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Sharon Kozicki[1] and P.A. Tinsley[2]

[1]Research Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
skozicki@bankofcanada.ca

[2]Birkbeck College
University of London

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Abstract

This paper uses real-time briefing forecasts prepared for the Federal Open Market Committee (FOMC) to provide estimates of historical changes in the design of U.S. monetary policy and in the implied central-bank target for inflation. Empirical results support a description of policy with an effective inflation target of roughly 7 percent in the 1970s. Moreover, the evidence suggests that mismeasurement of the degree of economic slack was largely irrelevant for explaining the Great Inflation while favouring a passive-policy description of monetary policy. FOMC transcripts provide a neglected interpretation of the source of passive policy—intermediate targeting of monetary aggregates.

JEL classification: E3, E5, N1
Bank classification: Central bank research; Monetary aggregates; Monetary policy implementation

Résumé

Les auteurs se fondent sur les prévisions en temps réel produites à l'intention du Comité de l'open market de la Réserve fédérale pour mesurer les changements survenus dans la conception de la politique monétaire américaine et les variations de la cible d'inflation implicite de la banque centrale. Les résultats empiriques portent à croire que la cible se situait dans les faits aux alentours de 7 % durant les années 1970. Ils donnent également à penser que la forte inflation des années 1970 ne peut s'expliquer par des erreurs de mesure de la marge de capacités inutilisées au sein de l'économie. Les résultats sont favorables à une autre explication, qui privilégie la passivité de la politique monétaire. À cet égard, l'analyse des comptes rendus des réunions du Comité de l'open market fait ressortir un facteur, négligé jusqu'ici, qui aide à comprendre la faible réactivité de la politique monétaire : la poursuite d'objectifs intermédiaires de croissance des agrégats monétaires.

Classification JEL : E3, E5, N1
Classification de la Banque : Recherches menées par les banques centrales; Agrégats monétaires; Mise en œuvre de la politique monétaire

1. Introduction

For more than a decade, discussions of U.S. monetary policy have been organized around variants of the benchmark description advanced by Taylor (93),

$$r_t = \bar{\rho} + \bar{\pi} + c_2(\pi_t - \bar{\pi}) + c_3(y_t - \bar{y}_t) + \epsilon_{r,t}, \tag{1}$$

where r denotes the short-term policy rate controlled by the central bank; $\bar{\rho}$ is the natural rate of the real interest rate; $\pi - \bar{\pi}$ measures the gap between inflation and the central-bank target for inflation; and $y - \bar{y}$ is the log output gap. Although this description was based on data from 1987-1992, a period that includes the initial five years of Federal Open Market Committee (FOMC)[1] decisions under the Greenspan tenure, variations have been applied to the behavior of many other central banks and to the historical behavior of the FOMC.[2]

In applying this description to U.S. monetary policy in earlier decades, empirical studies have suggested modifications to one or more arguments of equation (1). In particular, several variations of (1) have been advanced to rationalize the behavior of U.S. monetary policy in the 1970s. *Calibration* exercises can support a large number of possible policy variations in the 1970s. For instance, assuming equation (1) provides an adequate characterization of the responses of postwar U.S. monetary policy, then the three natural rates (of output, $\bar{y}_t$, inflation, $\bar{\pi}$, and the real interest rate, $\bar{\rho}$) and two parameters of this equation fully describe the determinants of policy. If combinations of variations in the five arguments are considered, alternative calibrations of equation (1) could support $\sum_{i=1}^{5} \left(\frac{5!}{i!(5-i)!} \right) = 31$ possible theories of policy failure during the Great Inflation.[3]

Among *data-based* explanations of U.S. policy in the 1970s, two interpretations dominate: one involving changes in the response coefficients and the other based on alternative characterizations of the central-bank perceptions of natural rates.[4]

[1] The FOMC is responsible for the actions of U.S. monetary policy through open market operations.

[2] A sizeable literature explores regression estimates of U.S. policy responses over postwar samples, including Judd and Rudebusch (1998), Taylor (1999), Romer and Romer (2002), and Nelson (2005).

[3] Inconclusive calibration exercises of two competing theories of the Great Inflation are discussed in Collard and Dellas (2004). Recent surveys of alternative interpretations of U.S. inflation in the 1970s are presented in Velde (2004) and Nelson (2005).

[4] A third notable interpretation is that the central bank attempted to exploit a perceived permanent tradeoff between unemployment and inflation, as in Sargent (1999) and Sargent, Williams, and Zha (2004). This conjecture is not supported by central-bank real-time implementations of the Phillips curve in the 1970s, as in Enzler and Pierce (1974) which assumed the absence of a long-run tradeoff. Notwithstanding, Cogley and Sargent (2005a) ingeniously suggest policy may have optimized a collection of competing macro models, including the permanent-tradeoff specification, where a subset of models (with low posterior odds) predict

One interpretation has been labelled the *passive-policy* explanation. In the influential work of Clarida, Gali, and Gertler (2000), this interpretation is supported by empirical estimates of the policy-rate equation that indicate the estimated policy response of the nominal federal funds rate in the 1970s did not keep pace with inflation. In terms of equation (1), the passivity of policy is summarized by the inequality, $\hat{c}_2 < 1$.[5]

The other leading explanation of the Great Inflation is the *natural-rate-error* interpretation. In a series of important papers, Orphanides (2003a, 2003b, 2004) suggests policy responses to inflation and the output gap, such as c_2 and c_3 in equation (1), were consistent with stable policy responses in the 1970s. However, lower levels of the policy rate were induced by substantial and persistent overestimation by the central bank of the natural rate for output, $\bar{y}_t$. Although this research has instigated useful work on consequences of real-time errors in estimates of the natural rate of output and trend productivity, the applicability to policy formation in the 1970s is conjectural.

A major obstacle to confirming the natural-rate-error interpretation of monetary policy in the 1970s is the lack of a continuous historical record of central-bank estimates of the natural rate for output. Although Federal Reserve Board briefing documents (known as Greenbooks) since April 1970 report staff estimates of the "high-employment fiscal surplus or deficit" to measure changes in discretionary fiscal policy, estimates of high-employment GNP are not recorded and were not used to gauge inflationary pressure.[6] In the absence of historical briefing estimates of $\bar{y}_t$ by the central bank, Orphanides (2003a) uses output natural rates presented in annual reports of the Council of Economic Advisors (CEA) as a real-time proxy. However, CEA natural rate estimates are infrequently cited in the FOMC *Memorandum of Discussion* (MOD) during the 1970s, and do not appear to have been supported by staff forecasts. Examples include:

> (T)he potential GNP as estimated by the Council of Economic Advisers is based on a 3.8 per cent unemployment rate. That may well be too low an unemployment target for sustainable economic growth without inflation. (Partee, FOMC Economist (MOD, 11/17/1970, p.31))

infinite costs for disinflations in the 1970s.

[5] Analytical determinacy conditions for a variety of interest-rate response formats are explored in Woodford (2003). In the absence of a stable policy response to inflation, Clarida et al. (2000) suggest that private-sector expectations of inflation in the 1970s may have been driven by non-fundamental (sunspot) shocks.

[6] Staff estimates of the high-employment fiscal surplus or deficit were based on the methodology suggested in Okun and Teeters (1970).

> Mr. Partee observed that the target for the unemployment rate referred to in the Annual Report of the Council of Economic Advisers already seemed to have been increased from 4 to 4-1/2 percent....according to the (Greenbook) projections, even a 5 per cent unemployment rate would be associated with considerable continuing inflation in the short run. (MOD, 3/19/1973, p.28)

Moreover, given representative specifications of aggregate pricing equations in the 1970s and as suggested in the above citation, it is more likely that the FOMC used aggregate unemployment to gauge real-resource slack.

Two shortcomings of the previous literature examining monetary policy in the 1970s are the lack of empirical work to recover the implied inflation target of the U.S. central bank and the constrained scope of the analysis to descriptions of policy in which the policy rate responds directly to measures of economic slack and inflation. Each of these is addressed in the current study.

Drawing on the history of forecasts presented to the FOMC, the evolution of the policy-response function and movements in the implied inflation target are estimated. An important difference from prior studies is that the effective inflation target is not treated as implicit in fixed intercepts or assumed to be a known constant. The estimated inflation target is an *effective* target, implied by the structure of the policy-response function. Of course, the estimate may not correspond to the intentions of policy-makers. Moreover, although an individual decision-maker may maintain an invariant preference distribution over the domain of policy objectives, the historical record of FOMC discussions suggests differences in preference distributions among members of the FOMC. Because U.S. monetary policy is determined by a twelve-member subset of the FOMC, rotations of voting eligibility and of tenure on the FOMC, as well as variations in framing voting choices, vid. Arrow (1951), imply that the effective target for inflation selected by the central bank will likely vary over time.

The empirical results generally support the passive-policy theory of Clarida et al. (2000), but also suggest the effective inflation target of U.S. monetary policy was quite elevated through the 1970s—on the order of 7 percent. However, the results suggest also an alternative interpretation that provides additional insights into the design of US monetary policy in the 1970s.

As noted earlier, a potential weakness of much of the literature on the conduct of monetary

policy in the 1970s is its focus on direct policy-rate responses to economic activity and inflation. By contrast, policy documents from the 1970s indicate that FOMC policy in the 1970s followed a strategy based on intermediate targeting of monetary aggregates.[7] This paper reexamines the consequences of a two-stage policy design, with economic projections conditioned on money-growth paths in one stage and mappings between such targeted money-growth rates and nominal interest rates in a separate stage. Accounting for the two-stage set-up provides a deeper understanding of the policy design that accommodated passive responses and elevated effective inflation targets.

The next section proceeds with a discussion the methodology and data used to estimate the inflation target implied by historical policy responses. Empirical results, summarized in section 3, suggest a reconsideration of policy responses in the 1970s. Consequently, section 4 explores a description of U.S. monetary policy in that period that incorporates intermediate money-growth targeting. Section 5 concludes.

2. Historical policy responses and estimates of the effective inflation target

This section discusses the methodology and data used to estimate implicit U.S. central-bank targets for inflation, $\bar{\pi}_t$. The methodology is motivated by two important observations. First, in the absence of an announced and fully-credible numerical inflation goal, the true central-bank target for inflation explicitly appears only in the description of policy-rate responses. Second, policy decisions are based on knowledge (including, at least, data and economic models) as they were available at the time the decisions were made.

Estimation uses a policy-response function to identify variations in the effective policy target for inflation. Private-sector behavior is influenced by the private-sector perception of the central-bank target for inflation. Such perceptions anchor forward expectations of inflation, which appear in both the pricing equations of firms and the forward policy-rate perceptions of traders in financial asset markets. However, under asymmetric information, private-sector perceptions may not match the the true central-bank target for inflation, vid. Kozicki and Tinsley (2001, 2005, 2006b). Consequently, only central-bank policy depends explicitly on the central-bank inflation goal. For this reason, estimation in this section uses the policy response function to identify variations in the effective policy target for inflation.

[7]Friedman (1977) and the collection of papers in the same volume of the *Journal of Monetary Economics* discuss the two-stage procedure and the issues it raises.

To avoid providing a revisionist view of policy, the empirical analysis uses real-time data on macro indicators obtained from FOMC central-bank briefing documents (Greenbooks) prepared in advance of FOMC meetings. Use of real-time data on macro indicators is critical for historical evaluations of policy (Runkle (1998); Croushore and Stark (2000); Kozicki (2004)). Indeed, Orphanides (2002) clearly shows how policy actions taken based on available data can differ considerably from recommendations based on subsequently revised data. Moreover, as discussed in the introduction, in order to be more consistent with measures of economic slack emphasized in real time, the unemployment gap is chosen over the output gap as a preferred gauge of economic activity.

