Optimal Policy Projections*

Lars E.O. Svensson[a] and Robert J. Tetlow[b]
[a]Princeton University
[b]Federal Reserve Board

We outline a method to provide advice on optimal monetary policy while taking policymakers' judgment into account. The method constructs optimal policy projections (OPPs) by extracting the judgment terms that allow a model, such as the Federal Reserve Board staff economic model, FRB/US, to reproduce a forecast, such as the Greenbook forecast. Given an intertemporal loss function that represents monetary policy objectives, OPPs are the projections—of target variables, instruments, and other variables of interest—that minimize that loss function for given judgment terms. The method is illustrated by revisiting the economy of early 1997 as seen in the Greenbook forecasts of February 1997 and November 1999. In both cases, we use the vintage of the FRB/US model that was in place at that time. These two particular forecasts were chosen, in part, because they were at the beginning and the peak, respectively, of the late 1990s boom period. As such, they differ markedly in their implied judgments of the state of the world in 1997 and our OPPs illustrate this difference. For a conventional loss function, our OPPs provide significantly better performance than Taylor-rule simulations.

JEL Codes: E52, E58.

*We thank Brian Madigan, Dave Reifschneider, John Roberts, Dave Small, Peter Tinsley, and participants in a seminar at the Federal Reserve Bank of New York for helpful suggestions, and Brian Ironside for research assistance. All remaining errors are ours. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or the views of any other person associated with the Federal Reserve System. Author contact: Svensson: www.princeton.edu/∼svensson. Tetlow: www.roberttetlow.com.

> Policy . . . depends on forecasts of probabilities developed from large macromodels, numerous submodels, and judgments based on less mathematically precise regimens. Such judgments, by their nature, are based on bits and pieces of history that cannot formally be associated with an analysis of variance. Yet there is information in those bits and pieces. (Greenspan 2004, 39)

There has long been a gulf between *advice* on monetary policy conduct, as gleaned from the academic literature, and the *practice* of monetary policy, as captured, for example, in the historical record of the U.S. Federal Reserve System. Academic treatments of monetary policy have tended to stress commitment to fixed monetary policy rules and the forbearance of discretion. To many academics, the conduct of monetary policy is, or should be, a largely mechanical exercise. Descriptions of the practice of monetary policy, on the other hand, have focused on the accumulation of experience by policymakers and the application of judgment based on that experience, as the above quotation from the Chairman of the Board of Governors of the Federal Reserve System attests. Meaningful dialogue between the two camps has been hindered in the past by the absence of a structure within which the application of judgment can be applied.

The Federal Reserve staff recently began reporting to the Federal Reserve Board and the Federal Open Market Committee (FOMC) what we will call optimal policy projections (OPPs) (although they were not referred to by that name by the Federal Reserve staff).[1] The method of OPPs is a method to present options on optimal monetary policy while taking into account the judgment of policymakers or, as in the case of the Federal Reserve Board, that of the staff. It was implemented in June 2001 by Robert Tetlow using a mostly backward-looking variant of the Federal Reserve Board's FRB/US

[1] The staff of the Federal Reserve Board prepare for members of the FOMC an official Greenbook forecast (with a green cover) for each of the eight FOMC meetings per year. It also contains analysis of recent incoming data, an assessment of the state of the economy, and some alternative scenarios. Alongside the Greenbook, FOMC members receive the Bluebook (with a blue cover), which adds some analysis of financial and money market conditions and detailed policy alternatives based in large part on the Greenbook forecast. The Greenbooks and Bluebooks of the most recent five years are kept confidential by the Federal Reserve. In this paper, we will be using Greenbook baselines from prior to the five-year window to demonstrate the efficacy of OPPs.

