude of the multiplier. Rows 2 and 3 introduce "standard" monetary or fiscal reaction functions[33] one at a time, while holding the other authority to the steady growth policy.[34] These two standard policies are of almost identical strength: They achieve essentially the same Y-SCORE, and each serves to cut *both* multipliers in half. The only difference between rows 2 and 3 is that monetary policy (which "cares" about interest rate stability) gets a noticeably improved RS-SCORE.

Rows 4–7 display the effect of successively increasing the strength of fiscal policy while maintaining the standard monetary reaction function. Rows 8–10 deal with strengthening the monetary response to the GNP gap, with the standard fiscal reaction function. The two groups tell a similar story: A stronger policy reduces both the Y-SCORE and multipliers. Rows 11–13 investigate altering the monetary reaction function to attach greater concern to interest rate stability, and reveals little effect on the multipliers, but an improvement in the RS-SCORE at the expense of the Y-SCORE.

The final rows of the table consider some more extreme combinations of reaction functions, where the response of one authority is relatively weak while the other responds with increasing strength to the GNP gap. Within each group, this steadily reduces the multipliers and brings GNP closer to target at the expense of increasing the variability of interest rates. It will be noted that when the reactions of either monetary or fiscal policy become sufficiently strong, the true multipliers can get very small indeed (see rows 17 and 19).

Overall, then, Table 5 provides considerable evidence on the problems

33. The coefficients of the standard case were obtained by calculating the policy response that would eventually close the gap if the multipliers were as in row 1.

34. Thus these rows correspond to multipliers like equation (8′).

that reaction functions pose for multiplier calculations.[35] The results also shed some light on the success of alternative reaction functions as stabilizers and on the tradeoff between the stability of interest rates and the growth of income.

A DIGRESSION ON THE BEHAVIOR OF THE MONEY SUPPLY

The widely advocated monetary "rule" of maintaining a steady rate of growth of the money supply is not obeyed by any of our reaction functions, not even steady growth in the base. In fact, steady growth in the base does not yield the steadiest monetary growth. The reason is that while a reaction function destabilizes the monetary base, it tends to stabilize interest rates and hence the ratio of the money stock to the base; and either effect may dominate.

These results all refer to the deterministic part of the Moroney-Mason model. To assess the effect of stochastic terms, we generated twenty-five "histories" of random shocks (following the error distributions indicated by our estimation results) and applied these to seven versions of the model —differing only in the reaction functions present—to generate twenty-five different time paths of the money stock *for each policy rule*. We then looked at the stochastic variability of the money supply under alternative reaction functions by computing *for each quarter* the standard deviation across replications. Table 6 gives an overview of the results. The first column reports the average standard deviation over the fifty-two quarters. The remaining two columns exhibit the minimum and maximum standard deviations.[36]

To put these in perspective, it should be noted that a standard deviation of \$1.5 billion in M corresponds to a standard deviation of about 5 percentage points in the annual growth rate of M. On a quarter-to-quarter basis, therefore, reasonable reaction functions may lead to substantial variability in the growth rate of M. On the whole, as compared with the steady growth in the base, stabilization formulas generally mitigate the impact of

35. Similar experiments were conducted and analogous results obtained for an alternative model developed by Robert S. Pindyck. For the model see his "A Small Quarterly Model of the U.S. Economy" (April 1970; processed).

36. It is to be expected that the standard deviations would differ from one quarter to the next owing to (i) chance variations in the sizes of the random shocks, and (ii) systematic variations in the movements of the exogenous variables (especially exports) over time.

Table 6. Stochastic Variability of the Money Supply under Alternative Reaction Functions

Reaction function[a]	*Average standard deviation*	*Smallest standard deviation*	*Largest standard deviation*
1	4.04	2.24	5.55
2	3.94	2.24	5.31
3	3.07	1.52	4.21
6	2.93	1.52	4.04
13	2.97	1.40	3.99
17	2.83	1.52	3.87
19	4.73	2.20	6.76

Source: Estimated from Moroney-Mason model cited in Table 4.
a. These are defined in the corresponding row numbers in Table 5.

random shocks on the money stock.[37] To sum up, we find no necessary conflict between stability of income and interest rates, on the one hand, and stability of the money stock, on the other. A well-designed and well-executed mix of monetary and fiscal policies can hope to contribute to both objectives.

ESTIMATING THE MULTIPLIERS

The multipliers just discussed apply when the true parameters of the underlying model are known exactly. In practice, of course, the parameters would have to be estimated and then used to compute the reduced form. We now return to the Monte Carlo experiment used above to compute for the Moroney-Mason model both "proper" structural estimates (those that treat policy variables as endogenous) and "improper" ones (those that treat them as exogenous), and investigate the differences in the multipliers calculated from the solved-reduced-form multipliers of each of these structural estimates.

We took the twenty-five replicated economies of the preceding section—each estimated two ways—and used each estimated structure to derive dynamic multiplier paths for both monetary and fiscal policy. Although the underlying data had been generated in every case by a model that included two reaction functions (those of row 19 of Table 5), we computed dynamic multipliers two ways: First, by ignoring the reaction functions, we derived multipliers analogous to equation (6); then we used the reaction functions,

37. The only exception is reaction function 19, which is absurdly activist. In that one case, discretionary monetary policy actually makes M more responsive to random shocks than it is under the steady growth rules.

treating B and G as endogenous, to compute multipliers analogous to equation (8). For each quarter, we then calculated the mean of the twenty-five multiplier estimates and their standard deviations. Table 7 reports the results.

The first bank of columns in Table 7 presents the computations excluding reaction functions. These data show that the negligible estimation biases exhibited in Table 4 can in some cases build up to nonnegligible biases in estimating multipliers like (6). The average estimated steady-state multiplier for B when policy is taken as exogenous is 15.2, which is somewhat higher than the "true" multiplier of 13.5. The multipliers for earlier quarters are similarly overstated, as are the government spending multipliers. Even when the reaction functions are included in the multiplier calculations, as reflected in the second bank of columns, the stochastic multipliers are slightly (but only slightly) higher on average than the true ones.