Fitting policy responses to central-bank historical forecasts and using prior information on the structure of central-bank forecast models has an additional advantage. With asymmetric information, these steps mitigate a potential identification problem. In particular, Beyer and Farmer (2004), note that estimation of reduced-form policy-response functions using only historical realizations of inflation and output, may be unable to distinguish between competing dynamic specifications of central-bank responses and of other structural relationships in the macro system.[8]

The remainder of the section discusses the methodology used to uncover the implied inflation target from policy-response equations, a description of the real-time data, and details of the time-varying-parameter (TVP) methodology applied to estimate the policy-response equations.

2.1 Estimating implied $\bar{\pi}_t$ from policy response equations

The analysis in this paper explores a description of FOMC policy responses where, as noted earlier, the unemployment gap provides a plausible indicator of historical policy objectives regarding economic slack. In the absence of policy-rate smoothing, the desired setting of the federal funds rate at the FOMC meeting in period t_f is the forward-looking specification

$$r^*_{t_f} \quad = \quad \bar{\rho}_t + \bar{\pi}_t + c_{2,t}(\pi^k_{t|t_g} - \bar{\pi}_t) + c_{3,t}(u_{t+k|t_g} - \bar{u}_t) + c_{4,t}\Delta u_{t|t_g}, \tag{2}$$

where the subscript t_g denotes the date of the relevant Greenbook forecast, t_f the date of the FOMC meeting, $t_f > t_g$, and, generally, both are contained in the current quarter, t. The inflation and unemployment regressors on the right side of equation (2) are drawn from the

[8]For example, estimation of a weak policy response to expected future inflation may reflect the relative importance of backward-looking behavior of firms in the aggregate pricing equation.

Greenbook in period t_g. The inflation measure, $\pi^k_{t|t_g}$, is a four-quarter average of forecasts up to quarter $t+k$ in the forecast horizon and may also include Greenbook estimates of recent inflation, and $u_{t+k|t_g}$ is the Greenbook forecast of the unemployment rate in quarter $t+k$. To nest the possibility that FOMC policies may have placed a greater emphasis on the change in activity, as suggested by Judd and Rudebusch (1998) and Lansing (2002), the desired policy rate may also be a function of the projected change in the unemployment rate, $\Delta u_{t|t_g}$.

Dynamic adjustments of the funds rate are represented by

$$r_{t_f} = \beta_{5,t}\Delta r_{t_f-1} + (1-\beta_{6,t})r^*_{t_f} + \beta_{6,t}r_{t_f-1} + a_{t_f}, \tag{3}$$

which contains a term capturing any continuation of the policy-rate change selected in the last Greenbook; a partial adjustment of the funds-rate level to the desired setting; and an i.i.d. stochastic shock, a_{t_f}.

Combining equations (2) and (3) gives

$$\begin{aligned} r_{t_f} = {} & \beta_{1,t} + \beta_{2,t}\pi^k_{t|t_g} + \beta_{3,t}(u_{t+k|t_g} - \bar{u}_{t|t_g}) + \beta_{4,t}\Delta u_{t|t_g} \\ & + \beta_{5,t}\Delta r_{t_f-1} + \beta_{6,t}(r_{t_f-1} - \bar{\rho}_t) + \bar{\rho}_t + a_{t_f}. \end{aligned} \tag{4}$$

This is the equation that is estimated using TVP techniques. The central-bank target for inflation is:

$$\bar{\pi}_t = -\beta_{1,t}/(\beta_{2,t} + \beta_{6,t} - 1), \tag{5}$$

which is obtained by mapping the reduced-form parameters in (4) to the structural parameters and unobserved inflation target in expressions (2) and (3).

2.2 Description of real-time data

The policy rate is measured using data for the federal funds rate. While this data is not revised, care must be taken to ensure that the data is measured over intervals consistent with the dating of the Greenbook forecast data. The policy rate on the left side of equation (4) is the average of federal funds rates in the interval following the FOMC meeting in t_f to the next meeting. The lagged policy rate regressor, r_{t_f-1}, is the average funds rate since the previous FOMC meeting. As FOMC dates are not evenly spaced over the calendar, the number of days in the funds rate averages will vary but time-varying parameters may

partially compensate for this.[9]

Data on inflation and the unemployment rate are drawn from historical Greenbooks. The Greenbook is a staff briefing document presented to FOMC members before a policy meeting of the FOMC. Part II contains background analyses of recent economic and financial data, and Part I presents the staff multiperiod forecast of economic activity. The baseline Greenbook forecast is a "judgemental" forecast considered the modal, or most-likely, outcome, given recent policy decisions and objectives. Components of the forecast are selected in a series of meetings by the senior staff and sectoral specialists, who prepare initial projections for their area of expertise. Forecast assumptions conditioned on perceived current policy and objectives include the senior staff's judgement of likely outcomes in financial markets over the forecast horizon.

One potential concern with the use of Greenbook forecasts of inflation and activity measures is that these forecasts may reflect endogenous responses to future policy actions embedded in the conditioning policy assumptions. However, for near-term projections (i.e., low k) such endogenous responses are likely to be minimal. In any case, the real-time Greenbook projections should provide a more accurate measure of the policymakers' forecasts than constructions based on ex-post available (and often revised) data.

Because Greenbook forecasts are constructed on the basis of assumptions about current and future policy, in principle, it would be desirable to incorporate information about expected future policy rates as well. However, Greenbook forecast assumptions about future policy rates over the forecast horizon are not yet publicly available. To facilitate some smoothing of estimates and reporting at a fixed frequency, data associated with Greenbook dates falling in the same quarter, t, are stacked in the relevant observation vectors and matrices for quarter t. To simplify subscript notation, the FOMC and Greenbook conditioning dates, t_f and t_g, are generally suppressed in the remaining discussion.

The real-time Greenbook perception of the natural rate of unemployment, $\bar{u}_t$, is estimated using Greenbook data as described in Kozicki and Tinsley (2006a). The $\bar{u}_t$ estimate is based on a "hybrid" Phillips curve, that relaxes the constant parameter restrictions of Romer and Romer (2002) and admits both forward- and backwards-looking inflation expectations. Interestingly, the $\bar{u}_t$ natural rate estimate of 5.6, shown in Table 1 for $\bar{u}_t$ in the 1996Q1-97Q4 interval, is precisely the natural rate of unemployment assumed in the February 1997

[9]Fixed-coefficient regressions of meeting-to-meeting adjustments of the funds rate are explored in Froyen and Waud (2002).

Greenbook, as reported in Svensson and Tetlow (2005). A more detailed summary of the construction methodology is included in the Appendix.

In addition to their preferred estimate of the Greenbook-based real-time estimate of the natural rate of unemployment (used in the current study), Kozicki and Tinsley present a lower-bound alternative, $\bar{u}_t^b$, that is closer to that reported by Romer and Romer (2002). Differences between the two Greenbook-based estimates of the unemployment natural rate are illustrated in Table 1, which compares subsample averages of the two estimates with averages reported in Romer and Romer (2002) and with averages of the retrospective construction by the Congressional Budget Office (2004). Both the Romer and Romer estimates and the lower-bound alternative are based on a Phillips equation with backwards-looking inflation expectations, and imply substantial real-time underestimates of the CBO retrospective measure in the first half of the 1970s, of 2-3 percentage points (a 30-50% error). By contrast, the retrospective underestimation by $\bar{u}_t$ is less than one percentage point in the first half of the 1970s (a 17% error).

The natural rate of the real policy rate, $\bar{\rho}_t$, is measured as an HP filter of the historical funds rate less the Greenbook forecast of inflation, $r - \pi$. Following Ravn and Uhlig (2002), the Hodrick-Prescott smoothing parameter is 2^4 x $1600 = 25,600$, as the FOMC has met at least eight times a year during the sample used. The average of the natural rate construction is 2.6 over the full sample, with $\bar{\rho}_t$ falling below the average value in the mid-1970s and rising above the average in the first half of the 1980s.

The construction of the effective inflation target depends on the proxy used for the FOMCs perception of the natural rate of the real policy rate. The principal effect of alternative natural-real-rate measures is to alter the implied estimate of the central-bank target for inflation. Denoting $\delta(\bar{\rho}_t)$ as the deviation of the natural real rate from a constant, the time-varying adjustment to the implied estimate of target inflation is $\frac{\delta(\bar{\rho}_t)}{c_{2,t}-1}$, where the sign of the adjustment depends on the stability of the long-run response to inflation, $c_{2,t}$. Implications of alternative choices of the natural real rate will be discussed with the empirical results.

2.3 Model specification with time-varying-parameter policy responses

The effective measurement equation for the policy-response equations is

$$\begin{aligned} y_t &= \Xi_t \vec{\beta}_t + a_t, \\ &= [\tilde{X}_t, X_t] \begin{bmatrix} \tilde{\beta}_t \\ \bar{\beta} \end{bmatrix} + a_t \end{aligned} \tag{6}$$

where the vector y_t contains policy interest rates set at FOMC meetings that reference Greenbooks generated in quarter t. The matrix of regressors, $[\tilde{X}_t, X_t]$, conforms to the dimensions of y_t and the parameter vector, $\vec{\beta}_t$.

Partitioning according to whether coefficients are constant or time-varying follows Kozicki and Tinsley (2006a): The matrix X_t contains a unit column vector, in addition to Greenbook observations on $k-1$ regressors; the vector $\tilde{X}_t$ contains those elements of X_t whose coefficients are time-varying. The $\vec{\beta}_t$ vector is partitioned into a $k \times 1$ fixed vector, $\bar{\beta}$, and a $\tilde{k} \times 1$ time-varying vector of deviations, $\tilde{\beta}_t$, whose unconditional mean is zero. The effective time-varying coefficients of the forecast model, β_t, are obtained by summing the fixed and time-varying-deviation vectors

$$\beta_t \equiv \bar{\beta} + \begin{bmatrix} \tilde{\beta}_t \\ 0_{k-\tilde{k}} \end{bmatrix}, \tag{7}$$

where $0_{k-\tilde{k}}$ is a $(k-\tilde{k}) \times 1$ zero vector. Note that $\tilde{k} < k$ if the last $k-\tilde{k}$ elements of β_t are invariant over time.[10] The measurement error is normally distributed, $a_t \sim N(0, R_t)$, where $R_t \equiv \sigma_a^2 I$. The format of the *transition* equation is

$$\vec{\beta}_t = \Phi \vec{\beta}_{t-1} + e_t, \tag{8}$$

where the partitions of the transition matrix and the transition shock vector are

$$\Phi = \begin{bmatrix} \tilde{\Phi} & 0 \\ 0 & I_k \end{bmatrix}, \text{ and } e_t = \begin{bmatrix} \tilde{e}_t \\ 0 \end{bmatrix}. \tag{9}$$

The nonzero transition shocks are also normally distributed, $\tilde{e}_t \sim N(0, \tilde{Q}_t)$.

Results are presented for two TVP specifications. The different TVP specifications

[10] The matrix $\tilde{X}_t$ is a subset of X_t when $\tilde{k} < k$.

amount to different restrictions on the dimension of the time-varying partition, $\tilde{\beta}_t$, and on the eigenvalues of the associated transmission matrix, $\tilde{\Phi}$.

