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THE COSTS OF INTERMEDIATE TARGETING

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Introduction

The current policy of the Federal Reserve System is to set target ranges up to one year in advance for several monetary aggregates. However, the Fed is considering the possibility of augmenting or replacing those targets with ranges for other economic variables such as nominal GNP, the price level, and interest rates. Each such target range represents the intended course of a variable which is influenced, but not directly controlled, by the Fed. The ranges are designed to be compatible with the Fed's stated goals of maintaining sustainable economic growth and price stability. Once chosen, however, the ranges themselves, which are called intermediate targets, are treated as goals and policy instruments are adjusted according to the deviation of targeted variables from their specified ranges.

It is well known that the use of such an intermediate targeting procedure is an inefficient way to pursue the Fed's ultimate goals. As stated by Kareken, Muench and Wallace [1973], "It is not optimal to use predetermined sequences of target values, sequences which, although new observations are received, never get revised."

This problem with intermediate targeting has also been recognized by Federal Reserve Chairman Paul A. Volcker in his July 1983 discussion of a GNP objective. In testimony to Congress he said, "Encouraging manipulation of the tools of monetary policy to achieve a specified short-run numerical goal could be counterproductive to the longer-term effort, . . . decisions on monetary policy should take account of a variety of incoming information

. . . and [the Fed should] give weight to the lagged implications of its actions beyond a short-term forecast horizon."

Nonetheless, it appears that the Fed, for political or institutional reasons, will continue to use an intermediate targeting strategy. Given this situation, it may be of interest to investigate how much inefficiency is generated by intermediate targeting, and which strategies are likely to cause the least amount of harm.

In the context of an econometric model with a specified loss function, it is possible to measure the cost of intermediate targeting and to rank different target variables and targeting strategies. Such an exercise is illustrated below using a monthly vector autoregressive representation of the U.S. economy.

Instruments versus Targets

Before proceeding with the main body of this paper, it is important to distinguish two concepts which have often been confused in the economic literature, instruments versus targets.[1/] We define these distinct concepts as follows: instruments are variables directly controlled by the Federal Reserve; intermediate targets are paths or ranges specified by the Federal Reserve as desired values in future time periods for economic variables it influences, but does not necessarily directly control. In this paper, it will be assumed that the Federal Reserve's choice of instrument is the setting of the rate on federal funds. This choice is for convenience; it does not materially affect the consideration of intermediate targets.[2/]

Optimal Federal Reserve Policy

The general framework adopted here for the discussion of Federal Reserve policy is that of Kareken, Muench and Wallace [1973]. Let the economy be governed by

$$A_0X_t = AX_{t-1} + A_0P_t + A_0u_t$$
(4)
$$E(u_tu_t') = \Sigma_u$$

where X_t is an n x 1 vector describing the state of the economy, the n x n matrices A_0 and A give the economic structure, P_t is a vector giving the contemporaneous effect on observables of a Federal Reserve action, and u_t is a vector of serially uncorrelated economic shocks. We assume that A_0 is invertible and is normalized to have ones along its diagonal.

The Federal Reserve action, S_t, is a scalar which is assumed to have both systematic and random components. We assume

(5) $$P_t = \lambda S_t$$

and

$$S_t = FX_{t-1} + v_t$$
(6)
$$E(v_t^2) = \sigma_v^2$$

where the n x 1 vector λ is a set of weights which gives the contemporaneous impact of a Fed action on observables, F is a 1 x n vector which describes the systematic part of Fed behavior, and v_t gives the random component of Fed behavior.

Let the loss function for the Federal Reserve be given by

$$L = E\{\sum_{s=0}^{\infty} \beta^s (X_{t+s} - X^*_{t+s})' \Phi \, (X_{t+s} - X^*_{t+s})\}$$

where β is a discount rate and the n x n matrix Φ weights deviations of X from desired values X*.

Given a reduced form representation for X,

$$X_t = BX_{t-1} + w_t$$

(7)

$$E[w_t w_t'] = \Sigma_w$$

if we know λ, and if λ, A_0 and A remain fixed with respect to changes in F, then optimal control theory provides an algorithm for determining the linear feedback rule for Federal Reserve policy, F*, that minimizes the loss function.

Note that in this context there is no role for the use of intermediate target variables in the setting of optimal policy. It thus follows that any policy for which the construction of an intermediate target does play a meaningful role will be, in general, suboptimal.

A general characterization of such a suboptimal intermediate targeting strategy is as follows:

1) Let Z_t be a vector of future values, z_t, z_{t+1}, ..., z_{t+N} for an intermediate target variable. At time t find a value, $Z^*_t = [z^*_t, z^*_{t+1}, \ldots, z^*_{t+N}]$, which minimizes the expected loss conditional on the future z's, that is, $E\{L|Z^*_t\} \leq E\{L|\hat{Z}_t\}$ for all $\hat{Z}_t$.

2) For time periods $t + s + 1$, $s = 0, \ldots, N$ set the policy instrument according to $S_{t+s+1} = \gamma(z_{t+s} - z^*_{t+s})$ where γ is a scalar weight.[3/] At period $t + N + 1$ start over with step 1.

Policy Analysis With Vector Autoregressions

In this paper we illustrate the type of analysis described above in a simple example. We will compare a strategy which is close to, though not exactly, optimal with a variety of intermediate targeting strategies and measure the expected losses in terms of variance around real growth and inflation targets. The exercise is of interest primarily as an example of a nonstandard approach to policy analysis. It starts with a reduced form representation of the stochastic process generating the dynamic paths of economic variables. This representation is based on a Bayesian modeling strategy developed by Doan, Litterman and Sims [1984], and contains a minimal amount of a priori structure based on economic theory.

The approach then adds a crucial, but minimal identifying assumption--that the effect of Federal Reserve actions, λ, is known. The approach assumes that both λ and the unknown underlying structure of the economy, A_0 and A, remain invariant with respect to the choice of the Federal Reserve policy rule, F.

There is an obvious tradeoff involved in making these assumptions. The disadvantage of this approach is its inability to model systematic changes in either the response to Federal Reserve actions or the economic structure, as a function of changes in systematic Federal Reserve policy. Clearly, these invariance assumptions are subject to the 'Lucas critique,' (see Lucas [1976]). The advantage of the approach is that it provides quantitative answers to policy questions with a minimal set of a priori assumptions concerning the structure of the economy.