In summary, we have previously seen that ignoring reaction functions might lead some users to overstate policy multipliers rather seriously, *even if the economic structure were known perfectly*, and now confirm these findings for practical applications, where the structure must be estimated. Further, we find that if (and this may be a big "if") the reaction function can be correctly specified, the multipliers can be reasonably well estimated. Put another way, the differences between ignoring and taking account of correctly estimated reaction functions seem far more important than any structural estimation problems.[38]

Estimating Reduced Forms: Some Simulation Results

The second section examined analytically the consequences of using estimated reduced-form equations to evaluate policy multipliers when policy was formulated endogenously, and produced rather precise results for the large sample properties of an extremely simple model. But how would reduced-form estimation fare in a more complex model with a limited sample size?

To gain some perspective on this, we have utilized the hypothetical data generated in the third section to estimate directly reduced forms for the

38. In particular, even if the structural estimates are consistent (as in the case of a lagged reaction function with serially uncorrelated errors), the problem of appropriate use of the models when reaction functions exist still remains.

Table 7. Monetary and Fiscal Multipliers and Standard Deviations in Moroney-Mason Model, with Stabilization Policy Treated as Exogenous and Endogenous, Various Quarters[a]

	Stabilization policy treated as exogenous						*Stabilization policy treated as endogenous*					
	Monetary policy multipliers			*Fiscal policy multipliers*			*Monetary policy multipliers*			*Fiscal policy multipliers*		
		Estimated dY/dB			*Estimated dY/dG*			*Estimated dY/dB**			*Estimated dY/dG**	
Quarter	*True dY/dB*	*Mean*	*Standard deviation*	*True dY/dG*	*Mean*	*Standard deviation*	*True dY/dB**	*Mean*	*Standard deviation*	*True dY/dG**	*Mean*	*Standard deviation*
1	1.64	1.72	0.51	1.16	1.27	0.19	0.47	0.51	0.09	0.71	0.74	0.06
2	2.81	3.05	1.02	1.44	1.63	0.37	0.93	0.98	0.20	0.57	0.61	0.10
3	5.49	6.16	1.54	1.52	1.77	0.46	1.56	1.64	0.25	0.20	0.22	0.14
4	7.41	8.49	2.14	1.60	1.87	0.47	1.85	1.95	0.31	−0.05	−0.06	0.16
5	9.06	10.47	2.72	1.65	1.92	0.42	1.75	1.83	0.36	−0.07	−0.07	0.16
6	10.37	12.03	3.24	1.67	1.93	0.36	1.46	1.51	0.36	0.07	0.10	0.12
7	11.40	13.23	3.72	1.69	1.91	0.34	1.25	1.29	0.31	0.22	0.26	0.09
8	12.18	14.12	4.23	1.69	1.88	0.36	1.23	1.28	0.24	0.27	0.30	0.07
12	13.62	15.74	6.40	1.66	1.76	0.30	1.46	1.52	0.27	0.12	0.14	0.11
32	13.27	14.18	3.19	1.61	1.62	0.57	1.40	1.47	0.22	0.16	0.18	0.07
52	13.48	15.18	4.89	1.66	1.75	0.32	1.40	1.47	0.22	0.17	0.19	0.07

Source: Estimated from Moroney-Mason model cited in Table 4.

a. Y = gross national product; B = unborrowed reserves plus currency; G = government purchases; B^* and G^* = desired long-run trend values of the monetary base and of government expenditures, respectively.

Moroney-Mason model. That model (equations (25a) to (25g) above) can be solved to yield the partial reduced-form equation for GNP:

$$(26)\quad Y_t = \pi_0 + \pi_1 G_t + \pi_2 E_t + \pi_3 B_t + \pi_4(B_t RD_{t-1}) + \pi_5(B_t RS_{t-1}) + \pi_6 M_{t-1} + \pi_7 C_{t-1} + \pi_8 C_{t-2} + \pi_9 RL_{t-2} + \pi_{10} I_{t-1} + u_t.$$

Several points should be noted about equation (26): (a) the equation is linear in contemporary variables but contains some nonlinearities in lagged variables stemming from the money supply equation; (b) the structure implies a variety of restrictions on the π_i (for example, $\pi_1 = \pi_2$); (c) because (26) ignores reaction functions such as (25h) and (25i), it is not a true reduced form (that is, not all the right-hand variables are predetermined) and therefore coefficients such as π_1 are partial reduced-form multipliers like (6), not true reduced-form multipliers like (8).

These considerations suggest that ordinary least squares applied to (26) should yield relatively unsatisfactory estimates of the parameters, compared with the estimates obtained from a procedure that takes account of the simultaneity. The extent of these differences in a concrete case was assessed by taking the twenty-five data samples generated for use in the third section, and estimating (26) by two alternative procedures: (1) ordinary least squares (OLS), and (2) two-stage least squares (TSLS), correcting for serial correlation in both cases.

Table 8a reports, for selected parameters of the partial reduced form, estimates made with data generated under the activist monetary policy described in row 19 of Table 5. The OLS estimates seem noticeably more biased than the TSLS estimates. For example, the mean estimate of π_1, the coefficient of G, which has a true value of 1.16, is only 0.17 under OLS but rises to 0.75 with TSLS.[39] The comparisons based on the mean-squared errors also favor the TSLS estimates, but by a smaller margin, reflecting the generally greater variability of TSLS estimates as compared with OLS estimates. On balance, while the estimates are relatively better for TSLS, in absolute terms they are not all that satisfactory, especially for the money multipliers.[40]

39. Detail not in the table sheds further light on this. For example, the OLS estimate for the coefficient of B has the wrong sign in twenty-four out of twenty-five cases and is significant in fifteen of these. The TSLS estimates yield only three incorrect and significant coefficients, but still leave eighteen incorrectly signed coefficients.

40. For the monetary coefficients, this problem may in part reflect multicollinearity. Such multicollinearity should stem from the presence of B in both linear and multiplica-

Table 8. Estimates of Equation (26) under Strong Monetary and Fiscal Stabilization Policies

		Mean estimates		*Root mean-squared errors*	
Parameter[a]	*True value*	*Ordinary least squares*	*Two-stage least squares*	*Ordinary least squares*	*Two-stage least squares*
		a. Strong monetary stabilization			
π_1	1.16	0.17	0.75	1.08	1.23
π_2	1.16	0.93	1.02	0.57	0.50
π_3	1.69	−1.32	−0.85	3.07	2.73
π_4	−0.03	0.023	0.012	0.063	0.057
π_5	0.014	−0.041	−0.036	0.062	0.057
π_6	−0.14	0.129	0.097	0.517	0.522
		b. Strong fiscal stabilization			
π_1	1.16	−0.17	0.41	1.34	0.90
π_2	1.16	0.31	0.61	0.91	0.85
π_3	1.69	0.61	1.91	1.18	1.91
π_4	−0.03	−0.009	−0.022	0.038	0.041
π_5	0.014	0.011	0.012	0.016	0.029
π_6	−0.14	−0.041	−0.113	0.313	0.480

Source: Derived from equation (26).
a. The parameters refer to equation (26) shown in the text.