The random-walk-intercept (RWI) specification allows the intercept term to evolve according to a unit root process, but other coefficients are restricted to be constant. Estimation of the RWI specification uses the Stock-Watson (1998) median-unbiased estimator of the variance of the shocks driving the random walk.[11] After obtaining the median-unbiased estimate of the random-walk transition shock, the random-walk intercept and fixed slope means are estimated by Kalman filtering and smoothing equations. Although means and sampling errors are estimated for the remaining regression coefficients, $\bar{\beta}_i, i = 2, \ldots, k$, the fixed partition of the random-walk intercept is the initial condition, $\beta_{1,t_0} = \bar{\beta}_1$. To provide an approximate comparison with estimates of mean coefficients from alternative specifications, the finite-sample average of the random-walk intercept estimates is reported as the mean of estimates over the T-period sample, $\hat{\bar{\beta}}_1 \equiv \frac{1}{T} \sum_{t=1}^{T} \hat{\beta}_{1,t}$, along with the standard deviation of this finite-sample average.

In the other specification, a stationary-coefficients (SC) specification, all coefficients of the policy-response equation are allowed to be time-varying, with time-variation in all unrestricted coefficients captured by stationary autoregressive movements about fixed means.[12] The transition matrix, $\tilde{\Phi}$, and the covariance matrix of transition shocks, $\tilde{Q}$, are estimated by maximum likelihood, vid. Shumway and Stoffer (2000). The SC specification is motivated by the observation that modest variation in the response to inflation, $\beta_{2,t}$, or the partial-adjustment parameter, $\beta_{6,t}$, may lead to large changes in the constructed inflation target, $\bar{\pi}_t$, .

After examining a number of TVP applications, our experience is that the means of the coefficients, the maximum and minimum of the implied inflation targets, and the variance decomposition provide useful summary contrasts among alternative specifications. The

[11] The variance of the shocks driving the random walk is assumed to be $\nu^2 \sigma_u^2$, where u denotes residuals of the fixed coefficient regression, $y_\tau = X_\tau \bar{\beta}$. $\nu = \frac{\lambda}{T}$, where the probability of a zero pileup by maximum likelihood varies inversely with the local-to-zero parameter, λ, vid. Stock and Watson (1998, Table 1).

[12] In a third alternative that was considered, all coefficients were allowed to evolve according to unit-root processes. While tractable, random-walk specifications have some questionable implications, including assumptions that all parameter change is permanent and that parameters can evolve over time without finite bounds. Indeed, excessive drift in random-walk-coefficient specifications led to problems in the identification of the implicit inflation target for those few observations t when $\beta_{2,t} + \beta_{6,t}$ was very close to one. Overall, however, sample-average estimates of random-walk coefficients were quite close to sample-average estimates of stationary coefficients, providing evidence that the reported results are robust to such variations in specification.

steady-state variance of the dependent variable due to variation in β is

$$\text{var}(y) \;=\; \tilde{X}V(\beta)\tilde{X}',$$

where elements of the $\tilde{k} \times \tilde{k}$ steady-state covariance of the stationary parameters, $V(\beta)$, can be recovered from the column stack

$$\text{vec}V(\beta) \;=\; [I_{\tilde{k}^2} - \tilde{\Phi} \otimes \tilde{\Phi}]^{-1}\text{vec}\tilde{Q}.$$

A steady-state variance decomposition,

$$\text{vardecom}(\beta_j) \;\equiv\; \frac{100}{\text{var}(y)}[\tilde{X}_j^2 V_{jj} + \frac{1}{2}\sum_{i \neq j} \tilde{X}_i \tilde{X}_j V_{ij}], \tag{10}$$

is reported in which half of the covariance, V_{ij}, is assigned to each of β_i and β_j, following Swamy and Tinsley (1980).[13]

3. Empirical results

Policy responses are estimated for two samples. One combines the tenures of Arthur Burns and G. William Miller as chairmen of the FOMC, February 1970 through July 1979, while the second includes tenures of Paul Volcker and Alan Greenspan, August 1979 through December 1997.

The policy equation was also estimated over the full 1969 - 1997 sample containing 280 Greenbooks. The TVP specification accommodated two shifts in the variance of the measurement error, σ_a, to account for the change in operating procedures from 1979Q4 to 1982Q3.[14] In addition to the preferred estimate of $\bar{u}_t$, estimation was performed using an alternative Greenbook-based estimate that is closer to that reported by Romer and Romer (2002). However, these adjustments were insufficient to explain a major policy transition at the end of the 1970s detected by tests for structural change.[15] Consequently, the remainder of this section explores estimations of separate policy responses for the Burns/Miller and the Volcker/Greenspan tenures.

[13]Some elements of the variance decomposition may be negative under this convention.

[14]The use of a nonborrowed reserves instrument during the 1979-82 interval increased the effective variance of a_t by introducing shocks from money demand and the banking reserves market, vid. Tinsley, von zur Muehlen, and Fries (1982).

[15]The test statistics are robust to residual heteroskedasticity. The largest test statistics occur in early 1980 with zero p-values, using the tables in Hansen (1997).

3.1 Policy during the Burns/Miller tenures

Results of fitting equation (4) to Greenbook forecasts in the Burns/Miller era are presented in the top panel of Table 2. The policy regime, 1970Q1 through 1979Q2, spans 38 quarters and 115 Greenbooks. The horizon of forward expectations, k, in historical Greenbooks is limited in early years of the sample.[16] In Table 2, inflation is averaged over four quarters, including Greenbook estimates of inflation in the two preceding quarters, $h = -2, -1$, and the inflation forecasts for the current and next quarter in the policy horizon, $h = 0, 1$.[17]

In the top panel of Table 2, mean responses to both inflation and the first-difference of unemployment are statistically significant, but the mean response to the unemployment gap, $u_{t+1} - \bar{u}_t$, is marginally insignificant, with p-values of 0.09 for the RWI specification and 0.11 for the SC specification. The lower bound for the implied natural rate of inflation is negative for both specifications and the upper bound appears unrealistically low.

When drawing structural interpretations based on estimated parameters, as is done here, the presence of regressors that are not relevant, even if their estimated coefficients are insignificantly different from zero, can distort structural estimates. For intuition, recall that the constant term in a constant-parameter regression is equal to the sample average of the regressand less estimated coefficients multiplied by sample averages of respective regressors. Consequently, the estimated constant will be perturbed by all regressors unless their respective coefficients or sample averages are exactly zero. For this reason, it seems advisable to reestimate the model excluding regressors with insignificant coefficients. In addition, fixed-coefficient regression studies of U.S. monetary policy generally indicate that policy in the 1970s responded significantly to gap measures of real activity, with significant mean responses to output gaps reported in Judd and Rudebusch (1998), Taylor (1999), Clarida, Gali, and Gertler (2000), Nelson (2005), and Orphanides (2004). In exploring these suggestions, the second panel in Table 2 drops the unemployment-change regressor and the third panel

[16] Constraints on the horizon of early Greenbook forecasts constrained the data to only include two-quarter leads, $k = 1$, of data when estimating the policy equation (4). Even this limited degree of forward-looking behaviour could not be accommodated for all observations. The Greenbook of November 15, 1972 contains only a current-quarter forecast, i.e. the Greenbook forecast horizon, H, in that quarter is equal to the first period of the forecast, $h = 0$. For this Greenbook, the current-quarter forecast is repeated when a two-quarter forecast horizon is required, as for $k = 1$.

[17] Although both Clarida, Gali, Gertler (2000) and Orphanides (2004) estimate forward-looking policy rules, a number of studies including Taylor (1999) have estimated policy responses to backward-looking averages. As both recent measurements and forecasts of inflation can be subject to sizeable revisions over time, it seems plausible that FOMC members may differ in the emphasis placed on forecasts or recent measurements in weighing their policy decisions. Policy equations were also estimated for two-quarter averages, $h = 0, 1$ with estimation results similar to those in Table 2, but likelihood ratios preferred specifications with four-quarter averages for the inflation rate so these are the results included in the tables.

eliminates the unemployment-gap regressor. Results are consistent with the top panel, but implied bounds on the implicit inflation targets are more plausible.

When the first-difference of the unemployment rate is dropped as a regressor in the middle panel of Table 2, mean policy responses to the unemployment gap, $\bar{\beta}_3$, remain insignificant, with p-values around .2. In the bottom panel of Table 2, when the gap is dropped, mean policy responses to the first-difference of the unemployment rate are significant, as are the mean responses to inflation. In addition to the statistical insignificance of mean policy responses to the unemployment gap, $\bar{\beta}_3$, a Chi-squared test of the likelihoods in the top and bottom panels of Table 2 does not reject zero restrictions on the additional parameters required for a TVP policy response to the unemployment gap.

As shown in Figure 1, the long-run policy response to inflation remains below unity throughout the 1970s. Moreover, for the SC specification, the estimated long-run response to inflation falls in 1974. Recalling the two leading interpretations of U.S. policy in the 1970s, the evidence presented in this section supports the passive-policy interpretation. Indeed, the natural-rate-error explanation appears to be largely irrelevant, as there is little empirical support for a systematic policy response to the unemployment gap. The absence of a policy response to unemployment gaps also casts doubt on interpretations of 1970s U.S. monetary policy based on a difference between the natural rate of unemployment and a central-bank target for unemployment, such as posited in the time-inconsistency literature or the central-bank misperception analysis of Sargent, Williams, and Zha (2004). An alternative interpretation of US policy in the 1970s is explored in section 4.

3.2 Policy during the Volcker/Greenspan tenures

The policy equation (4) is estimated for the Volcker/Greenspan policy era, 1979Q3 through 1997Q4, a span of 75 quarters and 152 Greenbooks. Estimation results are summarized for two forecast horizons (k) in Table 3.

The construction of the inflation regressor, π_t^k, varies in the two panels of Table 3. The top panel follows the same strategy as was used for the Burns/Miller sample with inflation averaged over the first two quarters of the Greenbook horizon and the two preceding quarters, $h = -2, -1, 0, 1$. In addition, given the availability of longer Greenbook forecast horizons in the Volcker/Greenspan sample, in the bottom panel the four-quarter inflation average is shifted ahead by two quarters, $h = 0, 1, 2, 3$.

In contrast to the results obtained for the Burns/Miller period, the estimated mean policy responses to all regressors, including both the unemployment gap and the first-difference in unemployment, are generally statistically significant in Table 3. The estimate of the long-run policy response to inflation, $c_{2,t}$, remains above one throughout the sample, although it falls in the 1990s for the SC specification (Figure 2).

The estimated characteristics are similar in both panels of Table 3. A likelihood ratio suggests a slight advantage for the specification where the four-quarter average of inflation, π_t^k, contains both forward forecasts and backward real-time estimates, $h = -2, -1, 0, 1$.[18]

The time profile of the central-bank target for inflation, $\bar{\pi}_t$, in the Volcker/Greenspan sample is shown in Figure 3, as implied by the equation in the top panel of Table 4. The effective target is estimated to be about 3 1/4 percent. The remaining variables in Figure 3 are discussed in the next section.

4. An alternative interpretation of policy in the 1970s

Simple policy response equations that relate movements of the policy interest rate, r, to changes in arguments of the central-bank preference function, such as inflation, π, and real economic activity, y or Δy, are the basis of many useful empirical descriptions of historical monetary policy. However, positing a direct link between the policy instrument and ultimate policy objectives conceals a major flaw in the design of monetary policy in the 1970s. This section indicates that intermediate targeting of monetary aggregates–a monetarist strategy that dominated FOMC policy in the 1970s–provides a unified interpretation of the Great Inflation, explaining the irrelevance of the natural-rate-error interpretation and providing a more historically accurate description of policy design in the 1970s.

4.1 The gathering influence of monetarism on US monetary policy

In a collection of highly influential essays, Milton Friedman (1960) indicated that "I share the doubts that the Federal Reserve has repeatedly expressed about the desirability of using price level stability as an intermediate guide to policy." Instead, he proposed that the central bank pursue constant growth of the money stock. In 1960, a unified measure of the money supply was published in the October Federal Reserve *Bulletin*. In the June 1966 FOMC meeting, the FOMC Policy Directive to the trading desk of the Federal Reserve Bank of

[18]Several papers demonstrate that indeterminacy may occur if policy responds to arguments in distant forecasts; see the numerical analysis in Batini and Pearlman (2002).