model, although explorations of methods of this nature using other large-scale models at the Board go back to the 1970s.[2] The procedure has subsequently been extended to versions of the FRB/US model incorporating rational expectations in asset pricing. This paper explains OPPs in terms of a generalization of the linear-quadratic model of optimal policy with judgment and forward-looking variables laid out in Svensson (2003) and (2005). It also demonstrates the feasibility of using OPPs to help inform policymaking under the real-world conditions faced by the Federal Reserve. We examine policy options in early 1997 when the U.S. economy appeared to be reaching capacity. We do this using two vintages of the FRB/US model and two Greenbook baselines: the February 1997 Greenbook, when the state of the world was unclear, and again with the November 1999 vintage and database, when there was a bit more clarity with the benefit of hindsight.[3] Unbeknownst to the Board's staff at the time, the economy in 1997 was in the early stages of a productivity boom, a fact that was evident by 1999. Examining these two baselines and the models that were used at the time allows us to isolate the influence of judgment on the OPP.

The remainder of the paper proceeds as follows. Following this introduction, section 1 lays out the method of OPPs. Section 2 provides a real-world example. Section 3 offers some concluding remarks.

1. The Method of Optimal Policy Projections

1.1 A Model of the Policy Problem with Judgment

The method of OPPs is for simplicity illustrated in a linear model (FRB/US is a near-linear model). Consider the following linear model of an economy, in a form that includes a role of judgment and allows for both backward- and forward-looking elements,

$$\begin{bmatrix} X_{t+1} \\ Cx_{t+1|t} \end{bmatrix} = A \begin{bmatrix} X_t \\ x_t \end{bmatrix} + Bi_t + \begin{bmatrix} z_{1,t+1} \\ z_{2,t} \end{bmatrix}. \tag{1}$$

[2]The early Federal Reserve work was pioneered by Peter Tinsley. See, in particular, Kalchbrenner and Tinsley (1976).

[3]Under the Federal Reserve's information-security rules, the November 1999 Greenbook was the most recent one that was available to the public at the time section 2 of this paper was prepared. The February 1997 forecast is extended beyond the regular Greenbook range in a manner to be described.

Here, X_t is an n_X-vector of *predetermined* variables in period t; x_t is an n_x-vector of *forward-looking* variables; i_t is an n_i-vector of *instruments* (the forward-looking variables and the instruments are the *nonpredetermined* variables); z_{1t} and z_{2t} are exogenous n_X- and n_x-vector stochastic processes, respectively; $z_t \equiv (z'_{1t}, z'_{2t})'$ is called the *deviation* in period t ($'$ denotes the transpose); A, B, and C are matrices of the appropriate dimension; and $y_{t+\tau|t}$ denotes $\mathrm{E}_t y_{t+\tau}$ for any variable y_t, the rational expectation of $y_{t+\tau}$ conditional on information available in period t. The variables can be measured as differences from steady-state values, in which case their unconditional means are zero. Alternatively, one of the components of X_t can be unity, so as to allow the variables to have nonzero means.

The standard case of this problem is when $z_{2,t} \equiv 0$ and $z_{1,t}$ is a vector of iid zero-mean shocks. The new element here is that z_t, the deviation, is an arbitrary exogenous stochastic process. As discussed in more detail in Svensson (2005), the deviation represents the difference between the model outcomes and the actual realizations of data and includes all extra-model explanations of the actual data. Below, the central bank's *judgment* will be represented as the central bank's projections of the future deviations. This allows us to incorporate the fact that a considerable amount of judgment is always applied to assumptions and projections. Projections and monetary policy decisions cannot rely on models and simple observable data alone. All models are drastic simplifications of the economy, and data give a very imperfect view of the state of the economy. Therefore, judgmental adjustments in both the use of models and the interpretation of their results—adjustments due to information, knowledge, and views outside the scope of any particular model—are a necessary and essential component in modern monetary policy. The only restriction we shall impose below on the stochastic process of the deviation is that the expected deviation is constant (and, without loss of generality, zero) beyond a particular horizon.