To examine the same issues with reaction functions that rely mainly on fiscal rather than monetary policy, we chose the reaction functions given in row 17 of Table 5, generated some new artificial data, and repeated the experiments.

Table 8b reveals that the OLS estimates are again uniformly more biased than the TSLS results, while the two sets of estimates have comparable RMSEs. It also confirms the suggestion of our analysis above that the stronger fiscal reactions increase the OLS biases for the fiscal variables, and reduce the biases for the monetary variables. With the relative weakness of monetary action, the money multipliers improve in accuracy for both OLS and TSLS and, in fact, are remarkably close to the true values for TSLS

tive forms along with the lagged money stock. Imposing the restrictions implied by the structure is one way of getting around these problems. But this is just another way of saying that unrestricted least squares estimation of the reduced form is an inefficient means of estimating the solved reduced form.

However, since this problem appears to disappear in the "strong fiscal policy" case considered next, it may well stem from some simultaneity problems.

(though the RMSEs are large). The fiscal multipliers, while distinctly better for TSLS,[41] still leave much to be desired.

On balance, estimation of unrestricted reduced forms, even if done properly, is not a particularly good technique for evaluating policy multipliers. There appears to be no simple substitute for specifying reaction functions and estimating the complete structure.

As a final illustration of the pitfalls in reduced-form estimation, we examine how a simple St. Louis equation would perform in a world that in fact accorded with the Moroney-Mason model. The St. Louis equation, as it appears in the work of Andersen and Carlson, is

$$\Delta Y_t = \sum w_i \Delta B_{t-1} + \sum w_i' \Delta G_{t-1} + u_t. \tag{27}$$

If estimated by OLS, it would suffer from problems of both omitted variables and simultaneity. In the present instance, as we see it, a somewhat better St. Louis-type equation could be constructed if the investigator knew all the exogenous variables in the underlying structural model. He might then fit the following equation:

$$\Delta Y_t = \sum w_i \Delta B_{t-i} + \sum w_i' \Delta(G + E)_{t-i} + \sum w_i'' \Delta RD_{t-i} + u_t. \tag{28}$$

Equation (28) can be viewed as a linear approximation to the final form[42] of the Moroney-Mason model where B, RD, and $(G + E)$ are regarded as exogenous variables.

We estimated both (27) and (28) for each of the two sets of data described above, that is, one set with predominantly monetary stabilization and the other with predominantly fiscal stabilization. We employed the Almon lag technique with a fourth-degree polynomial and a seven-quarter lag.[43] The results are reported in Table 9.

Since both (27) and (28) attempt to assess the impact of B and G when no endogenous reactions occur, the relevant "true" multipliers would appear

41. Some relevant detail helps to supplement the information in the table. The fiscal multiplier from OLS is incorrectly signed in twenty-four of twenty-five cases and is significant in ten of these. For TSLS, almost the reverse is true: Nineteen have the correct sign and thirteen of these are significant.

42. The final form for Y expresses Y as a function of current and lagged values of the exogenous variables and lagged values of Y. The approximation would stem from the linearization and from the particular form assumed for the lag patterns in (28).

43. Andersen and Carlson used a fourth-degree polynomial with five lags. However, since in the present case—see Table 7—the lags are somewhat longer, the use of seven lags seemed fairer. We also ran the regressions under the Andersen-Carlson lag specification, and found they were almost always less satisfactory.

Table 9. Reduced-form Estimates of Monetary and Fiscal Policy Multipliers

	Average sum of lag coefficients[a]		
Policy and equation	*Unborrowed reserves plus currency, B*	*Government purchases, G^b plus exports, E*	*Discount rate, RD*
Strong monetary stabilization			
Equation (27)	1.90	2.77	...
	(11.74)	(1.74)	
Equation (28)	3.38	1.63	−3.60
	(10.23)	(0.67)	(11.93)
Strong fiscal stabilization			
Equation (27)	3.95	0.36	...
	(9.72)	(1.32)	
Equation (28)	4.01	0.42	−0.76
	(9.80)	(1.27)	(14.19)
True steady-state multipliers (ignoring reaction functions)	13.48	1.66	−14.71

Source: Derived from equations (27) and (28).
a. Numbers in parentheses are the root mean-squared errors.
b. In equation (28) this variable is government purchases plus exports.

to be those excluding reaction functions, which are entered in the final row of the table. Under a regime of strong monetary policy, (28) yields a rather good estimate of the government spending multiplier but, as expected, a marked understatement (as well as very large sampling variability) for the base and discount rate multipliers. Equation (27), which also suffers from omitted-variables bias, gives even more unsatisfactory results, in terms of both biases and RMSEs.

Under a regime of strong fiscal policy, equation (28), though slightly superior to (27), gives a highly unsatisfactory fiscal multiplier. The base multiplier is improved but still strongly understates the true multiplier, and the discount rate multiplier is worse yet. Both equations are highly unreliable, as illustrated by the large RMSEs. It appears that equations of the St. Louis type are not likely to resolve our problems.

RECAPITULATION

We have analyzed from a variety of points of view the estimation of policy multipliers in the face of conscious stabilization actions. Our basic conclusion is that, for a rather broad range of plausible behavior patterns of the authorities, successful evaluation of policy multipliers, at least by the outside economist, requires explicit recognition of reaction functions. Both analytically and via sampling experiments, we have shown that reduced-form estimation will not suffice. A more structural approach—including the reaction functions—is required. Even if the remainder of the model is pinned down with a high degree of precision, ignoring the reaction functions may well give a very misleading picture of policy.