New York contained the first "proviso" reference to the required-reserves aggregate as a secondary target. Finally, in the second FOMC meeting chaired by Arthur Burns, the Policy Directive adopted at the March 10, 1970 meeting selected the growth of monetary aggregates as principal targets of US monetary policy.

Policy forecasting and FOMC policy discussions in the 1970s were shaped by the two-stage design that is characteristic of intermediate targeting. Greenbook forecasts of economic activity were conditioned on the assumption of a trajectory for the money supply over the forecast horizon, vid. Kalchbrenner and Tinsley (1977).[19] To assist sectoral specialists, the senior staff translated the money-supply assumption into staff expectations of bond yields over the forecast horizon.

By contrast, short-run policy options were formulated as competing money-growth paths associated with alternative settings of the policy instrument, usually the nominal federal funds rate. In principle, the competing options for the money-supply represented different short-run paths toward the baseline money-supply trajectory assumed in the Greenbook. These short-run policy options were presented in a briefing document known as the Blue Book. Each Blue Book contained a brief summary of recent activity in money and banking markets and suggested, generally, three policy options for discussion by the FOMC.[20] Forecasts of money growth associated with alternative policy-rate settings appear in the Blue Book presented at the first FOMC meeting chaired by Arthur Burns on February 10, 1970. Although alternative forecasts of the money supply were initially limited to the current quarter, as in the February

[19]Generally, the monetary-policy assumption of the Greenbook forecast was the M_1 growth-rate target selected at the last FOMC meeting. For example: "That growth rate of money (4%) had been assumed for projection purposes because the Committee had been employing such a rate as a target over the past several months." Partee, FOMC Economist (MOD, 6/23/70, p.31); and "In developing our base projection, which is laid out in detail in the green book, we have adopted several policy assumptions. The monetary policy assumption calls for a continuation of the present policy stance through 1976, as indexed by the growth in the narrow money supply at around the 6-1/4 per cent midpoint of the range that has been announced by the Committee." Partee (MOD 6/16/75, p.4).

[20]Two examples of staff interpretations of the Bluebook policy options are: "Mr. Axilrod observed that among the alternative sets of relationships between monetary aggregates and money market conditions presented in each blue book, there was always one that represented a continuation of the Committee's current longer-run target for the aggregates. There was always another alternative that represented a continuation of prevailing money market conditions." (MOD, 11/20/72, p.52); and "Mr. Partee said it might be helpful if he explained how the staff proceeded in formulating the blue book alternatives. One of the alternatives always shown involved the maintenance of prevailing money market conditions; in the present case, that was alternative C, the tightest of the three. Another alternative always shown involved the longer-run growth rate for M1 adopted by the Committee at its previous meeting. Since on this occasion that alternative called for a rather sizeable near-term decline in the Federal funds rate followed by an upturn before the end of the 6-month projection period, the staff thought it probably would be as liberal a policy as the committee was likely to consider within the range of reasonableness. Consequently, that alternative was labeled"A" and the third was formulated to fall between the other two." (MOD, 1/21/75, pp. 61-2).

4 Bluebook, or also included the next quarter ahead, as in the March 4 Bluebook, horizons of the Bluebook conditional money-supply forecasts were eventually lengthened to four-quarter horizons in 1975, including the current quarter, $h = 0, 1, 2, 3$.

4.2 Empirical evidence for intermediate targeting in the Burns/Miller era

Intermediate targeting of the money supply is summarized by three equations,

$$\Delta m_t = \pi_t + \Delta y_t - \Delta v_t, \tag{11}$$

$$\Delta \bar{m}_t = \bar{\pi}_t + \Delta \bar{y}_t - \Delta \bar{v}_t, \tag{12}$$

$$r^*_{t_f} = \bar{\rho}_t + \bar{\pi}_t + c_{2,t}(\Delta m_t - \Delta \bar{m}_t + (\Delta v_t - \Delta \bar{v}_t)), \tag{13}$$

where equation (11) is the monetarist equation of exchange that links Greenbook forecasts of inflation and output growth to the projected growth of the monetary aggregate. Equation (12) is a natural rate variant that indicates what target growth of the monetary aggregate is consistent with the natural rates for inflation and output growth. The desired setting of the funds rate at the FOMC meeting in period t_f is defined by equation (13). This is an adjusted variant of intermediate targeting, where monetary-aggregate growth is adjusted for the staff prediction of transient velocity growth, $\Delta v_t - \Delta \bar{v}_t$.[21]

Substituting the first two equations, (11) and (12), into the third equation (13), gives the

[21]By construction, a persistent shift in trend velocity alters the natural-rate estimate, $\Delta \bar{v}_t$. "Shift-adjusted"' monetary aggregate targets, to account for the estimated effects of financial innovations such as the nationwide introduction of negotiable order of withdrawal (NOW) accounts, were not publicly announced until 1981. The transient-velocity-growth adjustment, $\Delta v_t - \Delta \bar{v}_t$, of equation (13) approximates the "zone of indifference" the FOMC adopted in the 1970s to accommodate transient movements within growth-rate target ranges. The evolution of the "zone of indifference" is illustrated by the following selections from the *Memorandum of Discussion*:"On balance he would not object to some shading of the funds rate if the aggregate growth rates appeared to be close to the upper or lower limits. However, more vigorous action should be taken only if the growth rates appeared to be outside the range." Burns, (MOD 10/17/72, p.40)."Chairman Burns remarked at the last meeting he had initially defined the ranges for the aggregates as zones of no action. He had then modified that—in response to Mr. Holmes' remarks—to provide for a movement in the funds rate of up to but no more than 1/8 of 1 percentage point as the aggregates approached their limits. In the event that the aggregates appeared to be moving beyond their limits, however, full and free use was to be made of the range for the funds rate." (MOD, 11/20/72 p. 50). "(Governor Partee's) preference was for (a range) of 4 to 8...for M-1...with a zone of indifference of 5 to 7....Chairman Burns observed that he could accept the zones of indifference proposed by Mr. Partee." (MOD, 3/16/76, p.74).

desired funds rate explicitly conditioned on averages of Greenbook forecasts,

$$\begin{aligned} r^*_{t_f} &= \bar{\rho}_t + \bar{\pi}_t + c_{2,t}((\pi^k_t - \bar{\pi}_t) + (\Delta y^k_t - \Delta \bar{y}_t)), \\ &= \bar{\rho}_t + \bar{\pi}_t + c_{2,t}(\Delta x^k_t - \Delta \bar{x}_t), \end{aligned} \tag{14}$$

where $\Delta x^k_t - \Delta \bar{x}_t$ is a proxy for the gap of nominal output growth using Okun's Law, $\Delta x^k_t - \Delta \bar{x}_t = \pi^k_t - \bar{\pi}_t - a' \Delta u^k_t$; and the superscript, k, indicates four-quarter averaging over forecast periods through $h = k$.

Note that equation (14) is a restricted version of the desired funds rate equation specified earlier in (2). Three restrictions are required by money-growth intermediate targeting: First, the policy response to the unemployment gap is zero, $c_{3,t} = 0$. Second, the difference in the unemployment rate, Δu^k_t, is averaged over the same number of periods as the inflation-rate regressor. Third, the long-run policy responses to the inflation average, π^k_t, and the average of the unemployment-rate-difference proxy, $-a' \Delta u^k_t$, are the same, $c_{2,t}$. The dynamic adjustment of the funds rate is the same as that specified earlier in equation (3).

Time-varying estimates of the policy-rate-response equation implied by money-growth intermediate targeting are presented in Table 4. The Okun's Law coefficient was set based on estimates for the 1970s in Tatom (1978), $a' = 2.2$. Equations in the bottom panel are estimates of the policy-response equation when all three restrictions associated with intermediate targeting of the money growth are imposed. The unemployment gap regressor, $u_{t+k} - \bar{u}_t$, is added to equations in the top panel of Table 4. Similar to the results in section 3, the estimated mean policy responses to the unemployment gap, $\bar{\beta}_3$, are statistically insignificant. In addition, the average difference in the unemployment rate, Δu^k_t, is added to the equations reported in the middle panel of Table 4. These equations also indicate that the mean policy response of the Burns/Miller sample to the difference in the unemployment rate does not differ significantly from the response expected under money-growth intermediate targeting.

Although not shown, the estimated long-run policy responses, $c_{2,t}$, to the nominal-growth proxies, Δx_t, implied by the TVP specifications in the bottom panel of Table 4 move between 0.5 and 0.7 during the 1970s. Thus, the implied long-run responses to inflation are even further below one than those estimated in section 2 for the Burns/Miller sample.

The effective inflation target is estimated to lie between 6.1 and 7.2 percent, and about 6.8 percent on average for the SC specification (Figure 3). Other studies have obtained

comparable results, using a variety of approaches, but limiting analysis to latest available data rather than real-time Greenbook data. In a two-state Markov-switching set-up, Dueker and Fischer (1996) estimated that the implicit inflation target in the 1970s was on the order of 6 percent. To the extent that low frequency movements in inflation reflect the effective inflation target, results are also consistent with those obtained by Cogley and Sargent (2005b), who, in a VAR with drifting coefficients and stochastic volatilities, estimated that "core inflation" in the 1970s was roughly in a range of 5 to 8 percent.

To assess the sensitivity of the estimates of this paper to the choice of measure of the natural real rate of interest, analysis was repeated using an expanding-sample mean to proxy for the natural real rate. With this alternative measure, a somewhat lower range of estimates of the effective inflation target was obtained (4.3 to 4.8 percent, and about 4.5 percent on average).[22] While this alternative range is not as elevated, it remains considerably above 2 percent, the target value typically assumed in constant-target implementations of the Taylor rule.

Finally, differences between the central-bank target for inflation implied by Greenbook forecasts, $\bar{\pi}_t$, and estimates of private-agent perceptions of the central-bank inflation target, $\bar{\pi}_t^p$, are charted in Figure 3. The two thick lines are estimates of $\bar{\pi}_t$ for the Burns/Miller era from 1970Q1 through 1979Q2 (from the bottom panel of Table 4), and for the Volcker/Greenspan sample from 1979Q3 through 1997Q4 (from the top panel of Table 3). The thick dashed line is a concatenation of real-time survey estimates of long-term inflation expectations by private agents.[23] The thin line is an estimate of the evolution of private-sector perceptions of the central-bank target for inflation, $\bar{\pi}_t^p$, from Kozicki and Tinsley (2001).[24]

Figure 3 suggests that at the beginning of the 1970s, the central bank benefited from a private-sector perception $\bar{\pi}_t^p$ that provided a low anchor for inflation expectations relative to the effective target for inflation, $\bar{\pi}_t$. Thus, despite policy actions consistent with an elevated inflation target, the rise in inflation may have been moderated by this anchor. However,

[22] As suggested, the difference between the two ranges is largely accounted for by the difference between real rate estimates. Over the 1970-79 Burns/Miller sample, the mean of the real funds rate in the expanding mean was 1.88 and the mean in the hp filter was 1.10. Changes to the estimated long-run policy response parameter $c_{2,t}$ were smaller with the mean estimate rising from 0.64 when the HP natural-real-rate measure was used to 0.70 with the expanding-mean measure.

[23] Until July 1990, survey estimates are drawn from the Hoey survey of expected inflation in the second five years of a 10-year forecast horizon. The remainder of the series is long-run expected inflation from the Survey of Professional Forecasters, published by the Federal Reserve Bank of Philadelphia.