In applied work the assumption of structural stability, whether it applies to reduced form parameters, coefficients of demand functions, or parameters of preferences and technology, is always an approximation. The applicability of the approximation depends on the context of the analysis and it is therefore important to emphasize that this exercise is not intended to suggest radically new, untested policy regimes, but rather to quantify and make explicit the assumptions underlying current policy and thereby perhaps to offer some marginal improvement. To the extent that the rules investigated below are close to those observed in the post-war period, the invariance assumptions may be reasonable approximations.

In particular, in the context of this exercise, a policy regime might be taken to refer primarily to a given loss function adopted by the policymaker, rather than to the particular operating procedure currently followed to minimize that loss. Here we do not attempt to assess the effects of changes in the loss function, we attempt only to quantify it. Thus, in this context, all of the alternative procedures considered, as well as the procedures historically in place, could be considered to be minor variations within the same overall policy regime.

In this exercise a key assumption that we make is that the underlying structure of the economy remains unchanged when a new policy rule is adopted. There are really two conceptual issues here. First, in what sense can we identify the structure of the economy from a reduced form vector autoregressive representation? In particular, isn't it the case that the reduced form representation has imbedded in it the Federal Reserve policy during the period over which it applies? Second, given a change in Federal Reserve policy, isn't it likely that the structure will also change?

Turning to the question of whether we can identify the stable structure, A_0 and A, the answer is that while it is true that we cannot disentangle past Fed policy from economic structure in the reduced form, as long as we can identify the effect of a policy action, λ, we can proceed to investigate the effects of alternative policy rules. The economic structures we consider are the class of economies

$$X_t = CX_{t-1} + u_t$$

where

$$E(u_t u_t') = \Sigma_u$$

and

$$C = \hat{B} + \lambda F$$

with $\hat{B}$ an autoregressive representation estimated over an earlier period in which data was generated from a combination of the unknown economic structure, A_0 and A, and an unknown Fed policy rule with systematic component F_1.

Thus, $\hat{B}$ is an estimate of the autoregressive structure given in (7), where

$$B = A_0^{-1}A + \lambda F_1 \tag{8}$$

and

$$\Sigma_w = \Sigma_u + \sigma_v^2(\lambda\lambda'). \tag{9}$$

In order to find the optimal policy it is not necessary to identify the economic structure, A_0 and A. Instead, it is enough to know the reduced form, B, and the contemporaneous effect of a Fed policy action. First, suppose that we restrict ourselves to deterministic policy rules. Then the class of feasible economies is given by

$$X_t = CX_{t-1} + u_t \tag{10}$$

where

$$\begin{aligned} C &= A_0^{-1}A + \lambda F, \\ E(u_t u_t') &= \Sigma_u \end{aligned} \tag{11}$$

and

$$F \in R^n.$$

Now let A_0 and A be unknown. Consider the class of economies given by

$$
\begin{aligned}
C &= B + \lambda F \\
&= A_0^{-1}A + \lambda(F_1 + F)
\end{aligned}
\tag{12}
$$

where

$$F \varepsilon R^n.$$

This class is identical to the class defined above. Thus, it is not necessary to identify A_0, A, or F_1 in order to find the optimal feasible economic structure. Of course, the F that is added to B is not, itself, the Fed policy rule; it is the change in the old control vector, F_1, which is necessary to generate the optimal rule.

If we consider policy rules with a random component, v_t, with variance σ_v^2, then the class of feasible economies is given by

$$X_t = CX_{t-1} + w_t \tag{13}$$

where C is defined as before and

$$E(w_t w_t') = \Sigma_w = \Sigma_u + \sigma_v^2(\lambda\lambda'). \tag{14}$$

A simple example may help clarify what is going on. Suppose the economic structure is a money demand equation.

$$M_t = \alpha_1 r_t + \alpha_2 M_{t-1} + u_{1t} \tag{15}$$

The previous Fed policy rule was

$$r_t = \beta_1 M_t + \beta_2 M_{t-1} + v_t \tag{16}$$

where v_t represents random shocks to policy which may or may not have been present. The contemporaneous response to a random policy action, v_t, is λ, given by

(17)
$$\lambda_1 \equiv \frac{\partial M_t}{\partial v_t} = \frac{\alpha_1}{1 - \alpha_1 \beta_1}$$
$$\lambda_2 \equiv \frac{\partial r_t}{\partial v_t} = \frac{1}{1 - \alpha_1 \beta_1} \,.$$

The reduced form for this system is

(18)
$$M_t = \gamma_1 M_{t-1} + w_{1t}$$
$$r_t = \eta_1 M_{t-1} + w_{2t}$$

where

$$\gamma_1 = \frac{\alpha_2 + \alpha_1 \beta_2}{1 - \alpha_1 \beta_1}, \quad w_{1t} = \frac{u_{1t} + \alpha_1 v_t}{1 - \alpha_1 \beta_1}$$

$$\eta_1 = \frac{\beta_2 + \beta_1 \alpha_2}{1 - \alpha_1 \beta_1}, \quad w_{2t} = \frac{v_t + \beta_1 u_{1t}}{1 - \alpha_1 \beta_1}.$$

Notice that in this example policy responds to the contemporaneous value of M. In other words, the Fed generates a supply schedule such that r depends on the contemporaneous money demand shock, u_{1t}. The easiest way to fit this structure into the above feedback rule notation is by augmenting the state vector to include next period's shock to money demand.