Correspondingly, in an environment with incomplete coordination, a policy maker who neglects the behavior of other government authorities can commit significant policy errors. We have investigated this possibility in terms of the stabilization functions of the administration and the Federal Reserve but the point applies more generally to any systematic behavior within the public sector. For example, some macro models already provide for an endogenous determination of state and local government spending. Similarly, researchers have begun to examine the behavior of agencies such as the Federal Home Loan Bank Board and the Federal National Mortgage Association that can have a major impact on savings flows, mortgage funds, and the housing sector.[44]

This trend is a desirable one and has important ramifications for the construction and refinement of large-scale macroeconometric models. The results of this study suggest that more of the resources devoted to such models should be directed toward provisional attempts at specifying and estimating behavioral relationships for the public sector. Of course, this is not an easy task.

Specifying and Estimating Empirical Reaction Functions

Previous sections established that the severity of the various problems posed by reaction functions is strongly dependent on the character of the functions employed. It is thus extremely important to get at least a crude handle on both the qualitative and quantitative nature of the reaction functions that have characterized U.S. policy making. This section focuses first on a number of pitfalls in specifying and estimating reaction functions, and then on some actual attempts to do so. In view of the serious conceptual problems that undermine the empirical work, the results are surprisingly good and seem to hold out the hope that better specifications could lead to still better equations.

44. W. L. Silber, "A Model of FHLB and FNMA Behavior," forthcoming in *Review of Economics and Statistics.*

SOME CONCEPTUAL PROBLEMS

In many ways, the problems in specifying reaction functions are quite general, resembling the difficulties encountered in fitting, say, a consumption function. Reaction functions have their analogs to the key decisions in formulating a consumption function, such as reliance on the hypothesis of utility maximization, the length of the planning horizon, the degree of commodity aggregation, the choice of a certainty or an uncertainty model, the nature of expectations, and efforts to integrate labor-leisure or portfolio choices with the consumption decision.

Formal treatments of policy making—as exemplified by the work of Theil, Brainard, Chow, and others—generally start with a quadratic preference function for the policy maker that is to be maximized subject to the underlying economic model as he perceives it. Given this model, the mechanism by which forecasts are generated, and the optimal values of the target variables, the utility-maximization hypothesis could be used to derive optimal policy rules.

There are a number of variations on this general theme. For example, a one-period horizon would lead to a policy rule of the sort considered in the third and fourth sections, while a multiperiod horizon would result in a more complex lagged feedback policy rule of the kind considered by Chow. As Brainard points out, policy rules may also differ if the authorities attach a degree of uncertainty to their multiplier estimates instead of treating them as known constants. One also has a choice of the degree of aggregation, and the specification of complex interrelationships between monetary and fiscal decision making.

The appropriate degree of aggregation assumes particular importance in the present context. In general, each stabilization authority will have several weapons at its disposal. For example, the fiscal authority might control federal purchases, transfer payments, and several tax rates. This suggests estimating either a set of reaction functions (one for each instrument) or a single reaction function explaining a combined measure of fiscal influence such as the weighted full employment surplus. The choice depends on the manner in which policy was actually formulated. If, during the period in question, the fiscal authorities treated each instrument as one ingredient of a fiscal "portfolio," in the manner suggested by Brainard, then a set of interrelated reaction functions should be estimated. Alternatively, if the choices of fiscal instruments were essentially arbitrary or political, and the government cared only about some overall measure of fiscal influence, a single reaction function for that overall measure is in order. This procedure requires knowledge of the strength that the government attributes to each policy tool in computing its aggregate measure of stimulus or restraint, that is, of the government's model of the economy.

While efforts have been made to construct a unified measure of net fiscal influence,[45] and a single measure of monetary influence,[46] these results have not been used systematically to specify the dependent variable for a reaction function. This is a potentially fruitful area for future research.

A still more serious problem arises if the fiscal and monetary authorities coordinate their actions perfectly so as to arrive at an appropriate total stabilization package, but use some arbitrary procedures for allocating the burden between themselves. A single reaction function is then needed with some measure of the net influence of *both* fiscal and monetary policy as the dependent variable. In practice, fiscal and monetary policies are not perfectly coordinated. But so long as some cooperation exists, it must be recognized in any serious effort to estimate reaction functions.

The stability of behavioral relations over time also plagues macroeconomic model building generally, and the estimation of reaction functions particularly. For the fiscal authorities, a change in the political administration is quite likely to alter reaction patterns for at least three reasons. First, the new administration may have different ideas about the relative importance to be attached to the various goals of policy. Second, the economic model held by the government may be revised. Third, a new relationship between the executive and legislative branches may affect the mix of stabilization instruments. Such political changes may even sway the conduct of monetary policy—especially where questions of fiscal-monetary coordination are concerned.

45. See, for example, Edward M. Gramlich, "Measures of the Aggregate Demand Impact of the Federal Budget," in Wilfred Lewis, Jr. (ed.), *Budget Concepts for Economic Analysis* (Brookings Institution, 1968); and William H. Oakland, "Budgetary Measures of Fiscal Performance," *Southern Economic Journal*, Vol. 35 (April 1969), pp. 347–58. This literature is summarized in the forthcoming survey of fiscal policy by Blinder and Solow.

46. James S. Duesenberry, "Tactics and Targets of Monetary Policy," in *Controlling Monetary Aggregates*, Proceedings of the Monetary Conference Sponsored by the Federal Reserve Bank of Boston, 1969 (FRBB, 1969), pp. 83–95.

Further, quite apart from changing administrations, the attention that the authorities pay to the competing goals of macro policy may change subtly over time. For example, if the Fed gears policy sometimes toward reducing unemployment, and sometimes toward lowering the balance-of-payments deficit, estimation becomes very difficult indeed. A small but growing econometric literature explores ways to handle such problems,[47] and these techniques could be fruitfully applied to the estimation of reaction functions.

In sum, before we can hope to do a good job of explaining stabilization policies endogenously, we may have to (a) devise better summary measures for fiscal and monetary influence; (b) find ways of building into models the complex interactions between fiscal and monetary policy making; and (c) develop more refined techniques for estimating behavioral relations that are subject to abrupt structural change.

A SURVEY OF EXISTING EMPIRICAL WORK

Such thorny conceptual and statistical problems have rarely stopped those interested in policy from pursuing their investigations, and the case of reaction functions is no exception. The literature contains a modest number of studies that estimate behavioral relations for policy makers. These studies have examined (and generally accepted) the hypothesis that the authorities have behaved in a manner more or less consistent with the formal optimization scheme outlined above.[48] Most of these studies have focused on central bank behavior, but one has concerned itself with some federal agencies, and another has considered both the fiscal and monetary authorities of the United States. A brief review will help to bring out the flavor of the results as well as how the authors have attempted to come to grips with some of the pitfalls discussed above.