[24] This estimate is based on multinomial-logit aggregation of alternative changepoint estimators of $\bar{\pi}_t$. Although this estimate of perceived long-run inflation is similar to the survey of long-term expected inflation, survey information was not used in the estimated learning model of private-sector perceptions.

in the absence of improvements in actual inflation (as shown by the central tendency of inflation, represented in the chart by the HP filter of real-time inflation), private-sector perceptions adjusted upward toward inflation and the effective target, and this moderating factor gradually evaporated. In the 1980s, the situation was largely reversed. The effective inflation target was lowered considerably with the change in policy instituted by Chairman Volcker in late 1979 and the early 1980s, but private-sector perceptions remained elevated. At the beginning of the 1990s, the credibility gap between the effective target and the perceived target was about five percentage points, and this gap only slowly closed by the end of the sample.

4.3 Consequences of money growth intermediate targeting

The most striking outcomes of the TVP specifications of policy in the 1970s are the rather high estimates of the central-bank target for inflation, $\bar{\pi}_t$, and the uniformly low estimates of the long-run policy responses, $c_{2,t}$. Intermediate money-growth targeting provides a unified explanation of these two characteristics of policy given the observed shocks in the 1970s.

First, when monetary policy targets the growth rate of the money supply, the effective inflation target is vulnerable to two types of fundamental shocks, both of which occurred in the 1970s. Renormalizing equation (12), the effective central-bank target for inflation under intermediate targeting is defined by

$$\bar{\pi}_t \;=\; \Delta\bar{m}_t - \Delta\bar{y}_t + \Delta\bar{v}_t. \tag{15}$$

Given a target growth rate for the money supply, $\Delta\bar{m}_t$, the effective inflation target is increased if the central bank is unable to detect a reduction in growth of the natural-rate trend of output, $\Delta\bar{y}_t$, or an increase in trend velocity, $\Delta\bar{v}_t$. In fact, both of these shocks were a feature of the policy environment in the 1970s. Growth of the output-natural-rate trend slowed in the late 1960s and early 1970s. Subsequently, due to financial innovations fuelled by higher inflation and deregulation of banking and financial markets, the trend of velocity began a long march of upward shifts in the mid-1970s.

A literature review of estimated shifts in US trend productivity is provided in Bullard and Duffy (2004). Real-time estimates of trend-productivity growth from 1970-2004 are discussed in Edge, Laubach, and Williams (2004), including available historical estimates from the CEA. The latter's estimate of trend productivity fell by about 1.3 percentage points over the 1970s. Real-time errors in the CEA estimates of trend productivity are also used to

support the natural-rate-error interpretation of the 1970s, except money-growth targeting is vulnerable to errors in trend growth rather than the associated cumulative errors in the output gap.

Larger errors were associated with predictions of trend velocity, and these errors are unique to a policy based on money-supply intermediate targeting. In the 1970s, the unpredicted shifts in trend velocity were substantial. The December 12, 1980 Bluebook contains an analysis of money-demand models. Conditioned on retrospective measurements of explanatory variables, the annual underestimate of velocity growth over the last half of the 1970s by the 1980 vintage of the staff model was 1.8 percentage points, including errors of 5.1 percentage points in 1975 and 2.9 percentage points in 1976.[25]

The second unusual characteristic of policy in the 1970s is that the estimated long-run policy response to the money-supply-growth proxy, $c_{2,t}$, remained well below one in the Burns/Miller sample. As shown in Figure 4, FOMC decisions led to flat or modest meeting-to-meeting adjustments of the policy-rate level after 1974, until the large upward adjustments of the policy rate in the initial FOMC meetings chaired by Paul Volcker after October 1979 (not shown).

The passivity of policy through much of the second-half of the 1970s is also illustrated in Figure 5 where the policy rate is plotted against the Greenbook prediction of the four-quarter average of the nominal-growth proxy, $\Delta x_t^1 = \frac{1}{4} \sum_{h=-2}^{1} \Delta x_{t+h}$. Even if velocity had been perfectly predicted, variations of the funds rate did not keep pace with Greenbook predicted movements of nominal growth during most of the 1970s.

Passivity of policy needs to be differentiated from contemporaneous critiques of money-growth targeting in the 1970s that included criticism of the relatively tight FOMC ranges on inter-meeting variations of the policy rate, vid. Poole (1975). Clearly, tight inter-meeting ranges did not prevent sizeable meeting-to-meeting adjustments of the policy rate in 1973-74 and, consequently, are an unlikely source of policy passivity (Figure 4).

Inconsistencies with real-time policy actions and discussions plague other interpretations of the 1970s that attempt to find fault with explicit or implicit constraints on policy rather than with the design of the money-growth targeting policy itself. One interpretation of the 1970s is that the FOMC did not believe it had popular support for large increases in the

[25]Goldfeld (1976) indicates that a representative money-demand model of the early 1970s generates larger prediction errors, with an out-of-sample RMSE of 6.3 percentage points from 1974Q1 to 1975Q2.

policy rate, vid. DeLong (1997) and Meltzer (2005). This explanation is not consistent with policy actions in mid-1974, when the funds rate was driven near 13%, nor with discussion in the FOMC *Memorandum of Discussion*:

> "Chairman Burns said he might offer his appraisal of the existing support for current Federal Reserve policy. He agreed that support in Congress was strong; he had been receiving almost no critical mail from that source. Of the letters that reached his desk from individuals across the country, a majority were still commendatory." (MOD, 6/18/74, p.62).

> "More generally, in his many recent conversations with Congressman he had found widespread acceptance of the need for slow economic growth: they reported their constituents were more anxious about inflation than unemployment." Burns (MOD, 7/16/74, p.34)[26]

Another possible interpretation is that the FOMC may have become disenchanted with intermediate targeting of the monetary aggregates in the mid-1970s. The role of intermediate targets in operational policy was reviewed in the Stage II report of the Subcommittee on the Directive (1976) distributed to FOMC members in early 1976.[27] The initial portion of this report reviewed a staff proposal that the policy instrument, such as the funds rate or nonborrowed reserves, directly target ultimate objectives, such as unemployment and inflation, relegating the money supply to one of many potential indicators of unobserved movements in ultimate objectives. However, the remainder of the report endorsed the two-stage strategy of intermediate targeting with monetary aggregates. FOMC discussion of this report in the 3/15/76 meeting supported a continuation of intermediate targeting:

> "Mr. Wallich added that if optimal control were applied to monetary policy it would tend to focus attention on such ultimate objectives as full employment and price stability. However, he had strongly endorsed the Subcommittee's recommendation that monetary policy continue to focus primarily on intermediate objectives, rather than on ultimate objectives....In further discussion individual members of the Subcommittee

[26]It might be noted that these real-time quotes differ considerably from the retrospective Per Jacobsson Lecture, often cited by policy historians, where Burns (1979) suggests: "As the Federal Reserve, for example, kept testing and probing the limits of its freedom to undernourish the inflation, it repeatedly evoked violent criticism from both the Executive Branch and the Congress."

[27]The Subcommittee was chaired by Governor Holland, with Governor Wallich, President Balles (Federal Reserve Bank of San Francisco), and President Morris (Federal Reserve Bank of Boston) as members.

commented on the reasons why they had not favored directly relating an operational instrument, such as nonborrowed reserves or the federal funds rate, to ultimate objectives. These reasons included the difficulty of linking instrumental variables to ultimate objectives, both intuitively or through use of econometric models; the problem of reaching an agreement on necessary tradeoffs among ultimate objectives; and the complications created by the fact that monetary policy was but one of many influences on the ultimate objectives." (MOD, 3/15/76, p.16)

The FOMC *Memorandum of Discussion* (MOD) suggests several issues that may have contributed to passive policy-rate responses to nominal-growth gaps.

One possibility is that the FOMC may been optimistic about interest rate elasticities, selecting policy rate adjustments that were too small to reverse predicted nominal growth gaps.[28] In particular, two procedures could have led to effective overstatement of interest rate effects:

In framing final voting choices, FOMC members were free to pick policy rates from one Bluebook option and monetary target ranges from another option. The problem of inconsistent choices from an "a-la-carte menu" was occasionally addressed in Bluebook presentations.

"The blue book can be viewed as a menu of consistent targets....The Committee is, of course, free to choose among the various objectives presented, taking due account of the risks being run. There is the risk, for instance, of choosing incompatible objectives. However, this risk has to be weighed against the probability there will be errors in the staff's estimates of relationships likely to prevail among bank reserves, monetary aggregates, and interest rates." Axilrod, FOMC Economist (MOD, 11/20/72, p.43)

A more direct route to optimistic views of interest-rate effects is that projections of interest rates associated with alternative options were judgmentally adjusted by senior staff. Especially after staff models began to overpredict M_1 growth in the mid-1970s, there appear to have been nontrivial downward judgmental adjustments of interest rate changes associated with alternative money-growth paths.

[28]The full system interest rate elasticity of the money supply is necessarily greater than the interest rate elasticity of nominal output if the interest rate elasticity of money demand is also negative.

"(Mr. Partee) believed that (interest) rates would be especially high if the rate of growth in M1 was at the midpoint of the Committee's long-run range....Actually, the econometric model had yielded still higher rates, but the staff believed the model tended to overstate rate increases." (MOD, 8/19/75, p.58)

"Mr. Gramley said there was considerable uncertainty about the projections of interest rates, which were among the most difficult variables to project. As Committee members knew, the staff tended to make rather large judgmental adjustments to the interest rate projections produced by the model. In the latest projection,...the model had produced a short-term interest rate in the fourth quarter of 1976 that was 2-3/4 percentage points above the staff's judgementally projected rate." (MOD, 9/16/75, p.25)

"In view of recent projection errors of the model, the staff had tended to lower the level of interest rates it associated with any assumed rate of monetary growth." Axilrod (MOD, 11/18/75, p.33)

A second interpretation of the effective passivity of policy is that increased uncertainty about properties of empirical money-demand functions after the mid-1970s may have induced more cautious policy adjustments.