The upper block of (1) provides n_X equations determining the n_X-vector X_{t+1} in period $t+1$ for given X_t, x_t, i_t, and $z_{1,t+1}$,

$$X_{t+1} = A_{11}X_t + A_{12}x_t + B_1 i_t + z_{1,t+1},$$

where A and B are decomposed according to

$$A \equiv \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}, \qquad B = \begin{bmatrix} B_1 \\ B_2 \end{bmatrix}. \tag{2}$$

The lower block provides n_x equations determining x_t in period t for given $x_{t+1|t}$, X_t, i_t, and z_{2t},

$$x_t = A_{22}^{-1}(Cx_{t+1|t} - A_{21}X_t - B_2 i_t - z_{2t});$$

we assume that the $n_x \times n_x$ submatrix A_{22} is invertible.

Let the Y_t be an n_Y-vector of *target* variables, measured as the difference from an n_Y-vector Y^* of *target levels*. This is not restrictive, as long as we keep the target levels time invariant.[4] If we would like to examine the consequences of different target levels, we can instead interpret Y_t as the absolute level of the target levels and replace Y_t by $Y_t - Y^*$ everywhere below. Assume that the target variables can be written as a linear function of the predetermined, forward-looking, and instrument variables,

$$Y_t = D \begin{bmatrix} X_t \\ x_t \\ i_t \end{bmatrix}, \tag{3}$$

where D is an $n_Y \times (n_X + n_x + n_i)$ matrix. Let the intertemporal loss function in period t be

$$\mathrm{E}_t \sum_{\tau=0}^{\infty} \delta^\tau Y'_{t+\tau} W Y_{t+\tau}, \tag{4}$$

where $0 < \delta < 1$ is a discount factor and W is a symmetric positive semidefinite matrix.

Let $y^t \equiv \{y_{t+\tau,t}\}_{\tau=0}^{\infty}$ denote a central-bank *projection* in period t for any variable y_t, a central-bank mean forecast conditional on central-bank information in period t. As mentioned above, the projection of the deviation, $z^t \equiv \{z_{t+\tau,t}\}_{\tau=0}^{\infty}$, is identified with judgment.

[4]This restriction can be easily relaxed.

For given judgment, z^t, let the projection model of the central bank for the projections (X^t, x^t, i^t, Y^t) in period t be

$$\begin{bmatrix} X_{t+\tau+1,t} \\ Cx_{t+\tau+1,t} \end{bmatrix} = A \begin{bmatrix} X_{t+\tau,t} \\ x_{t+\tau,t} \end{bmatrix} + Bi_{t+\tau,t} + \begin{bmatrix} z_{1,t+\tau+1,t} \\ z_{2,t+\tau,t} \end{bmatrix}, \tag{5}$$

$$Y_{t+\tau,t} = D \begin{bmatrix} X_{t+\tau,t} \\ x_{t+\tau,t} \\ i_{t+\tau,t} \end{bmatrix} \tag{6}$$

for $\tau \geq 0$, where

$$X_{t,t} = X_t \tag{7}$$

and X_t is given.

The policy problem in period t is to find the optimal projection $(\hat{X}^t, \hat{x}^t, \hat{\imath}^t, \hat{Y}^t)$, that is, the projection that minimizes the intertemporal loss function,

$$\sum_{\tau=0}^{\infty} \delta^\tau L_{t+\tau,t}, \tag{8}$$

where the period loss, $L_{t+\tau,t}$, is specified as

$$L_{t+\tau,t} = Y_{t+\tau,t}{}' W Y_{t+\tau,t}. \tag{9}$$

The minimization is subject to given X_t, z^t, and (5) for $\tau \geq 0$. For the policy problem in terms of projections, we can allow $0 < \delta \leq 1$, since the above infinite sum will normally converge also for $\delta = 1$. The optimization is done under commitment in a "timeless perspective"; however, we do not discuss here the details of how the timeless perspective shall be implemented, but instead refer to Svensson (2005).