One of the arliest and best-known studies is that of Wood, who explained open market operations in 1952–63 by both "defensive" and "dynamic"

47. Most of this is summarized in Stephen M. Goldfeld and Richard E. Quandt, *Nonlinear Methods in Econometrics* (Amsterdam: North-Holland, 1972), Chap. 9.

48. In addition, some writers have been concerned with deducing the preference functions of the authorities. See, for example, Ann F. Friedlaender, "Macro Policy Goals in the Postwar Period: A Study in Revealed Preference," Discussion Paper 6 (Boston College, Department of Economics, November 1970).

considerations.[49] A variable defined as "other factors affecting reserves" is used to capture the defensive element in open market operations. The dynamic variables include some of the typical stabilization objectives as well as the national debt held outside the Treasury, which is included because the Fed usually assists the Treasury in financing operations. One important feature of Wood's specification, which has not been followed up in later work, is the inclusion of a rough measure of fiscal influence that attempts to take some account of the coordination between the stabilization authorities. Wood also approximates an overall measure of monetary impact, by correcting open market operations for changes in reserve requirements. His specification makes the policy variable a function of several *current* endogenous variables, and he handles the simultaneity problem by using two-stage least squares. His overall conclusion is that while the bulk of the Fed's actions are aimed at offsetting other factors affecting reserves, a significant portion of its behavior is in systematic response to "targets and target variables specified in the Employment Act of 1946."[50]

The temporal stability of coefficients has been subjected to extensive scrutiny by Christian, who used twenty-seven overlapping sample periods to examine the stability of the Dewald and Johnson reaction functions.[51] For each of these periods he related several possible monetary control vari-

49. John H. Wood, "A Model of Federal Reserve Behavior," in George Horwich (ed.), *Monetary Process and Policy* (Richard D. Irwin, 1967), pp. 135–66. Wood's study contains a careful treatment of the formal framework that is sketchily outlined above and has strongly influenced a number of subsequent studies, such as Raymond G. Torto, "An Endogenous Treatment of Open-Market Operations" (paper presented at the Twenty-ninth Annual Conference of the Southern Economic Association, St. Louis, November 1969; processed).

50. Wood, "Model of Federal Reserve Behavior," p. 156. Other early studies that reached similar conclusions include the following: William G. Dewald and Harry G. Johnson, "An Objective Analysis of the Objectives of American Monetary Policy, 1952–61," in Deane Carson (ed.), *Banking and Monetary Studies* (Richard D. Irwin, 1963), pp. 171–89; Stephen M. Goldfeld, *Commercial Bank Behavior and Economic Activity* (Amsterdam: North-Holland, 1966), pp. 188–90; Thomas Havrilesky, "A Test of Monetary Policy Action," *Journal of Political Economy*, Vol. 75 (June 1967), pp. 299–304; and Grant L. Reuber, "The Objectives of Canadian Monetary Policy, 1949–61: Empirical 'Trade-offs' and the Reaction Function of the Authorities," *Journal of Political Economy*, Vol. 72 (April 1964), pp. 109–32.

51. James W. Christian, "A Further Analysis of the Objectives of American Monetary Policy," *Journal of Finance*, Vol. 23 (June 1968), pp. 465–77. It should be noted that Reuber, in "Objectives of Canadian Monetary Policy," tested his reaction functions for stability and found no indication of structural change.

ables to the various stabilization objectives employed by Dewald and Johnson. Overall, he reinforces the evidence given by Wood, but he finds considerable instability, especially with respect to the inflation and balance-of-payments objectives. In particular, these latter two variables tend to be significant only in sample periods in which price stability and the balance of payments drew much official concern. Christian leaves open the question of whether preferences have changed or a more complicated preference function is needed. The thrust of his argument strongly suggests the need for some other techniques of estimation.

Keran and Babb have provided another attempt at explaining Federal Reserve behavior.[52] In the general spirit of Wood's work, they related changes in the monetary base to a proxy for stabilization objectives,[53] a measure of interest rate stability, and the change in the debt held outside trust accounts (the last as a measure of "even-keel" financing needs). At a technical level, Keran and Babb make the valuable point that the use of quarterly changes in the monetary base as a dependent variable reduces the need for explanatory variables measuring "defensive" policy actions, since, if open market operations are used to smooth out other factors affecting reserves, the monetary base need not be affected by these factors. They do, however, employ some "defensive" variables in their monthly equations explaining open market operations. The authors examine their basic equation for structural stability, but only by the simple expedient of using a shift variable to distinguish between political administrations. They find this shift variable to be highly significant, suggesting that the behavior of the Fed may be subject to the kinds of political shifts described earlier.

Finally Friedlaender has made a noteworthy effort to estimate *individual* reaction functions for each of three monetary variables (the discount rate, open market operations, and reserve requirements) and three fiscal variables (government spending, personal taxes, and corporate taxes). As noted above, whether this disaggregation is appropriate depends on the underlying nature of coordination in the policy process. Friedlaender estimates all six functions separately for Republican and Democratic administrations,

52. Michael W. Keran and Christopher T. Babb, "An Explanation of Federal Reserve Actions (1933–68)," *Federal Reserve Bank of St. Louis Review*, Vol. 51 (July 1969), pp. 7–20.

53. One major drawback of the Keran-Babb study is the rather strained use of free reserves as a single proxy for income, balance-of-payments, price, and unemployment objectives.

and again finds that substantial differences emerge for both fiscal and monetary authorities.

Taken as a whole, this brief review uncovers at least modest evidence that reaction functions do in fact exist. Furthermore, virtually all of the studies cited use current endogenous variables to explain policy behavior. As a result, the estimation problems stressed earlier in this paper appear to be very real ones. Certainly, further research along these lines seems to be called for. As a matter of strategy, the most sensible approach might be to investigate reaction functions in the context of a specific econometric model. On the one hand, such an investigation would guide the specification of the dependent variables for the reaction functions. On the other hand, integration of a reaction function into a complete model is the only way in which to assess the consequences of any particular policy rule. Allowing for this two-way interaction between the model and the reaction functions would be an important contribution to understanding of the policy process.