"Shortfalls in M1 growth may also reflect a weakening of economic activity relative to staff projections....one option for the Committee to consider is whether it wishes to await somewhat more sustained weakness in M1 before contemplating a policy that permits relatively sizeable interest rate declines." Axilrod, FOMC Associate Economist (MOD, 9/10/74, pp.35)

"In recent years, the Committee had been focusing more on monetary aggregate targets because of the problems it had experienced earlier with interest rate targets. At present there would be less risk associated with a reduction in interest rates than, say, 2 months ago, both because the aggregates had been falling short of the Committee's targets and because the economic outlook had weakened considerably. Even so, the precise consequences of a sharp reduction in interest rates remained unclear. Growth in the aggregates would be stepped up substantially, but it is hard to say by how much; and the effects, over time, that the rate reduction would have on expectations and on spending behavior were highly uncertain. To advocate a prompt, sizeable reduction in rates was to ignore all such uncertainties." Partee, FOMC Senior Economist (MOD, 12/17/74, p.71)

"The actual stock of money has been running well short of what either our quarterly or monthly money market models would have predicted for some time, given actual GNP and interest rates....given uncertainties with respect to the meaning of recent money supply behavior as well as still unresolved issues affecting the municipal market, the committee may wish to consider giving somewhat more weight than usual to money market conditions in framing its instructions." Axilrod, FOMC Economist (MOD, 11/18/75, pp.33-5)

"Mr. Volcker said he felt rather strongly that the right approach to policy today was to hold interest rates fairly steady....Mr. Axilrod's remarks, which he had found stimulating and even persuasive, provided a further indication of how little was known about the short-term relationship between interest rates and the money supply." (MOD, 11/18/75, p. 39)

"Mr. Axilrod said he felt highly uncertain about the current projection. In particular, he was not sure whether the demand for money would keep shifting down, stabilize, or shift back up." (MOD, 3/16/76, p. 60)

"(A)n additional element of uncertainty was introduced by the disparity between the projections made by the New York staff and those made by the Board staff for the coming period–with the former showing stronger growth, particularly for M1. Against that background, this did not seem to him to be an appropriate time for a major change in policy.....Turning to the specifications for the Federal funds rate, he favored maintaining the present range and keeping the rate at about its current 4-3/4 per cent level." Volcker (MOD, 3/16/76, pp. 63-4)

Finally, a third conjecture concerning the framing of policy choices is that differences in the underlying relationships and forecast horizons of the short-run policy options of the Bluebook and of the multiperiod predictions of the Greenbook may have made it difficult for FOMC deliberations to connect current policy decisions to longer-run predicted outcomes.[29]

[29]Judgemental adjustments of interest rates associated with alternative policy options, discussed earlier, were motivated not only by money-demand forecast errors in the 1970s but also by differences among competing staff models, such as the monthly money-market model used in Bluebook analyses and quarterly models used for Greenbook analyses. "Mr. Gramley replied that the staff's interest rate projections depended on the relationship between growth in money and growth in nominal GNP. Personal income was used only in the monthly model, because no better monthly indicators of aggregate expenditures was available....Mr. Axilrod remarked that recent work done by the Board's staff indicated that in the first year of recovery interest-rate projections based on nominal GNP were too high while those based on personal income were too low. In making its interest-rate projections for the blue book, the staff had taken those results into account." (MOD, 9/16/75, pp. 32-3) As noted earlier, it is not historically accurate to assume that all judgemental forecast

"Mr. MacLaury remarked that he was disturbed by what he perceived as a lack of clarity in the Committee's methodology. While the Committee now was publicly announcing its longer-term targets, he has less confidence than before in his understanding of the path by which these objectives were to be achieved....it seemed strange for the blue book to state that all of the three alternatives it presented were generally consistent with the 12-month ranges. He believed it made a difference whether the Committee embarked on the path indicated by the high alternative or on that indicated by the low alternative." (MOD, 5/20/75, p.59)

5. Concluding remarks

Recent studies, including Kozicki and Tinsley (2005), indicate that dynamic properties of empirical macro models are often more realistic if allowance is made for differences in perceptions among private and public agents regarding the central-bank target for inflation. The current paper provides estimates of the target for inflation implied by empirical policy response functions, where the real-time conditioning information is based on Greenbook briefing forecasts presented before FOMC meetings from the 1970s through the mid-1990s.

In contrast to the assumption of a fixed inflation target, the inflation-target constructions not only vary considerably over time but are substantially different from available survey information on the long-horizon inflation expectations of private-sector agents.

Regarding the conjecture that U.S. inflation in the 1970s is due largely to central-bank overestimation of potential output or, equivalently, underestimation of the natural rate of unemployment, there is little evidence that policy responses in the 1970s were directed at central-bank perceptions of expected levels of the unemployment rate and the natural rate of unemployment.

Of two leading empirical interpretations of the Great Inflation, the *passive-policy* description is perhaps the most optimistic, as empirical analyses of historical U.S. monetary policy generally indicate stable policy responses have been maintained since the 1980s. The *natural-rate-error* description has a seductive appeal for central banks for it suggests that unlucky mistakes were made, but carries also the pessimistic inference that these mistakes will likely occur in the future. The empirical evidence presented in section 4 indicates that

adjustments were confined to intercept adjustments. Kalchbrenner and Tinsley (1977) discuss differences between policy use of auxiliary measurements and use of competing models.

monetary policy in the 1970s is better represented by money-growth intermediate targeting. This implies that U.S. central-bank errors in estimating natural-rate gaps for output or the unemployment rate are largely irrelevant to explanations of the Great Inflation.

The empirical evidence in section 4 also supports the passive-policy interpretation, as adjustments of the central-bank policy rate in the 1970s were not sufficiently vigorous to result in stable responses to movements in inflation. However, the passive-policy interpretation is merely a description of unstable policy, not an explanation. A description of the Great Inflation based on intermediate targeting of money-supply growth offers a neglected search area for explanations of passive-policy responses.

Given the advantage of hindsight, there will always be mistakes in the execution of monetary policy, including errors in estimating current values of conditional equilibria or natural rates. Perhaps the deeper flaw of intermediate targeting in the 1970s is that it obscured the ultimate objectives of policy by shifting the official gauge of policy performance from inflation and economic activity to the growth rate of the money supply. Empirical results in this paper support the assessment of Milton Friedman (2006): "The use of the quantity of money as a target has not been a success."

References

Arrow, K., 1951. *Social Choice and Individual Values.* New York: John Wiley and Sons.

Batini, N. and J. Pearlman, 2002. "Too Much Too Soon: Instability and Indeterminacy with Forward-Looking Rules." Bank of England, External MPC Unit Discussion Paper Number 8, July.

Beyer, A. and R. Farmer, 2004. "On the Indeterminacy of New-Keynesian Economics." European Central Bank working paper 323, March.

Bullard, J. and J. Duffy, 2004. "Learning and Structural Change in Macroeconomic Data." Federal Reserve Bank of St. Louis working paper 2004-016A, August.

Burns, A., 1979. "The Anguish of Central Banking." Reprinted in *Federal Reserve Bulletin*, September, 1987, 687-98.

Clarida, R., J. Gali, and M. Gertler, 2000. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *Quarterly Journal of Economics*, February, 147-80.

Cogley, T. and T. Sargent. 2005a. "The Conquest of U.S. Inflation: Learning and Robustness to Model Uncertainty." *Review of Economic Dynamics*, 8(2), April, 528-63.

Cogley, T. and T. Sargent, 2005b. "Drifts and Volatilities: Monetary Policies and Outcomes in the Post WWII US." *Review of Economic Dynamics*, 8(2), April, 262-302.

Collard,F. and H. Dellas, 2004. "The Great Inflation of the 1970s." European Central Bank working paper 336, April.

Congressional Budget Office. 2004. *The Budget and Economic Outlook: Fiscal Years 2005-2014.*

DeLong, B., 1997. "America's Only Peacetime Inflation: The 1970s," in C. Romer and D. Romer (eds.) *Reducing Inflation: Motivation and Strategy.* Chicago: Chicago University Press.

Edge, R., T. Laubach, and J. Williams, 2004, "Learning and Shifts in Long-Run Productivity Growth," Federal Reserve Board Finance and Economics Discussion Series No. 2004-21.

Enzler, J. and J. Pierce, 1974. "The Effects of Inflationary Shocks." *Brookings Papers on Economic Activity,* 1, 13-54.

FOMC. "Monetary Aggregates and Money Market Conditions," or after October 1980 "Monetary Policy Alternatives." FOMC Secretariat Bluebook, selected issues.

FOMC. "Summary and Outlook." FOMC Secretariat, Greenbook, selected issues.

FOMC. "Memorandum of Discussion." FOMC Secretariat, selected issues

FOMC Subcommittee on the Directive. 1976. *Interim Staff Report: Stage II for the Subcommittee on the Directive.* FOMC Secretariat.

Friedman, M., 1960. *A Program for Monetary Stability.* New York: Fordham University Press.

Friedman, M., 2003. "Lunch with the FT," *Financial Times.* June 6.

Friedman, B.M., 1977. "Empirical Issues in Monetary Policy: A Review of Monetary Aggregates and Monetary Policy." *Journal of Monetary Economics*, 3(1), 87-101.

Froyen, R. and R. Waud, 2002. "The Determinants of Federal Reserve Policy Actions: A Re-examination." *Journal of Macroeconomics*, 24(3), September, 413-28.

Goldfeld, S., 1976. "The Case of Missing Money." *Brookings Papers on Economic Activity,* 76(3), 683-730.

Hansen, B., 1997. "Approximate Asymptotic P Values for Structural-Change Tests." *Journal of Business & Economic Statistics*, 15(1), January, 60-7.

Judd, J. and G. Rudebusch, 1998. "Taylor's Rule and the Fed: 1970-1997." *Economic Review*, Federal Reserve Bank of San Francisco, 3, 3-16.

Kalchbrenner, J. and P. Tinsley. 1977. "On Filtering Auxiliary Information in Short-Run Monetary Policy." *Carnegie-Rochester Conference Series on Public Policy (Journal of Monetary Economics supplement)*, 7, 39-84.

Kozicki, S., 2004. "How Do Data Revisions Affect the Evolution and Conduct of Monetary Policy?" *Federal Reserve Bank of Kansas City Economic Review,* 89, First Quarter, 5-38.

Kozicki, S. and P. Tinsley, 2001. "Term Structure Views of Monetary Policy under Alternative Models of Agent Expectations." *Journal of Economic Dynamics & Control*, January, 149-84.

Kozicki, S. and P. Tinsley, 2005, "Permanent and Transitory Policy Shocks in an Empirical Model with Asymmetric Information." *Journal of Economic Dynamics & Control*, 29, 1985-2015.

Kozicki, S. and P. Tinsley, 2006a. "Minding the Gap: Central Bank Estimates of the Unemployment Natural Rate." *Computational Economics*, 27, 295-327..

Kozicki, S. and P. Tinsley, 2006b, "Survey-based Estimates of the Term Structure of Expected U.S. Inflation," Bank of Canada Working Paper.

Lansing, K., 2002. "Real-Time Estimation of Trend Output and the Illusion of Interest Rate Smoothing," *Economic Review*, Federal Reserve Bank of San Francisco, 17-34.

Meltzer, A., 2005. "Origins of the Great Inflation." *Review*, Federal Reserve Bank of St. Louis, March/April, part 2, 145-76.

Nelson, E., 2005. "The Great Inflation of the Seventies: What Really Happened?" *Advances in Macroeconomics*, 5(1). [http://www.bepress.com/bejm/advances/vol5/iss1/art3]

Orphanides, A., 2002, "Monetary Policy Rules and the Great Inflation." *American Economic Review*, 92(2), May, 115-120.

Orphanides, O., 2003a. "The Quest for Prosperity Without Inflation." *Journal of Monetary Economics,* 50, 633-63.

Orphanides, O., 2003b. "Historical Monetary Policy Analysis and the Taylor Rule." *Journal of Monetary Economics,* 50, 983-1022.

Orphanides, O., 2004. "Monetary Policy Rules, Macroeconomic Stability and Inflation: A View from the Trenches." *Journal of Money, Credit and Banking*, 36, April, 151-75.

Poole, W., 1975. "Monetary Policy During the Recession." *Brookings Papers on Economic Activity,*, 1, 123-39.

Raven, M. and H. Uhlig, 2002. "On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations." *The Review of Economics and Statistics*, 84(2), May, 371-5.

Romer, C. and D. Romer, 2002. "The Evolution of Economic Understanding and Postwar Stabilization Policy." NBER working paper 9274, October.

Shumway, R. and D. Stoffer, 2000. *Time Series Analysis and Its Applications.* New York: Springer-Verlag.

Sargent, T., 1999. *The Conquest of American Inflation.* Princeton: Princeton University Press.

Sargent, T., N. Williams, and T. Zha, 2004. "Shocks and Government Beliefs: The Rise and Fall of American Inflation." NBER working paper 10764, September.

Stock, J. and M. Watson, 1998. "Median Unbiased Estimation of Coefficient Variance in a Time-Varying Parameter Model." *Journal of the American Statistical Association*, 93(441), March, 349-58.

Svensson, L. and R. Tetlow. 2005. "Optimal Policy Projections" *International Journal of Central Banking,* December 1(3), 177-207.