Ideally, the implementation of the optimal policy in period t would involve announcing the OPP, conditional on the judgments of the monetary authority, and setting the instrument in period t equal to the first element of the instrument projection,

$$i_t = \hat{\imath}_{t,t}.$$

Announcing the policy would serve to direct the expectations of a possible skeptical public toward the goals of policy and over time provide a framework for the central bank to discuss the evolution of its views. In period $t+1$, a new OPP, $(\hat{X}^{t+1}, \hat{x}^{t+1}, \hat{\imath}^{t+1}, \hat{Y}^{t+1})$, is derived, conditional, once again, on X_{t+1} and z^{t+1}, and announced together with a new instrument setting,

$$i_{t+1} = \hat{\imath}_{t+1,t+1},$$

and so on.

1.2 Extracting Judgment

Consider a given reference projection $(\tilde{X}^t, \tilde{x}^t, \tilde{\imath}^t)$, a projection $(\tilde{X}^t, \tilde{x}^t)$ conditional on $\tilde{\imath}^t$. This could be, for instance, a largely judgmental forecast for all relevant variables $(\tilde{X}^t, \tilde{x}^t)$, conditional on a particular federal-funds-rate projection $\tilde{\imath}^t$, or it could be a model-based projection. Define the corresponding judgment, $\tilde{z}^t$, as the projection (the projection of the future deviations) $\tilde{z}^t$ that fulfills

$$\begin{bmatrix} \tilde{X}_{t+\tau+1,t} \\ C\tilde{x}_{t+\tau+1,t} \end{bmatrix} = A \begin{bmatrix} \tilde{X}_{t+\tau,t} \\ \tilde{x}_{t+\tau,t} \end{bmatrix} + B\tilde{\imath}_{t+\tau,t} + \begin{bmatrix} \tilde{z}_{1,t+\tau+1,t} \\ \tilde{z}_{2,t+\tau,t} \end{bmatrix} \tag{10}$$

for $\tau \geq 0$. This is the judgment that makes the projection model reproduce the reference projection. What "judgment" represents depends on the context. In purely model-based forecasting, judgment is the extra-model information that the central bank brings to bear on the forecast. Judgment obviously depends on the model and on the reference projection. The method of OPPs assumes that the dynamics of the economy are adequately represented by the coefficients of the matrices A, B, and C, and that the relevant difference between the model and the economy can be adequately captured by the judgment.[5] However, this is not as restrictive as it might seem on the surface. The method of OPPs involves overlaying a "policy

[5]An example might be the adjustments of forecasts done in 1999 due to the Y2K phenomenon at the century's end. Y2K is a particularly clean-cut example because it was seemingly important, but since it had never happened before, no model could be expected to encompass it. Notice that judgment can be attributed to either the structural equations in the upper block of the system, or to beliefs, or expectations, conditional on structure, as is the case in the lower block. Continuing with our Y2K example, there are the perfect-foresight implications of a "destruction" of a part of the capital stock that Y2K represented; plus there are the implications of people's beliefs of a shock that no one had experienced before.

round" on top of a baseline forecast, however produced. Two assumptions are required to make this operational: first, that those aspects of (5) that pertain to the monetary policy transmission mechanism are consistent with the forecasters' views; and second, that the judgment itself, z^t, can be taken as exogenous with respect to policy actions. The first of these assumptions means that, in principle, the forecast could be carried out using a "model" that is very different from the model with which the OPP is to be conducted. The second is a mild restriction, the prospective violation of which would require the modelers to add the relevant equations to accommodate the case. For example, forecasters could include judgment about the existence of a stockmarket bubble but could not capture an assumed direct effect of policy on bursting the bubble without first adding equations to the model to capture this effect.