APPENDIX

Derivation of Equations

Most of the bias formulas presented in the section entitled "Problems in Estimating Reduced-form Equations" can be viewed as special cases of the following general model. Assume that income is determined by the simple partial reduced-form equation:

$$Y_t = R + \alpha F_t + \beta M_t + \epsilon_t. \tag{A-1}$$

Assume further that the correlation between F_t and ϵ_t is ρ_F, the correlation between M_t and ϵ_t is ρ_M, and the correlation between F_t and M_t is r. If the symbol C_{XY} denotes the sample covariance between X and Y, the expressions for the ordinary least squares regression coefficients are

$$\begin{aligned} \hat{\alpha} &= \frac{C_{FY}\,C_{MM} - C_{YM}\,C_{FM}}{C_{FF}\,C_{MM} - C_{FM}^2} \\ \hat{\beta} &= \frac{C_{YM}\,C_{FF} - C_{YF}\,C_{FM}}{C_{FF}\,C_{MM} - C_{FM}^2}. \end{aligned} \tag{A-2}$$

Substituting the various moments into (A-2), and taking probability limits yields

$$
\text{(A-3)} \qquad
\begin{aligned}
R^{\alpha} &\equiv \frac{plim\ \hat{\alpha}}{\alpha} = 1 + \frac{\rho_F - r\rho_M}{(1 - r^2)(\alpha S_F/\sigma_\epsilon)} \\
R^{\beta} &\equiv \frac{plim\ \hat{\beta}}{\beta} = 1 + \frac{\rho_M - r\rho_F}{(1 - r^2)(\beta S_M/\sigma_\epsilon)},
\end{aligned}
$$

where S_F, S_M, and σ_ϵ are the standard deviations of F_t, M_t, and ϵ_t, respectively.

In the model of equations (14) and (15) in the text, it is a trivial matter to calculate that

$$
\text{(A-4)} \qquad
\begin{aligned}
S_F &= \frac{\sigma_\epsilon}{\alpha}(1 + \gamma^2)^{\frac{1}{2}} & \qquad S_M &= \frac{\sigma_\epsilon}{\beta}(1 + \delta^2)^{\frac{1}{2}} \\
\rho_F &= -(1 + \gamma^2)^{-\frac{1}{2}} & \qquad \rho_M &= -(1 + \delta^2)^{-\frac{1}{2}} \\
r &= \frac{1 + \rho\gamma\delta}{(1 + \gamma^2)^{\frac{1}{2}}(1 + \delta^2)^{\frac{1}{2}}},
\end{aligned}
$$

where the symbols ρ, γ, and δ are defined as in the text. Substitution of all these expressions into (A-3) yields equation (16).

An Alternative Forecasting Rule

William Poole has pointed out to us that the forecasts ϵ_F and ϵ_M as described in the text are suboptimal forecasts. In particular, they have a larger mean-squared error than an alternative set of forecasts, $\overset{*}{\epsilon}_F$ and $\overset{*}{\epsilon}_M$, which have the following simple relation to our old forecasts:

$$\overset{*}{\epsilon}_F = \rho_F^2\, \epsilon_F, \qquad \overset{*}{\epsilon}_M = \rho_M^2\, \epsilon_F.$$

The essential difference is that, whereas ϵ_F and ϵ_M had the property that the forecast errors were uncorrelated with ϵ, the true value, $\overset{*}{\epsilon}_F$ and $\overset{*}{\epsilon}_M$ are such that the errors are uncorrelated with the forecasts themselves.

Fortunately, this new forecasting scheme can be accommodated by a trivial modification. In particular, we need only change the reaction functions (equations (14) in the text) to

$$F = -\frac{\overset{*}{\epsilon}_F}{\alpha} = -\frac{\rho_F^2\, \epsilon_F}{\alpha}, \qquad M = -\frac{\overset{*}{\epsilon}_M}{\beta} = -\frac{\rho_M^2\, \epsilon_M}{\beta}.$$

This leaves ρ_F, ρ_M, and r as in (A-4) and lowers the standard deviations of F and M to

$$S_F^* = \rho_F^2 \frac{\sigma_\epsilon}{\alpha}(1+\gamma^2)^{\frac{1}{2}} = \rho_F^2 S_F$$

$$S_M^* = \rho_M^2 \frac{\sigma_\epsilon}{\beta}(1+\delta^2)^{\frac{1}{2}} = \rho_M^2 S_M.$$

Substituting these into (A-3) yields the expressions

$$\text{(A-5)} \qquad \begin{aligned} R^\alpha - 1 &= (1+\gamma^2)(R_0^\alpha - 1) \\ R^\beta - 1 &= (1+\delta^2)(R_0^\beta - 1), \end{aligned}$$

where R_0^α and R_0^β are the expressions given in equation (16). Inspection of (A-5) shows that this alteration in the forecasting scheme in no way alters the basic story. As expected, the improved forecasts aggravate the biases: R^α and R^β are further from unity than R_0^α and R_0^β were. However, the signs of the biases are in no way affected, and neither is our conclusion about which authority gets the larger percentage bias (see proposition 4 in the text). To see this, divide the two equations in (A-5) to get

$$\frac{R^\alpha - 1}{R^\beta - 1} = \frac{(1+\gamma^2)}{(1+\delta^2)}\left(\frac{R_0^\alpha - 1}{R_0^\beta - 1}\right).$$

According to proposition 4, the ratio $(R_0^\alpha - 1)/(R_0^\beta - 1)$ will be greater than unity if and only if γ is greater than δ. But, by the above equation, this will certainly mean that $(R^\alpha - 1)/(R^\beta - 1)$ is greater than unity as well.

Standard Errors

Tables 2 and 3 report hypothetical t-ratios based on the asymptotic standard errors of the estimators, $\hat{\alpha}$ and $\hat{\beta}$. For the basic model these standard errors are given by

$$\text{(A-6)} \qquad \begin{aligned} S_{\hat{\alpha}} &= \alpha\gamma\delta[(1-\rho^2)^{\frac{1}{2}}(1+\delta^2)^{\frac{1}{2}}]/\Delta \\ S_{\hat{\beta}} &= \beta\gamma\delta[(1-\rho^2)^{\frac{1}{2}}(1+\gamma^2)^{\frac{1}{2}}]/\Delta, \end{aligned}$$

where Δ is defined as in the text.