Swamy, P. and P. Tinsley, 1980. "Linear Prediction and Estimation Methods for Regression Models with Stationary Stochastic Coefficients." *Journal of Econometrics*, February, 108-42.

Tatom, J., 1978. "Economic Growth and Unemployment: A Reappraisal of the Conventional View." *Review,* Federal Reserve Bank of St. Louis, October, 16-22.

Taylor, J. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy (Journal of Monetary Economics supplement),* 39, 195-214.

Taylor, J., 1999. "A Historical Analysis of Monetary Policy Rules." in J. Taylor (ed.) *Monetary Policy Rules.* Chicago: University of Chicago Press, 319-41.

Tinsley, P., P. von zur Muehlen, and G. Fries, 1982. "The Short-Run Volatility of Money Stock Targeting." *Journal of Monetary Economics*, 215-37.

Velde, F. 2004. "Poor Hand or Poor Play? The Rise and Fall of Inflation in the U.S." *Economic Perspectives*, Federal Reserve Bank of Chicago, Q1, 34-51.

Woodford, M., 2003. *Interest and Prices.* Princeton, N.J.: Princeton University Press.

Table 1: Alternative estimates of unemployment natural rates (%)

policy regime	natural rate source			
	CBO (2004)	Romer & Romer (2002)	$\bar{u}_t^{b}$ [1]	$\bar{u}_t$ [2]
Burns_1 70Q1-75Q2	6.0	3.1	3.9	5.2
Burns_2 75Q3-78Q1	6.2	8.2	4.3	5.3
Miller 78Q2-79Q2	6.3	4.6	4.3	5.3
Volcker 79Q3-87Q2	6.1	8.0	5.4	5.6
Greenspan_1 87Q3-96Q4	5.7	6.7	5.7	6.2
Greenspan_2 96Q1-97Q4	5.2	n.a.	5.0	5.6

1. Implied by a Phillips equation with backward-looking inflation expectations, using Greenbook forecasts of inflation and unemployment, Kozicki & Tinsley (2005).
2. Implied by a Phillips equation with both backward- and forward-looking inflation expectations, using Greenbook forecasts, vid. Kozicki and Tinsley (2005).

Table 2: Federal-Funds-Rate Policy Rule Burns/Miller sample [1]

$$
\begin{aligned}
r_t^* &= \bar{\rho}_t + \bar{\pi}_t + c_{2,t}(\pi_t^k - \bar{\pi}_t) + c_{3,t}(u_{t+1} - \bar{u}_t) + c_{4,t}\Delta u_t, \\
r_t &= (1-\beta_{6,t})r_t^* + \beta_{5,t}\Delta r_{t-1} + \beta_{6,t} r_{t-1} + a_t, \\
&= \beta_{1,t} + \beta_{2,t}\pi_t^k + \beta_{3,t}(u_{t+1} - \bar{u}_t) + \beta_{4,t}\Delta u_t + \beta_{5,t}\Delta r_{t-1} + \beta_{6,t}(r_{t-1} - \bar{\rho}_t) + \bar{\rho}_t + a_t, \\
\bar{\pi}_t &= -\beta_{1,t}/(\beta_{2,t} + \beta_{6,t} - 1).
\end{aligned}
$$

tvp format		estimated $\bar{\beta}_i$ [2]						estimated $\bar{\pi}_t$	
		β_1	β_2	β_3	β_4	β_5	β_6	min	max
RWI	mean coeff	.025	.116	-.067	-.229	.532	.893	-3.7	-0.1
	p-value	[.60]	[.01]	[.09]	[.03]	[.00]	[.00]		
SC	mean coeff	.017	.120	-.066	-.242	.523	.891	-9.0	1.1
	p-value	[.90]	[.01]	[.11]	[.03]	[.00]	[.00]		
	(var decomp %)	17	42	1	0	0	40		
RWI	mean coeff	.148	.076	-.057		.604	.908	6.1	10.7
	p-value	[.00]	[.07]	[.20]		[.00]	[.00]		
SC	mean coeff	.111	.081	-.048		.606	.908	8.2	15.6
	p-value	[.41]	[.06]	[.24]		[.00]	[.00]		
	(var decomp %)	23	37	1		0	38		
RWI	mean coeff	.049	.073		-.208	.551	.920	6.5	9.7
	p-value	[.31]	[.04]		[.04]	[.00]	[.00]		
SC	mean coeff	.045	.075		-.209	.545	.920	6.7	14.8
	p-value	[.74]	[.04]		[.05]	[.00]	[.00]		
	(var decomp %)	19	38		0	0	42		

1. sample 1970Q1-1979Q2; $r-$ average federal funds rate in FOMC meeting-to-meeting intervals; π^k - GB annualized inflation forecasts, averaged over the forecast periods, h = -2, -1, 0,1; k =1.
2. [.] - p-values; $\bar{\beta}_i-$ sample average of $\beta_{i,t}$ for random walk specifications.

Table 3: Federal-Funds-Rate Policy Rule Volcker/Greenspan sample [1]

$$
\begin{aligned}
r_t^* &= \bar{\rho}_t + \bar{\pi}_t + c_{2,t}(\pi_t^k - \bar{\pi}_t) + c_{3,t}(u_{t+k} - \bar{u}_t) + c_{4,t}\Delta u_t, \\
r_t &= (1-\beta_{6,t})r_t^* + \beta_{5,t}\Delta r_{t-1} + \beta_{6,t} r_{t-1} + a_t, \\
&= \beta_{1,t} + \beta_{2,t}\pi_t^k + \beta_{3,t}(u_{t+k} - \bar{u}_t) + \beta_{4,t}\Delta u_t + \beta_{5,t}\Delta r_{t-1} + \beta_{6,t}(r_{t-1} - \bar{\rho}_t) + \bar{\rho}_t + a_t, \\
\bar{\pi}_t &= -\beta_{1,t}/(\beta_{2,t} + \beta_{6,t} - 1).
\end{aligned}
$$

tvp format		estimated $\bar{\beta}_i$ [2]						estimated $\bar{\pi}_t$	
		π^k - GB forecast average, h = -2, -1, 0,1; k = 1.							
		$\bar{\beta}_1$	$\bar{\beta}_2$	$\bar{\beta}_3$	$\bar{\beta}_4$	$\bar{\beta}_5$	$\bar{\beta}_6$	min	max
RWI	mean coeff	-.159	.222	-.073	-.296	.364	.833	2.2	3.5
	p-value	[.05]	[.00]	[.01]	[.01]	[.00]	[.00]		
SC	mean coeff	-.154	.229	-.066	-.286	.406	.819	3.1	3.4
	p-value	[.20]	[.02]	[.03]	[.09]	[.00]	[.00]		
	(var decomp %)	5	58	0	0	0	37		
		π^k - GB forecast average, h = 0,1,2,3; k = 3.							
		$\bar{\beta}_1$	$\bar{\beta}_2$	$\bar{\beta}_3$	$\bar{\beta}_4$	$\bar{\beta}_5$	$\bar{\beta}_6$	max	min
RWI	mean coeff	-.205	.214	-.050	-.237	.361	.845	2.7	4.0
	p-value	[.02]	[.00]	[.08]	[.04]	[.00]	[.00]		
SC	mean coeff	-.149	.194	-.049	-.273	.371	.846	3.5	4.0
	p-value	[.19]	[.00]	[.06]	[.03]	[.00]	[.00]		
	(var decomp %)	14	37	1	0	0	48		

1. sample 1979Q3-1997Q4; $r-$ average federal funds rate in FOMC meeting-to-meeting intervals; $\bar{u}_t-$ TVP average expectations.
2. [.] - p-values; $\bar{\beta}_i-$ sample average of $\beta_{i,t}$ for random walk specifications.

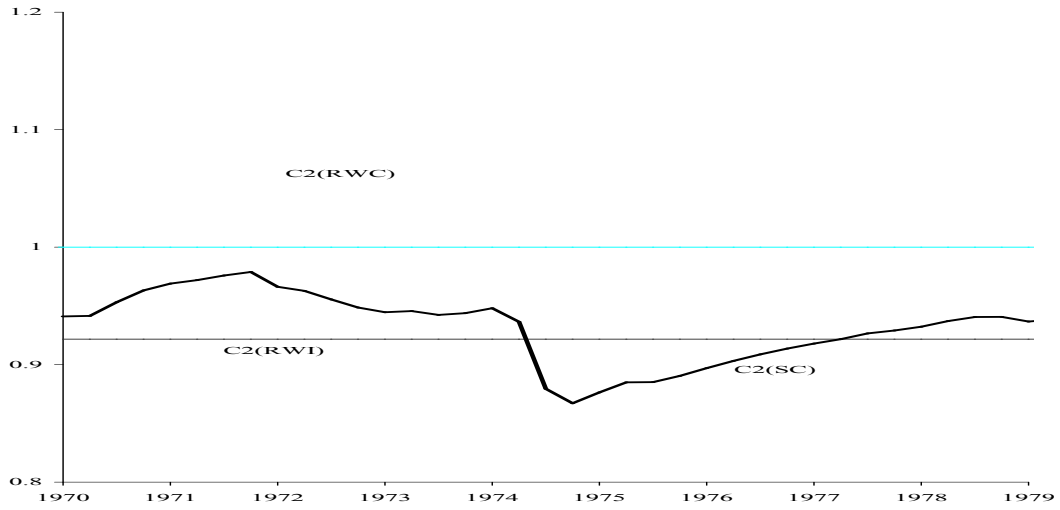
Table 4: Federal-Funds-Rate Policy Rule Burns/Miller sample: money growth targeting [1]

$$
\begin{aligned}
r_t^* &= \bar{\rho}_t + \bar{\pi}_t + c_{2,t}(\Delta x_t^k - \Delta \bar{x}_t) + c_{3,t}(u_{t+1} - \bar{u}_t) + c_{4,t}\Delta u_t^k, \\
\Delta x_t^k - \Delta \bar{x}_t &= \pi_t^k - \bar{\pi}_t - a'\Delta u_t^k, \\
r_t &= (1-\beta_{6,t})r_t^* + \beta_{5,t}\Delta r_{t-1} + \beta_{6,t} r_{t-1} + a_t, \\
&= \beta_{1,t} + \beta_{2,t}\Delta x_t^k + \beta_{3,t}(u_{t+k} - \bar{u}_t) + \beta_{4,t}\Delta u_t^k + \beta_{5,t}\Delta r_{t-1} + \beta_{6,t}(r_{t-1} - \bar{\rho}_t) + \bar{\rho}_t + a_t, \\
\bar{\pi}_t &= -\beta_{1,t}/(\beta_{2,t} + \beta_{6,t} - 1).
\end{aligned}
$$

tvp format		estimated $\bar{\beta}_i$ [2]						estimated $\bar{\pi}_t$	
		$\bar{\beta}_1$	$\bar{\beta}_2$	$\bar{\beta}_3$	$\bar{\beta}_4$	$\bar{\beta}_5$	$\bar{\beta}_6$	min	max
RWI	mean coeff	.156	.037	-.008		.518	.942	6.3	7.5
	p-value	[.00]	[.03]	[.80]		[.00]	[.00]		
SC	mean coeff	.149	.040	-.009		.509	.940	6.8	7.8
	p-value	[.21]	[.02]	[.78]		[.00]	[.00]		
	(var decomp %)	30	11	2		0	56		
RWI	mean coeff	.024	.093		.114	.557	.906	9.4	27.1
	p-value	[.61]	[.02]		[.12]	[.00]	[.00]		
SC	mean coeff	.037	.092		.114	.545	.904	7.4	118
	p-value	[.78]	[.02]		[.13]	[.00]	[.00]		
	(var decomp %)	16	33		0	0	51		
RWI	mean coeff	.146	.037			.523	.941	6.1	7.1
	p-value	[.00]	[.03]			[.00]	[.00]		
SC	mean coeff	.142	.038			.515	.940	6.5	7.2
	p-value	[.21]	[.02]			[.00]	[.00]		
	(var decomp %)	32	10			0	58		

1. sample 1970Q1-1979Q2; $r-$ average federal funds rate in FOMC meeting-to-meeting intervals; $\pi^k, \Delta u^k$ - GB annualized forecasts, averaged over the forecast periods, $h = -2, -1, 0, 1; k = 1$.
2. [.] - p-values; $\bar{\beta}_i-$ sample average of $\beta_{i,t}$ for random walk specifications.