(19)
$$X_t \equiv \begin{bmatrix} M_t \\ r_t \\ u_{1,t+1} \end{bmatrix} \text{ and } \quad u_t \equiv \begin{bmatrix} 0 \\ 0 \\ u_{1,t+1} \end{bmatrix}$$

The above economic structure then is represented with

$$(20) \qquad A_0 \equiv \begin{bmatrix} 1 & -\alpha, & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad A \equiv \begin{bmatrix} \alpha_2 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}.$$

The Fed policy rule is given by

$$(21) \qquad F_1 \equiv [\beta_2 + \beta_1 \alpha_2 \quad 0 \quad \beta_1].$$

and

$$(22) \qquad S_t = F_1 X_{t-1} + v_t$$

The reduced form in this notation is given by

$$(23) \qquad X_t = BX_{t-1} + w_t$$

where

$$(24) \qquad B = A_0^{-1} A + \lambda F_1 = \begin{bmatrix} \gamma_1 & 0 & (1-\alpha_1\beta_1)^{-1} \\ \eta_1 & 0 & \beta_1(1-\alpha_1\beta_1)^{-1} \\ 0 & 0 & 0 \end{bmatrix}$$

and

$$(25) \qquad w_t = \lambda v_t + u_t = \begin{bmatrix} \lambda_1 v_t \\ \lambda_2 v_t \\ u_{1,t+1} \end{bmatrix}.$$

Because of the addition of $u_{1,t+1}$ to the state vector, the error terms in the previous notation w_{1t} and w_{2t}, are the appropriate components of the sum of the third column of B times u_{1t} plus w_t.

Suppose we now change the policy rule in order to peg the value of r_t at $f\ M_{t-1}$. In terms of the economic structure we have

$$
(26)\qquad
\begin{aligned}
M_t &= \alpha_1 r_t + \alpha_2 M_{t-1} + u_{1t} \\
r_t &= f\ M_{t-1}
\end{aligned}
$$

The reduced form is

$$
(27)\qquad
\begin{aligned}
M_t &= \gamma_1^* M_{t-1} + w_{1t}^* \\
r_t &= \eta_1^* M_{t-1}
\end{aligned}
$$

where

$$
(28)\qquad
\begin{aligned}
\gamma_1^* &= \alpha_1 f + \alpha_2,\ w_{1t}^* = u_{1t} \\
\eta_1^* &= f.
\end{aligned}
$$

If we do not know the economic structure, however, we can use instead the original reduced form to find the effects of the new policy. We do this by specifying the rule for policy actions, S_t, such that $r_t = f\ M_{t-1}$. Thus, we find S_t such that

$$(29)\qquad r_t = \eta_1 M_{t-1} + w_{2t} + \lambda_2 S_t = f\ M_{t-1},$$

which implies

$$(30)\qquad S_t = (fM_{t-1} - \eta_1 M_{t-1} - w_{2t})/\lambda_2.$$

This means that the new policy rule is defined by adding

$$(31) \qquad \lambda S_t = \lambda F_2 X_{t-1}$$

where

$$(32) \qquad F_2 = [\lambda_2^{-1}(f-n_1) \quad 0 \quad -\beta_1]$$

to the reduced form and setting $v_t = 0$. The new structure is

$$(33) \qquad X_t = BX_{t-1} + \lambda F_2 X_{t-1} + w_t$$

which, when $v_t = 0$, yields

$$(34) \qquad \begin{aligned} M_t &= (\gamma_1 + \frac{\lambda_1(f-n_1)}{\lambda_2})M_{t-1} - \lambda_1\beta_1 u_{1t} + w_{1t} \\ &= (\alpha_1 f+\alpha_2)M_{t-1} + u_{1t} \end{aligned}$$

$$r_t = fM_{t-1}$$

and matches the reduced form derived above directly from the economic structure. This example illustrates that as long as λ is known, it is not necessary to know the economic structure in order to specify the rule for policy actions which when added to the original reduced form generates the correct reduced form structure under the new policy. Of course, it is possible to specify economic structures to which the Lucas critique applies, and for which this approach will not work. For example, in the above example if the money demand equation contains a term with rationally expected future interest rates, then the approach does not work.

A Test of Structural Stability

It is impossible to tell directly from a reduced form to what extent the Lucas critique applies for a given policy intervention. If there is previous evidence of policy changes similar to the one being considered, however, then it might be relevant to consider whether there is evidence of instability in the past. We believe we are in a position to perform such a test today, having observed an announced change in Federal Reserve behavior during the period October 1979 through September 1982. This was a period in which the Fed invoked new operating procedures and a clear increase in the variability of short-term interest rates. We propose to test to what extent the structure of the economy changed during this period.

Suppose we have estimated autoregressive structures β_1 and β_{II} for the economy during two regimes. We have

$$X_t = \beta_1 X_{t-1} + u_t \quad Var(u_t) = \Sigma_I \quad t \in \text{regime I}$$

(35)

$$X_t = \beta_{II} X_{t-1} + u_t \quad Var(u_t) = \Sigma_{II} \quad t \in \text{regime II.}$$

The assumption that the economic structure remains unaffected by large policy shocks may be represented as

(36) $$\beta_I = \beta_{II} \quad \Sigma_{II} \neq \Sigma_I$$

where Σ_{II} includes a component of innovation variance in regime II due to policy shocks. To the extent that policy in regimes I and II is predictable, however, we might also want to consider a representation where

(37) $$\beta_{II} = \beta_I + \lambda(F_{II}-F_I)$$

and the F's are the feedback rules representing different predictable behaviors during the two regimes.

The alternative view assumes that when policy changes, either predictably or not, other economic behavior changes and there is likely to be no simple relationship between β_I and β_{II}.

The results of the intermediate targeting exercise which follows are of interest only to the extent that the first view expressed above is a reasonable approximation to reality. In the exercise we hold β_I fixed and consider the stochastic properties of the system under alternative F's.

The null hypothesis to be tested is that the autoregressive structures in the two regimes are identical. However, in the face of possible changes in error term variance and in the context of a vector autoregressive system estimated with Bayesian priors, the usual tests for structural change do not apply.

The monthly model we use is a slight variation of the model described in Doan, Litterman, Sims [1984], and no attempt will be made to document it fully here. The differences between the model described there and the one used here are that the model used here includes 12 lags of each variable rather than 6, it does not include time variation of the parameters, and it imposes a much tighter prior distribution on sums of coefficients than did the earlier model. Also, the prior mean is adjusted to reflect a continuous time random walk in the data, rather than a discrete time random walk. These changes were intended to make this version of the model more accurate at longer forecast horizons. The net effect of the changes was to improve the out-of-sample forecasting performance by about 2 percent at a one-year horizon.