Policy Interactions

In this case, the monetary authority forecasts and attempts to offset both ϵ and fiscal policy. The model now consists of the partial reduced-form equation (A-1), the reaction functions (23) in the text, and an equation to generate the Fed's forecasts of fiscal behavior: $\hat{F} = F + e$, where the forecast error, e, is assumed to have variance $\tau^2\sigma_\epsilon^2$, and to be uncorrelated with F, ϵ, u_F, and u_M. The derivation proceeds exactly as in the simpler case. We compute the expressions for S_F, S_M, ρ_F, ρ_M, and r, substitute these into the general formulas (A-3), and simplify to obtain

$$R^\alpha = 1 + \frac{\lambda\delta(\rho\gamma - \delta) + s\gamma(\rho\delta - \gamma) - \lambda(s\alpha\tau)^2}{\Delta + (s\alpha\tau)^2(1 + \gamma^2)} \tag{A-7}$$

$$R^\beta = 1 + \frac{\omega\gamma(\rho\delta - \gamma)}{\Delta + (s\alpha\tau)^2(1 + \gamma^2)}. \tag{A-8}$$

Comparing (A-8) with the corresponding expression in (19), we find no change in the sign of the bias in estimating the monetary multiplier, but a decrease in the absolute magnitude. Furthermore, this decrease diminishes as the Fed's accuracy in predicting fiscal actions improves (that is, as τ shrinks). These are the results cited in proposition 8.

Proposition 9 is less obvious. To simplify things a bit, let the symbols R_1^α and R_1^β denote the expressions for the biases in equations (19). Then (A-7) can be rewritten as:

$$R^\alpha - 1 = (R_1^\alpha - 1)\theta + (R_1^\beta - 1)\left(\frac{s}{\omega}\right)\theta - \lambda\frac{(s\alpha\tau)^2}{\Delta + (s\alpha\tau)^2(1 + \gamma^2)}, \tag{A-9}$$

where

$$0 < \theta \equiv \frac{\Delta}{\Delta + (s\alpha\tau)^2(1 + \gamma^2)} < 1.$$

Thus, in the most plausible case, where $R_1^\alpha < 1$ and $R_1^\beta < 1$ (that is, where both biases were downward before the Fed began anticipating fiscal policy), the fiscal policy multiplier will again be biased downward. In the other possible case, where either $(R_1^\alpha - 1)$ or $(R_1^\beta - 1)$, but not both, is positive, it is still quite likely that $\hat{\alpha}$ will be biased down once the Fed begins predicting fiscal policy. $R^\alpha - 1$ may even be negative though $R_1^\alpha - 1$ is positive. These are the results cited in proposition 9 of the text.

Model with an Exogenous Variable

The last model considered in the text expands the partial reduced-form equation to

$$Y_t = k + \alpha F_t + \beta M_t + \mu X_t + \epsilon_t, \tag{A-10}$$

where X is an exogenous variable. The reaction functions are correspondingly expanded, as in equations (24). We introduce the following assumptions about the forecasts of X:

$$X_F = X + v_F \qquad X_M = X + v_M$$

$$\mathrm{Var}(v_F) \equiv \sigma_f^2 = c^2\sigma_x^2 \qquad \mathrm{Var}(v_M) \equiv \sigma_m^2 = d^2\sigma_x^2$$

$$E(v_F v_M) = \rho_v\,\sigma_f\,\sigma_m.$$

We further assume that the vs are uncorrelated with u_F, u_M, X, and ϵ. It can be shown that the relative biases in each coefficient in (A-10) are

$$R^\alpha = 1 + \frac{g^2}{\Delta^*}[g^2\delta(\rho\gamma - \delta) + \mu^2 d(c\rho_v - d)]$$

$$R^\beta = 1 + \frac{g^2}{\Delta^*}[g^2\gamma(\rho\delta - \gamma) + \mu^2 c(d\rho_v - c)] \tag{A-11}$$

$$R^\mu = 1 + \frac{g^2}{\Delta^*}[g^2\{\delta(\rho\gamma - \delta) + \gamma(\rho\delta - \gamma)\} + \mu^2\{d(\rho_v c - d) + c(\rho_v d - c)\}],$$

where

$$\Delta^* \equiv g^4[\Delta + (\mu^2 cd)^2(1 - \rho_v^2)]$$

and

$$g \equiv \sigma_\epsilon/\sigma_x.$$

Sufficient conditions for all of the biases to be negative can be easily derived. First note that if both ρ and ρ_v are nonpositive, equations (A-11) immediately imply that all coefficient estimates are biased toward zero. Thus we need worry only about cases in which ρ or ρ_v, or both, is positive. Suppose first that ρ is positive while ρ_v is not. Then by (A-11), the sufficient conditions are $\rho\gamma - \delta < 0$; $\rho\delta - \gamma < 0$. As demonstrated in the text these can be written in the more compact form,

$$\frac{1}{\rho} > \frac{\delta}{\gamma} > \rho. \tag{A-12}$$

Now turn to the case where ρ_v, but not ρ, is positive. The sufficient conditions derived from (A-11) become $\rho_v c - d < 0$; $\rho_v d - c < 0$, or simply

$$\text{(A-13)} \qquad \frac{1}{\rho_v} > \frac{d}{c} > \rho.$$

Finally, in the case where both ρ and ρ_v are positive, jointly sufficient conditions for all biases to be downward are that both (A-12) and (A-13) hold. Proposition 10 in the text assumes that both of these conditions are met.

Comments and Discussion

John Kareken: I found this paper not only very good but very encouraging in suggesting that endogenous policy responses do not necessarily impair the structural estimation of the workings of the economy and economic policy. Even though that conclusion is balanced precariously on one observation, it is still cause for encouragement. One can reasonably assume a centralized stabilization authority for purposes of extracting optimal fiscal and monetary policy rules. I would have been happier if the authors had actually done more experiments, systematically altering the variances in the reaction functions, although I have no basis for questioning their judgment that it takes a lot to get a perceptible difference in the estimation.

I was also encouraged to find several additional explanations of the defects in reduced-form models like that of the St. Louis Federal Reserve. But I am not persuaded by the explanation that the Fed is a poor forecaster compared with, say, the Council of Economic Advisers or the Treasury. That may have been true in the early 1960s but I do not believe it has been true recently.

The analysis in the paper depends on the existence of a reaction function for the fiscal authority. There seem to be several fiscal authorities in our government; implementing fiscal policy has been one of the greatest difficulties of the postwar period, and from reading the newspapers, I gather the problem is still alive. Indeed, I am surprised that Goldfeld and Blinder are able to report any fiscal policy reaction functions that seem to fit history.