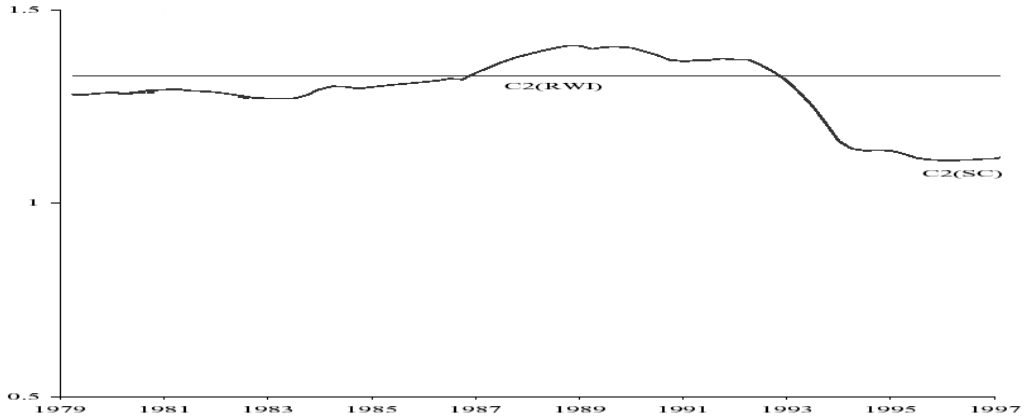
Figure 1
Long-run policy response to inflation, Burns/Miller tenures [1]



(i) Coefficients from specifications in the bottom panel of Table 2.
C2(RWI) – $c_{2,t}$ from random-walk-intercept specification, RWI.
C2(SC) – $c_{2,t}$ from stationary-coefficients specification, SC.

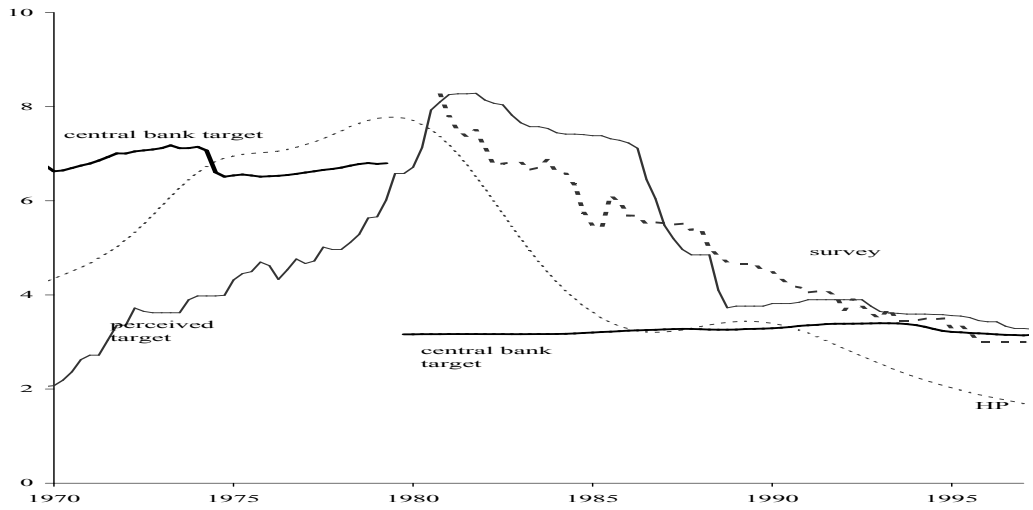
Figure 2

Long-run policy response to inflation, Volcker/Greenspan tenures [1]



1. Coefficients from specifications in the top panel of Table 3.
   C2(RWI) – $c_{2,t}$ from random walk intercept specification, RWI.
   C2(SC) – $c_{2,t}$ from stationary coefficients specification, SC.

Figure 3
Historical and perceived inflation targets, 1970-1997 [1]



(i) Central-bank target implied by SC specification: bottom panel of Table 4 for Burns/Miller sample and top panel of Table 3 for Volker/Greenspan sample.
Perceived target – private-sector perception from Kozicki and Tinsley (2001).
Survey – Hoey survey of 5-10 year expected inflation (see text).
HP – HP filter of real-time inflation.

Figure 4
Federal funds rate and FOMC tolerance ranges, Burns/Miller tenures [1]

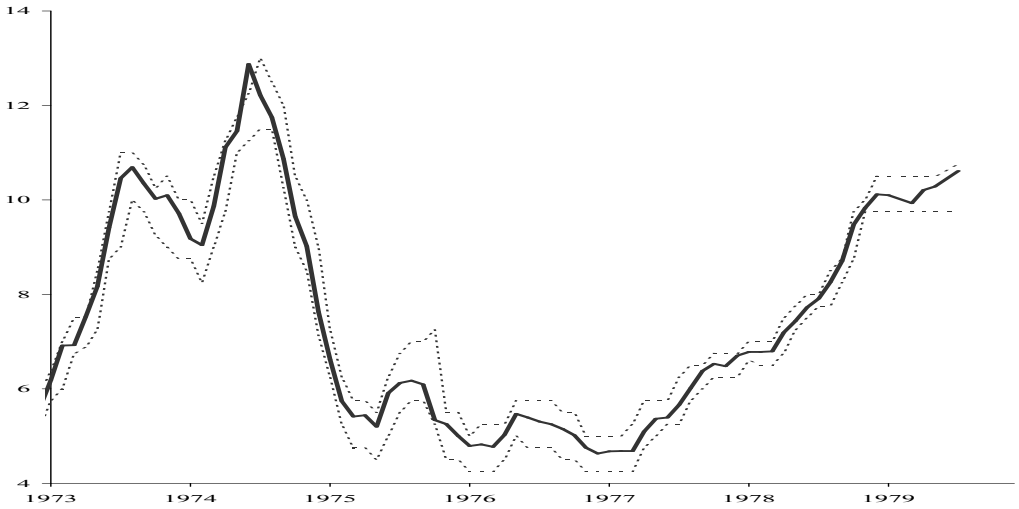
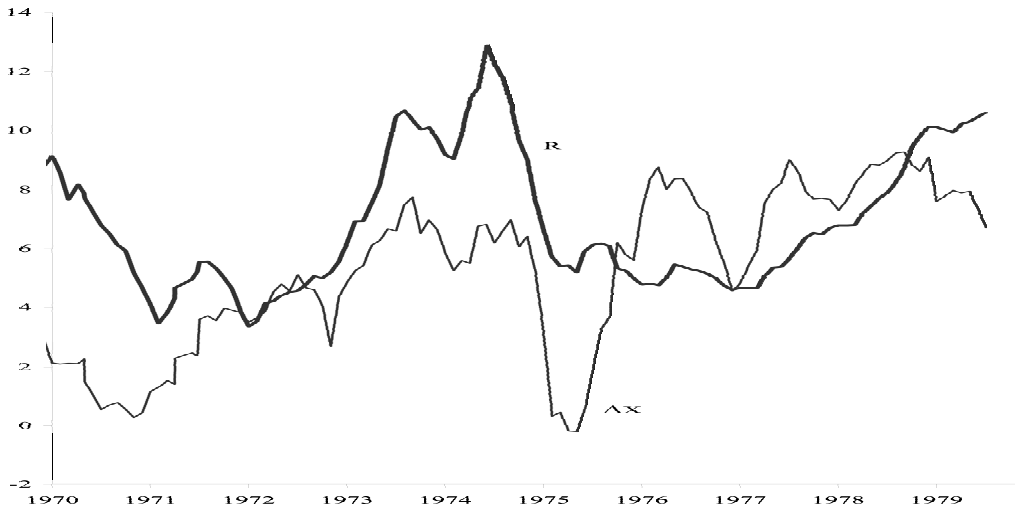


Figure 5
Federal funds rate and the predicted nominal growth proxy, Burns/Miller tenures [1]



(i) R - Federal funds rate; ΔX - 4-qtr avg of the predicted nominal growth proxy, using Greenbook estimates for forecast periods, $h = -2, -1, 0, 1$; (see text).

Appendix A: Kozicki and Tinsley (2006a) Estimates of the Greenbook Perception of the Natural Rate of Unemployment

The natural rate of unemployment, $\bar{u}_t$, is drawn from Kozicki and Tinsley (2006a). The methodology is a generalization of the approach taken by Romer and Romer (2002), who solve for $\bar{u}_t$ from the following constant-coefficient restricted version of a backward-looking Phillips curve:

$$\Delta\pi_t + \Delta\pi_{t+1} + \Delta\pi_{t+2} = -0.125 \sum_{h=0}^{2} (u_{t+h} - \bar{u}_t). \tag{A1}$$

By contrast, in Kozicki and Tinsley, the basic structural model of inflation is the forward-looking Phillips curve:

$$\pi_{t+h} = E_t \pi_{t+h+1} + b_{2,t}(u_{t+h} - \bar{u}_t). \tag{A2}$$

The preferred specification smooths the measure of unemployment by taking a time-varying weighted average of u_{t+h} and u_{t+h+1} and uses a hybrid mixture of forward-and backward-looking terms for expected inflation. The estimated pricing equation is:

$$\begin{aligned} \pi_{t+h} &= b_{1,t} + b_{2,t} u_{t+h} + b_{3,t} \Delta\pi_{t+h-1} + b_{4,t} \Delta u_{t+h+1} \\ &\quad + b_{5,t}(\pi_{t+h+1} - \pi_{t+h-1}) + \pi_{t+h-1} + a_{t+h} \end{aligned} \tag{A3}$$

with the time-varying natural rate of unemployment estimated as:

$$\bar{u}_t = -b_{1,t}/b_{2,t}. \tag{A4}$$

The alternative specification is a variation of the backward-looking equation implicit in (A1) with an estimated slope on the unemployment rate. Also, the lagged inflation-rate

prediction of expected inflation is replaced with a time-varying AR(2) process, $E_t\pi_{t+h+1} = (1 + b_{3,t})\pi_{t+h-1} - b_{3,t}\pi_{t+h-2}$:

$$\pi_{t+h} = b_{1,t} + b_{2,t}u_{t+h} + b_{3,t}\Delta\pi_{t+h-1} + \pi_{t+h-1} + a_{t+h} \quad \text{(A5)}$$

and, as before, the time-varying natural rate of unemployment is estimated as:

$$\bar{u}_t = -b_{1,t}/b_{2,t}. \quad \text{(A6)}$$

Data is taken from Greenbooks, with t indexing the quarter of the Greenbook. Estimation takes advantage of the multiperiod forecasts in each Greenbook by using observations for multiple values of h per Greenbook. In addition, each quarter contains observations from more than a single Greenbook. Kozicki and Tinsley describe the approaches taken to deal with computational challenges such as variations in the number of Greenbooks per year, differing forecast horizons per Greenbook, and the influence of judgmental add-factors on near-term forecasts.

Estimation of TVP specifications proceeds similar to the description in section 2.3. For additional details, including alternative TVP specifications and other variations of the accelerationist Phillips curve, see the discussion in Kozicki and Tinsley (2006a).