The test we apply is based on the following reasoning. If there is no change in the autoregressive structure from regime I to regime II, then using the observations in regime II should reduce the errors of out-of-sample forecasts of observations in regime I, relative to forecasts which ignore the information in regime II. To the extent that the structure of regime II differs from that of regime I, we would expect the inclusion of regime II in the sample to pull estimates away from the structure of regime I and thereby to increase the out-of-sample forecast errors in regime I. The out-of-sample nature of the experiment is as follows: for each observation, t, in regime I we form an estimator using all observations other than t--in one case including observations in regime II, and in the other case excluding observations in regime II.

In interpreting the results of this experiment we emphasize that we have no reason to assume that structural invariance is anything more than an approximation. The question is how good of an approximation is it, or to put it another way, how strong is the evidence in rejecting the hypothesis.

One simple measure of the strength of the evidence is whether the use of regime II in forecasting observations in regime I, out of sample, increases or decreased the forecast error variance. If the approximation error of assuming structural stability is small enough so that use of data under the changed policy improves forecasts of data under the old policy, then the error is likely to be small in using the existing data to forecast the effects of other similar changes in policy.

A more classical approach to measuring the strength of the evidence is to generate the distribution of the statistics measuring the change in forecast error variance. It might be the case, for example, that if there is a change in error covariance matrix, even if there is no change in coefficients, the forecast error variance might increase.[4/] On the other hand, while it is perhaps unlikely, the use of a Bayesian prior implies that it is possible for a structural change in coefficients in a direction away from the prior mean to lead to a decrease in forecast error variance more than would be expected under the null hypothesis.

Therefore, in order to better assess the forecast error variance changes, we have generated by Monte Carlo simulation two sets of distributions, under the null hypothesis. The distributions are both generated by repeatedly simulating the data under the assumption that the coefficients are the same in the two regimes. (The coefficients are those estimated over the entire data period). We do allow the innovation error distributions to vary over the two regimes, however. From these simulations, we calculate the associated values of our test statistics. The two distributions differ in that in the first case, A, we assume the error processes are distributed normally with covariance matrices for each regime estimated over the respective regime; in the second case, B, we generate the errors by the bootstrap method--that is by randomly choosing estimated errors from the respective regimes. The second approach generates a distribution which is robust to deviations from the normality assumption.

We include the same ten variables used in Doan, Litterman, Sims [1984], using a data set beginning in 1951:1, and extending through 1983:12. Regime II includes observations from 1979:10 through 1982:9. The data for 1951 are taken as initial conditions. The rest of the observations are included in regime I.

An interesting pattern of results, shown in Table I, emerges. For eight of the ten variables forecast performance in regime I improves with the addition of regime II to the sample. Forecast performance gets worse for the trade-weighted dollar and the 3-month Treasury bill rate. This latter result is consistent with a systematic change in Fed policy in regime II (as in (36)) showing up primarily in the interest rate and trade-weighted dollar equations.

However, when we look at the sample distributions that we generated for these variables we find that the inclusion of regime II in the sample does not cause deterioration of forecast performance for any variable in regime I greater than what would be expected under the null hypothesis of no change in coefficients.

The two distributions, A and B, give essentially the same results. In both cases there is no evidence of forecast deterioration in regime I due to structural change in regime II. In fact, for several variables, such as the S & P 500 stock price index, forecast performance improves much more with the addition of regime II than is expected under the null hypothesis. These results suggest that for the purpose of predicting the effects of

Table I

Results of a Test of Structural Stability

Variable[a]	Root Mean Square Error (RMSE) Excluding Regime II	% Improvement in RMSE When Regime II Is included	Two[b] Measures of Significance A	B
Real GNP	.07804	.4690	.80	.92
GNP Deflator	.01671	.5636	.98	1.00
3-month Treasury bill	.28758	-.7585	.76	.74
Value of Dollar	1.02582	-.4187	.48	.48
Money, M1	.32956	.5869	.74	.84
S & P 500 stock price index	3.14564	.5011	1.00	1.00
total nonfinancial debt	.35056	.2051	.40	.52
change in business inventories	5.36608	1.1158	1.00	1.00
government expenditures	6.37050	.4795	.94	.96
government receipts	7.85491	.3331	.92	.90

a Units are percent except change in business inventories which is in billions of '72 $.

b Proportion of simulations (out of total of 50) under the null hypothesis with an increase in forecast variance greater than (or a decrease less than) that using actual regime II observations.

policy actions under a new policy rule, the use of a reduced form structure estimated over a previous period may not be a bad approximation.

An Identification Assumption

In order to implement our procedure for policy analysis we need to identify λ, the vector of contemporaneous effects of a Federal Reserve action. This is a minimal identification requirement which must be met either implicitly or explicitly by any exercise in policy analysis. Before proceeding it is worth considering how this identification is achieved in more standard approaches to policy analysis.

The most straightforward approach to identifying the effects of policy actions in the context of an economic model is to assume that the policy variable has been determined exogenously so that distributed lag regressions of endogenous variables on the policy variable pick up the effects of policy actions. The problem with this approach is that the exogeneity assumption is often untenable.

In fact, for the purpose at hand, exogeneity is a stronger assumption than is necessary. Predeterminedness of the policy variable is a sufficient condition to allow the effects of policy actions to be captured by the response functions estimated in reduced form projection equations including the policy variable.

The problem with assuming predeterminedness of a Federal Reserve policy variable in monthly data is that movements among financial variables are highly correlated and there is abundant evidence that the Federal Reserve responds within periods of time shorter than a month to new information in variables such as the money supply and the foreign exchange value of the dollar. On the other hand, it is clear that these and other financial variables respond within a month to changes in Federal Reserve policy. This simultaneity of responses suggests use of the Cowles Commission approach to identification, which proceeds by specifying separate structural relationships to represent different behaviors in the economy.