Finally, in analyzing the sources of statistical bias, I would have preferred not to assume that the authorities react to current observations, for by definition they cannot have done so. The paper implies that the decision period for policy is shorter than the observation period for the data. A multitude of problems arises if one really believes that the Federal Reserve or some other authority is making monthly decisions. If the proper model is a monthly one but a quarterly model is estimated, an important problem of aggregation through time arises, which should be treated explicitly.

William Poole: For two reasons, I agree with Kareken that the problem of bias from endogenous policy elements is unlikely to be important in practice. First, as Kareken says, policy makers are not going to respond very much to the error term in the concurrent quarter because they cannot observe it. Even if they do respond to preliminary data, those data are likely to be quite different from the ultimately revised data that are used in statistical estimation of parameters; and hence bias from simultaneity is not likely to be severe. Second, most policy effects occur with substantial lags, which models try to capture through distributed lags. It is likely that only a small part of the total sum of the distributed lag is subject to the simultaneity problem, and hence the long-run multipliers and the total policy effects are not likely to be seriously biased.

The authors spend much of their effort criticizing simple reduced-form models like the St. Louis approach (just as proponents of such models seem inordinately preoccupied with criticizing large structural models). I wonder why so much time is devoted—on both sides—to talking about how bad the "wrong" models are, rather than to developing the right ones.

To a considerable extent, the analysis of this paper is stacked against the St. Louis approach. The authors have generated numbers for a hypothetical economy that is precisely specified by a simultaneous-equations model. Two different approaches are estimated, one recognizing and one ignoring endogenous policy. The reduced-form equations are then estimated, and they are full of problems. But their problems arise not because they are reduced-form equations but because they are misspecified. Let me put the point this way: Suppose that the hypothetical data were generated from a model in which the investment equation contains the long-term bond rate lagged two quarters. Suppose, now, that the equation is estimated with only the current long-term bond rate. That misspecified equation will be defective even though it is structural.

Critics of structural models argue that they are very likely to be misspecified, so that they produce the wrong cofficients and results more misleading and more troublesome than those emerging from the reduced-form approach. The question is, Which model is likely to cause the most trouble? The best evidence bearing on that question comes from examination of how well particular models perform after their sample period. That can suggest which of all the things a priori reasoning tells us *can* go wrong *does* go wrong. In my judgment the Andersen-Jordan model has performed poorly outside the period from which it was estimated. When I looked at this about a year ago, I had thirteen quarters of observations beyond the sample period. The bias in the GNP estimate over that period averaged $4 billion per quarter, or a cumulative error in the level of $53 billion. I suspect that larger structural models reveal the same defects, although because they contain many more lagged variables, they may not go off course quite so fast. I would guess that the 1968 version of the Federal Reserve model, for example, would not look very good right now in a true dynamic simulation. The trouble with econometric models is not that things *might* go wrong, but that they do in fact go wrong.

General Discussion

Robert Solow suggested that the problems of endogenous elements in policy that Goldfeld and Blinder discussed extended even to cases without an explicit policy reaction function. In the first place, automatic stabilizers work much as a reaction function does in responding contemporaneously to economic developments; any model that does not accurately specify the automatic effects may become biased for that reason. Indeed, that might conceivably account for the peculiar finding of the St. Louis model that expenditures are a better fiscal variable than the full employment surplus or any other variable that reflects tax changes. Furthermore, Solow suggested that monetary and fiscal policy makers might manage in some ways on some occasions to offset contemporaneous shifts from private demand even if they did not systematically behave according to any reaction function. Such unsystematic actions would be enough to make the policy variables correlated with the error terms in private demand equations.

Solow also wanted to tone down William Poole's emphasis on accurate prediction as a test of the adequacy of a model. Solow drew an analogy to Ptolemaic astronomy, which predicted reasonably well in many areas but was still an incorrect theory. Poole agreed that prediction is not all that matters, but suggested that it was one of the tests that any adequate model ought to be able to pass. David Fand noted that the converse of Solow's point was that a reduced-form model might conceivably predict well and even serve as a useful guide to policy for some purposes, even though it described the economic process incorrectly. Fand also suggested that the Goldfeld-Blinder warnings about economic relationships that are not articulated in models (and perhaps not even observable at all) were relevant to all forms of econometric work, not merely to reduced forms.

Solow and Franco Modigliani suggested that the most important specific issue of the paper is the attempt to understand why fiscal policy seems so impotent in the St. Louis and other reduced-form models. Modigliani reported on an experiment that has now been performed with four different econometric models, all of which contain substantial effects of fiscal policy in their structural equations. In each experiment, data are generated for a world that is accurately described by one of these models, and then a simple reduced-form regression equation is fitted to the fiscal and monetary variables. In every case, the fiscal multipliers tend to be substantially underestimated while the monetary multipliers come out about right. Several different types of correlations among variables and with time seem to contribute to this result; one—but only one—element is the feedback of economic conditions on fiscal policy that Goldfeld and Blinder analyzed. Poole asked whether the reverse could not also occur: If one specified a world where fiscal policy had no impact on GNP, could problems of statistical estimation incorrectly yield a positive fiscal multiplier? Modigliani agreed that could happen in principle; but he emphasized that his convictions on the presence of fiscal effects rested on basic theoretical and microeconomic evidence and not merely on time series findings. Moreover, Modigliani contended that he found it difficult to conceive of a theoretically plausible model of economic activity that would not produce some fiscal impact at least on nominal GNP.

Goldfeld responded to Kareken's skepticism about the existence of fiscal reaction functions. He pointed out that statistical estimation problems would arise even if only one of the stabilization authorities were using a reaction function or in any way behaving endogenously while the other behaved entirely exogenously. Replying to Poole's comments on specification errors, Goldfeld and Blinder suggested that the first basic question was whether reduced-form estimation created problems when policy reaction functions existed, even if the specification of the rest of the model was precisely accurate. Thus the authors had fitted the exact reduced form of the Moroney-Mason model in their paper. In that sense, neither the structural nor the reduced-form approach had contained specification errors. Once that question is answered, it becomes important to ask where specification errors are likely to arise and how serious they may be. The paper had touched on that issue by investigating a few cases of omitted variables for both the structural and the reduced-form approach.