The Cowles approach also does not work very well in this case, however, because it requires the researcher to be able to specify enough exclusionary restrictions to identify the separate equations. This is difficult because the federal funds rate is determined in the market for bank reserves, and any new information which might affect Federal Reserve behavior is also likely to affect other market participants' demands. On the other side of the market, new information which might affect banks' demands for reserves is also new information that is likely to affect Federal Reserve behavior. There is some information, such as the official data on monetary aggregates, which is available to the Federal Reserve a few days before it becomes generally available, but such information is gathered and disseminated almost as rapidly by private agents as it is by the Federal Reserve. With respect to a monthly time period, the Federal Reserve and private market participants respond to essentially the same information.

Because of the speed with which financial markets respond to new information, identifying the response to policy actions on the basis of exclusionary restrictions in monthly or, as often the case, quarterly data is extremely difficult to justify. Because of this problem we have developed an alternative strategy which essentially relies on the use of exclusion restrictions in the context of weekly data to make the identification. As will become obvious as we proceed, however, even this approach leaves many questions about the appropriateness of the exclusion assumptions.

In order to justify the exclusion restrictions, we adopt the hypothesis that if the time period is made fine enough, policy variables will be predetermined. Thus, we will assume that Federal Reserve policy can be expressed as a weekly target for the rate on federal funds and that any contemporaneous correlation between weekly innovations in the federal funds rate and weekly innovations in other financial variables is due to the contemporaneous impact of Federal Reserve policy actions.

These assumptions are certainly not unassailable. Although the Federal Reserve announces desired operating ranges for the funds rate, it does not announce weekly targets. Moreover, during the period after October 1979, when the Federal Reserve followed an operating strategy which it referred to as targeting nonborrowed reserves, it announced that it was not targeting interest rates. Even if it were clear that the Federal Reserve was pegging the rate on federal funds, it is not entirely clear that weekly data represents a time unit fine enough to insure predeterminedness. In other words, it is possible the Fed could react within the week to economic shocks.

Nonetheless, the weekly innovations in the federal funds rate may be the best single measure of Federal Reserve policy actions which can be observed. One virtue of this measure is that it appears to closely correspond to the perceptions of money market analysts. Analyst Joel Stern, for example, recently explained (Stern [1984]) that "if we want to follow what the Fed is doing . . . what some of us do, what I try to do in particular, is watch what the federal funds rate is doing week to week relative to what I expected it to do--and that sometimes tells me what the Federal Reserve is doing."

The apparent inconsistency between a federal funds target and operating procedures using nonborrowed reserves may be more apparent than real if the reserves target is adjusted with an eye toward the resulting federal funds rate. For evidence along these lines, see Stevens [1981].

The purpose in considering weekly data is to try to separate the correlations in monthly data into those due to policy actions versus those due to nonpolicy, economic shocks. Our identifying assumption is that weekly innovations in the federal funds rate, in the context of a vector autoregression of weekly financial variables, are policy actions. We use the response patterns of the financial variables in the weekly data to decompose monthly innovations in these variables into policy and nonpolicy components.

The identification of the contemporaneous impact in monthly data of a Fed policy action is based on a five-variable vector autoregression estimated with weekly data. The model is specified with six lags on each variable and a constant. The variables are weekly averages of the federal funds rate, the Treasury bill rate, the value of the trade-weighted dollar, the money supply, M1, and the Standard & Poors 500 stock price index.

We have assumed that policy actions are composed of a systematic component and a stochastic component. Aside from the approximation error introduced by omitting the monthly variables for which we do not have weekly observations, the systematic component will be captured in the autoregressive structure of the weekly model, while the stochastic component will show up as innovations in the federal funds rate. Thus, to the extent that (a) Federal Reserve policy is stable and predictable, (b) all relevant information is included in the autoregression variables, and (c) the funds rate is predetermined by the Fed; policy actions, that is innovations in the funds rate, are not observed. If these conditions were always met in observed data, then the type of exercise we propose would be impossible. Because policy shocks would not be observed in the data, it would be impossible to identify λ. In fact, these conditions do seem to closely characterize the weekly data for the months 1973:2 through 1984:1, if we exclude the period 1979:10 through 1982:9. If, however, we focus on the weekly data in the months 1979:10 through 1982:10, we find that there is a considerable increase in the variance of federal funds rate innovations (the variance of weekly innovations in this period is eight times the variance in the other).

To compute the contemporaneous effect of a Fed policy action on a variable in the weekly model, we compute the responses of each variable to a federal funds rate innovation which includes components of each other variable based on the covariance matrix of weekly innovations. Because Fed actions are assumed to be predetermined, any correlations must be due to contemporaneous responses to Fed actions. We then calculate the monthly averaged response by giving equal, 7/31, weights to the first four weeks and a 3/31 weight to the fifth week of the response. Because the federal funds rate does not appear in our monthly model, we then normalize the elements of λ in terms of the impact on the 3-month Treasury bill rate.

Using this method we find that a Federal Reserve tightening at the beginning of a month which causes the rate on Treasury bills with a 3-month maturity to rise that month by 100 basis points (on a monthly averaged basis) is likely to lead (on the same basis) to a 1.5 percent decrease in the Standard & Poors 500 stock price index, a .16 appreciation in the trade-weighted value of the dollar, and a .17 percent decrease in the money stock.

These contemporaneous movements in financial variables in response to a Federal Reserve policy innovation are the nonzero elements of λ. We assume that the other variables in the monthly model do not respond contemporaneously to Federal Reserve policy. These other variables are real GNP, the GNP deflator, the change in business inventories, total nonfinancial debt, and federal government receipts and expenditures.

Identifying the Covariance Matrix of Economic Shocks

One final identification needed to proceed with the policy simulations is that of Σ_u, the covariance matrix of economic shocks. Recall that this matrix is not the same as Σ_w, the covariance matrix of innovations in the autoregressive representation of the economy. The difference is the stochastic component of policy.

We use the weekly model described in the previous section to estimate Σ_u. What we want to do is to use the weekly model to identify the stochastic component of policy and then to subtract it from the monthly autoregressive innovations, w_t. The result is a series u_t of economic shocks from which we can estimate Σ_u.

Unfortunately, the implementation of this calculation is complicated by the fact the λ we calculated in the previous section was based on a policy action at the beginning of the month. The actual policy shocks we identify occur each week. The weekly response to a large policy action in the last week of a given month will have only a small impact that month, but a larger impact the following month.

In order to approximately capture the monthly impacts of weekly policy shocks spread throughout the month we used the following procedure. Let w_t^i be the i^{th} component of the vector of innovations in the monthly autoregressive model. Let r_m^i be the response of that variable in weekly data to a unit policy action m weeks earlier. Finally, let R_i^j be the response in the monthly model of variable i to a unit innovation in variable j in the previous month. We take the component of w_t explained by policy innovations to be the response to weekly policy innovations in the current and previous month, less the component of that response captured by the previous month's policy innovation.

To be precise, for a given policy action, S_t, denote the direct response in the current month for variable i by $d^i_{S_t}$. We define

$$r^i_{S_t} \equiv S_t \cdot \sum_{m=0}^{M(t)-1} r^i_m W_0(m,t)$$

where r^i_m is defined above, M(t) is the number of complete or partial weeks, starting with t, contained in the current month, call it month T(t), and $W_0(m,t)$ is the number of business days of week t + m contained in month T(t) divided by the total number of business days in month T(t). This is the weighted average of the weekly response in the current month, with weights based on the number of days of the given week contained in the month.

The total direct policy impact on variable i in month T, from policy shocks in month T is given by summing $d^i_{S_t}$ over the policy shocks in month T. Thus,

$$d^i_T \equiv \sum_{t:T(t)=T} d^i_{S_t}.$$

The direct effect of the shock S_t on variable i in the following month, T(t) + 1, is given by $f^i_{S_t}$ where

$$f^i_{S_t} \equiv S_t \cdot \sum_{m=M(t)-1}^{M(t)+5} r^i_m W_1(m,t)$$

where $M(t)$ and r_m^i are defined as above, and $W_1(m,t)$ is the number of business days of week $t + m$ contained in month $T(t) + 1$ divided by the total number of business days in month $T(t) + 1$.

The total direct policy impact on variable i in the month $T + 1$ from policy shocks in month T is given by summing $f_{S_t}^i$ over the policy shocks in month T. Thus,

$$f_T^i \equiv \sum_{f:T(t)=T} f_{S_t}^i .$$

The cumulative impact of policy shocks on variable i in month T (we only consider shocks in the current and previous month) is defined to be $d_T^i + f_{T-1}^i$. To get the policy innovation of variable i in month T, v_T^i, we substract the component of the cumulative impact which was forecastable from the direct impact of shocks in month $T - 1$. That is, we calculate

$$v_T^i = d_T^i + f_{T-1}^i - \sum_{j=1}^{5} R_i^j d_{T-1}^j .$$

Finally, we generate a time series of economic shocks for variable i by calculating

$$u_T^i = w_T^i - v_T^i,$$

and we use this time series to estimate Σ_u.

If our model of the effects of policy shocks is accurate, and if the only change in structure in October 1979 was an increase in the size of policy shocks, then we would predict that the Σ_u's calculated before and after this date would be similar. This, however, is not the case. In fact, while there is, for example, a substantial increase in the policy component of the variance of Treasury bill innovations after this date, there is also an even larger increase in the component not explained by policy shocks. For the purpose of the exercise which follows, we use the estimate of Σ_u based on the period 1979:10 through 1982:9. This estimate of variance is generally larger than the estimated based on data from 1973:1 through 1979:9.

An Illustrative Example

The Fed's ultimate goals are sustained growth and price stability. Because the economy is a dynamic system with a considerable amount of inertia, these goals require policy to be forward looking. Intermediate targets this year must be designed with an eye toward the economic performance of next year and the years beyond. While such concerns can be incorporated in the type of loss functions described above, designing optimal policy then becomes a complicated problem in optimal control theory. In order to illustrate the type of analysis we are describing, while not overly complicating the problem, we consider a simplified, but perhaps not too unrealistic loss function. We assume that policymakers pick targets for the current year such that at the end of the year the economy will be positioned to achieve desired real growth and inflation goals in the following year.

If the Fed's goals for real growth and inflation one year ahead (that is growth from period t + N to period t + 2N) are y^* and Π^*, respectively, then at time t assume policy is designed to minimize the expected value of

$$(38) \qquad (\hat{y}_{t+N}-y^*)^2 + \phi(\hat{\Pi}_{t+N}-\Pi^*)^2$$

where $\hat{y}_{t+N}$ and $\hat{\Pi}_{t+N}$ are the year-end expected real growth and inflation for the following year. In other words, the Fed sets policy this year so that at the end of the year the economy is expected to have real growth and inflation the next year as close as possible to its desired goals.

We first describe a simple Fed policy rule which is not optimal, but which attempts to respond each period to the current state of the economy in order to minimize the variance around the Fed's ultimate goals. We refer to this as the static optimal policy. We then contrast the losses associated with this rule with those associated with rules based on intermediate targets.

Both the static optimal policy and the intermediate target policies begin by calculating paths for the Fed instrument which will lead to its goals being achieved on average. These settings for the policy instrument, S_{t+s}^* for s = 0, 1, ..., 11, are found by minimizing

$$\sum_{s=0}^{11}(S_{t+s}^*)^2$$

subject to

$$y^* - \hat{y}_{t+N} = \sum_{s=0}^{11} M_{12-s}^{y} S_{t+s}^*$$

and

$$\Pi^* - \hat{\Pi}_{t+N} = \sum_{s=0}^{11} M_{12-s}^{\pi} S_{t+s}^*,$$

where M_s^y and M_s^{π} are the responses of expected real growth and inflation to a unit policy shock s periods earlier.

In our static optimal policy rule these S^*_{t+s} settings represent the expected policy which will be modified each period in order to offset economic shocks. The static nature of the policy is that each period the choice of the Fed instrument setting minimizes the expected value of (38) taking as given, rather than revising, expected future instrument settings. The policy is also suboptimal in that it does not take into account the uncertainty of the effects of the policy actions.

In this simplified setup, the static optimal policy can be easily computed. The first step is to determine the tradeoff between expected real growth and expected inflation next year as a function of changes in the policy instrument this period. This tradeoff is a linear function which can be determined by simulating the model's response to a policy shock this period. Projecting the slope of the tradeoff through the current unconditional forecast of real growth and inflation next year determines a possibility frontier. Suppose the slope of the current tradeoff is $b_t = \partial\hat{y}/\partial\hat{\Pi}$, and the most recent forecast is $(\hat{y}_{t-1},\hat{\Pi}_{t-1})$. The possibility frontier is then given by

$$(39) \qquad \hat{y}_t = (\hat{y}_{t-1}-b_t\hat{\Pi}_{t-1}) + b_t\,\hat{\Pi}_t$$

The current period optimal policy is then one which leads to the point on this line which minimizes (38). Replacing $\hat{y}_t$ in (38) by the right-hand side of (39) and differentiating with respect to $\hat{\Pi}_t$, we find that the optimal $\hat{\Pi}_t$ is given by

$$(40) \qquad \hat{\Pi}^*_t = \{[y^*-(\hat{y}_{t-1}-b_t\hat{\Pi}_{t-1})]b_t+\phi\Pi^*\}/(\phi+b_t^2)$$

Thus, static optimal policy is to engineer a current period shock which produces an expected change in inflation next year by the amount $(\hat{\Pi}_{t-1}-\hat{\Pi}^*_t)$.

Recognizing that the response functions represent a linear approximation to a response which may in truth be highly nonlinear, also we entertain limits on the maximum size of the policy action each period. In our simulations we limit policy actions to have an expected contemporaneous impact on the Treasury bill rate of no more than 50 basis points.

We assume the sequence of events in implementing policy occurs in the following order. First, given last period's realization, the size of the optimal current period policy shock is determined as described above. This shock implies an expected level for the Treasury bill rate. We can consider alternate policies which differ in the degree to which the Fed is assumed to respond to current period nonpolicy interest rate shocks. At one extreme the Fed could ignore such shocks, at the other extreme we entertain the possibility that the Fed could completely offset shocks and thus peg the Treasury bill rate. Suppose the nonpolicy shock to the Treasury bill rate in period t is $\tilde{R}_t$. Then in the latter case the Fed's policy action, S_t, is altered by $\tilde{R}_t$, where we are normalizing the units of S_t by assuming the element of λ associated with the Treasury bill rate is one. We model the latter policy, which is intended to capture the effects of an operating procedure based on interest rate pegging.

Because other economic shocks occur in period t the realized expected real growth and inflation for the following year, $\hat{y}_t$ and $\hat{\Pi}_t$, will not match the values aimed at in the policy calculations. Given these new realized values, the Fed then calculates the optimal policy shock for period t + 1 using the new tradeoff. The tradeoff changes over time because of the different intervals between the time of application of policy and the period of concern.

In contrast to this static optimal strategy of revising policy each period in response to economic shocks, we consider targeting strategies defined by setting policy as a function of deviations of a target variable from a predetermined path.

At the beginning of the year, policy is set exactly as it is under the optimal policy. A special role, however, is then assigned to a target variable, Z. Let the expected path of the target variable at time t under the optimal policy defined by the S_{t+s}^*'s be $Z_t^* = \left[z_t^*, z_{t+1}^*, \ldots, z_{t+N}^*\right]$. The targeting strategy is then defined as setting policy during the year according to the rule $S_{t+s+1} = \gamma(z_{t+s} - z_{t+s}^*)$ where γ is the degree of responsiveness of policy to deviation of the target variable from its expected path.

Given the symmetry of this rule and the linear nature of the model, the expected values of $\hat{y}$ and $\hat{\Pi}$ under such a rule will be y^* and Π^*. The variance of $\hat{y}$ and $\hat{\Pi}$ around these targets will vary with γ. As was done with the static optimal policy rule, we here again entertain limits on the size of policy actions.

Simulation Results

The model used to simulate the effects of alternative policies is identical to the model described earlier in the section on testing for structural stability. The simulations include three sources of uncertainty: uncertainty arising from economic shocks, uncertainty in the contemporaneous effects of a given policy action, and uncertainty in the structure of the economic system.

The uncertainty due to economic shocks is generated by drawing shocks from a normal distribution, $u_t \sim N(0,\Sigma_u)$. We measure the uncertainty in the vector λ which is due to the estimation of the response functions in the weekly autoregressive model. We generate a covariance matrix for λ by Monte Carlo simulation of the weekly model. We repeatedly simulate weekly data from the original parameter estimates and then apply the procedure for estimating λ. These simulations generate a set of $\hat{\lambda}$'s, from which we estimate a normal distribution.

Finally, the structure of the monthly vector autoregressive model itself is uncertain. We simulate that uncertainty by drawing coefficients from a normal approximation to the posterior distribution of the coefficient estimates.

The simulations are made as if policy is being set for the year 1984 based on data through December 1983. The objective in this example is for policy during 1984 to put the economy at the end of 1984 in a position to achieve real growth of 4 percent and inflation of 5 percent in 1985. These goals were chosen to be realistic; their level is not an essential aspect of this exercise. Both the static optimal and targeting strategies will achieve the objective on average. The policies differ in their implications for the variance of outcomes around the target values.

The unconditional forecast as of 83:12 is for real growth of 3.4 percent from 84:12 to 85:12 and for inflation of 4.5 percent. The S_{t+s}*'s required to achieve the above goals call for a small degree of easing over the first half of 1984.

Each simulation begins with a random drawing of the system coefficients and the policy effect vector from the normal distributions described above. For the purpose of the simulation these draws represent the unknown, true structure of the economy. The static optimal policy is based on the response imbedded in the original estimates of the structure. This estimated structure does not change across simulations. For the intermediate targeting policies no assumption about the structure of the system is necessary. For each policy we calculate the variance of the resulting unconditional forecast of real growth and inflation for 1985 as of the end of 1984. The results are each based on 200 simulations, in each case using the same random numbers.

For each policy considered, we report three numbers,

σ_y: The variance of $\hat{y}$ (defined as expected growth of real GNP from 84:12 to 85:12 as of 84:12) around y^*.

σ_π: The variance of $\hat{\Pi}$ (defined as expected inflation from 84:12 to 85:12 as of 84:12) around Π^*.

and σ_R: The root mean square change in Treasury bills each period.

The first two variances are direct measures of loss, the third is a measure of the volatility of interest rates under each policy: for targeting strategies different degrees of activism are indexed by different values of γ. We label a completely passive policy, that is one with $\gamma = 0$, an interest rate targeting strategy. For the static optimal policy strategy different weights on output and inflation variances are indexed by ϕ.

The quantitative results of this experiment, shown in Table II, must be viewed as only preliminary indications of the types of results which might be likely to emerge with a more realistic loss function and a truly optimal control strategy. Nonetheless, the results are interesting in several respects. First, there is surprisingly little to be gained by actively seeking to hit intermediate targets. The passive policy of setting an interest rate path at the beginning of the year and sticking to it produces variances around the growth and inflation targets only a few percent worse than any of the targeting strategies investigated.

A second result of interest is that there do not appear to be strong grounds for choosing any one variable as the preferred target on the basis of this loss function. Of the variables we consider, the M1 target does perform marginally better than the others. On the other hand, there is evidence that an activist policy of responding vigorously to deviations of several variables, especially the GNP deflator or nominal GNP, may lead to excessive variance of real growth.

Finally, the use of the static optimal strategy outlined in the paper appears to offer some possibility of significant reduction in real growth variance, but little reduction in inflation fluctuations. This last result, however, may be particularly dependent on the one-year horizon in the loss function used here.

Table II

Optimal Policies

ϕ	σ_y	σ_π	σ_R
.1	.719	1.559	.704
.5	.729	1.484	.695
1.0	.747	1.420	.703
2.5	.845	1.305	.735
5.0	1.024	1.260	.773
10.0	1.315	1.241	.809
25.	1.751	1.249	.844

Nominal GNP Target

γ	σ_y	σ_π	σ_R
.005	1.393	1.361	.477
.010	1.391	1.359	.478
.025	1.391	1.354	.479
.050	1.405	1.347	.484
.100	1.480	1.338	.502
.250	1.833	1.347	.578
.500	2.183	1.403	.675
1.000	2.408	1.464	.775

Total Nonfinancial Debt Target

γ	σ_y	σ_π	σ_R
.005	1.394	1.363	.477
.010	1.393	1.363	.477
.025	1.392	1.361	.478
.050	1.391	1.360	.479
.100	1.394	1.356	.481
.250	1.438	1.348	.496
.500	1.572	1.344	.533
1.000	1.880	1.360	.615

Money Target

γ	σ_y	σ_π	σ_R
.005	1.392	1.362	.478
.010	1.389	1.361	.478
.025	1.383	1.356	.479
.050	1.376	1.350	.482
.100	1.372	1.340	.489
.250	1.432	1.323	.518
.500	1.545	1.310	.567
1.000	1.678	1.304	.651

GNP Deflator Target

γ	σ_y	σ_π	σ_R
.005	1.399	1.362	.477
.010	1.404	1.361	.477
.025	1.419	1.358	.478
.050	1.447	1.353	.479
.100	1.509	1.343	.483
.250	1.721	1.323	.506
.500	2.046	1.298	.558
1.000	2.487	1.295	.650

Trade-Weighted Value of the Dollar

γ	σ_y	σ_π	σ_R
-.005	1.390	1.362	.478
-.010	1.385	1.360	.479
-.025	1.378	1.356	.483
-.050	1.386	1.350	.493
-.100	1.457	1.347	.523
-.250	1.772	1.376	.620
-.500	2.031	1.425	.723
-1.000	2.167	1.470	.804

Federal Funds Target

γ	σ_y	σ_π	σ_R
.0	1.395	1.363	.477

Discussion

This experiment illustrates a general approach to the problem of quantifying the costs of using intermediate targets. The particular loss function investigated is motivated primarily by its computational convenience and the quantitative results are not intended to be definitive.

One obvious extension to this work would be to specify a more realistic loss function and to solve for the optimal and targeting strategies using a control theoretic framework. Another possible extension would be to consider alternative targeting strategies such as updating the target path every six months rather than once per year.

Footnotes

1/The classic paper in this area is by Poole [1970], which begins, "In this paper a solution to the instrument problem--more commonly known as the target problem--is determined. ..." In fact, Poole addressed only the problem of choosing instruments, not the problem of choosing intermediate targets.

2/The instrument problem can be simply illustrated in a two-equation static model. Following Leroy and Waud [1977], assume that the supply and demand for money are as follows:

$$(1) \qquad r = a_0 + a_1 m + a_2 i + u_1$$

$$(2) \qquad m = b_0 + b_1 i + u_2$$

where m, i, and r are the money stock, interest rate and reserves; and u_1 and u_2 are normally distributed, uncorrelated disturbances. Note that Poole's model is equivalent if income and money are substituted for m and r, respectively. It is assumed that the Fed knows the parameters, a_0, a_1, a_2, b_0, b_1, and the variances of u_1 and u_2.

The problem is to choose which instrument, in this context r or i, should be set in order to keep the goal variable, here m, as close as possible on average to its target value. As is well known, if the Fed chooses either r or i independently of the other, then which instrument is optimal depends on the values of the parameters and the variances.

Suppose instead that the Fed knows the current demand schedule for r as a function of i. Substituting (2) into (1) we have

$$(3) \qquad r = a_0 + a_1 b_0 + (a_2 + a_1 b_1)i + (u_1 + a_1 u_2)$$

The open market desk can learn this schedule by calling bond dealers and asking the quantity of Treasury bills they will buy or sell at different interest rates. Given this information on a linear combination of current shocks, the Fed can then equivalently set either r or i so as to achieve a superior performance to either of the strategies of independently setting r or i. This latter strategy, which Poole misleadingly labelled a "combination policy," does not require the use of both instruments. Rather, it differs from the earlier strategies only in its assumptions about information availability.

We see from the above discussion that under realistic assumptions about information there is no instrument problem--the Fed can achieve the same results by setting either reserves or the funds rate. Moreover, it should be clear that this type of analysis therefore has no bearing on the issue of intermediate targeting strategies.

3/Note that in this linear-quadratic model there is no purpose in considering nonlinear targeting strategies since they will perform no better than those in the class of linear feedback rules.

4/This follows because we assume in this test that the econometrician does not take account of the change in the error covariance matrix.

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