This specification assumes that the dimensions of the predetermined variables, nonpredetermined variables, and instruments are not less than the corresponding dimensions of the reference projection. If the dimension of the model is larger than the dimension of the reference projection, the judgment will not be unique. Since the FRB/US model is near-linear, the particular judgment chosen will not be of first-order importance for our results; the OPPs can be carried out with any fixed judgment. Alternatively, the judgment can be chosen so as to minimize the norm (a measure of the size) of the judgment, for instance. If the dimension of the model is smaller than that of the reference projection, then it is possible that the model is insufficient to capture all the details of the forecast.

In the case of the FRB/US model, there are elements of the Greenbook forecast that do not have direct analogues in the FRB/US model. For example, aircraft production and automobile sales to consumers are forecast in the staff's judgmental forecast but do not appear directly in the model; instead, the model judgments necessary to replicate these are contained within the investment and consumer durables equations, respectively. However, so long as the interest elasticities of these equations are representative of the beliefs of the policymaker, the OPP experiment will also be representative.

If the reference forecast includes all the variables in the projection model, the judgment $\tilde{z}^t$ is unique, since $\tilde{z}_{1,t+\tau+1,t}$ is given by the residuals of the upper block of (5),

$$\tilde{z}_{1,t+\tau+1,t} = \tilde{X}_{t+\tau+1,t} - A_{11}\tilde{X}_{t+\tau,t} - A_{12}\tilde{x}_{t+\tau,t} - B_1\tilde{\imath}_{t+\tau,t}$$

for $\tau \geq 0$, and $\tilde{z}_{2,t+\tau,t}$ is given by the residuals of the lower block,

$$\tilde{z}_{2,t+\tau,t} = C\tilde{x}_{t+\tau+1,t} - A_{21}\tilde{X}_{t+\tau,t} - A_{22}\tilde{x}_{t+\tau,t} - B_2\tilde{\imath}_{t+\tau,t}$$

for $\tau \geq 0$.

1.3 A Finite-Horizon Approximation

It is convenient to use a finite-horizon approximation to the above infinite-horizon projection model. The implementation below with the FRB/US model will also use a finite-horizon approximation.

As explained in detail in Svensson (2005), under suitable assumptions, there is a convenient finite-horizon approximation of this projection model, an approximation that can be made arbitrarily accurate by extending the horizon T. The first assumption is that the judgment is constant and, without loss of generality, zero beyond some horizon T,

$$z_{t+\tau,t} = 0 \qquad (\tau \geq T). \tag{11}$$

The second assumption is that the optimal projection asymptotically approaches a steady state. Assuming that the optimal projection reaches the steady state in finite time is then an approximation that is arbitrarily accurate if the horizon is sufficiently long. Svensson (2005) also notes that alternative assumptions can make the finite-horizon projection model exact, also for relatively short horizons.

Let the $(n_X + n_x + n_i)$-vector $s_t = (X_t', x_t', i_t')'$ denote the state of the economy in period t, and let $s_{t+\tau,t}$ denote a projection in period t of the state of the economy in period $t + \tau$. Let s^t, the projection of the (current and future) states of the economy, denote the *finite-dimensional* $(T + 1) \times (n_X + n_x + n_i)$-vector $s^t \equiv (s_{t,t}', s_{t+1,t}', \ldots, s_{t+T,t}')'$. Similarly, let all projections y^t for $y = X$, x, i, and Y now denote the finite-dimensional vector $y^t \equiv (y_{t,t}', y_{t+1,t}', \ldots, y_{t+T,t}')'$. Svensson (2005) shows that the finite-horizon projection model can be written compactly as

$$Gs^t = g^t, \tag{12}$$

where G is a $(T+1)(n_X+n_x) \times (T+1)(n_X+n_x+n_i)$ matrix, and g^t is a $(T+1)(n_X+n_x)$-vector defined as $g^t \equiv (X_t, z'_{1,t+1,t}, z'_{2,t,t}, z'_{1,t+2,t}, z'_{2,t+1,t}, \ldots, z'_{1,t+T,t}, z'_{2,t+T-1,t}, z'_{2,t+T,t})'$. Here, X_t denotes the given vector of predetermined variables in period t.

Since Y^t now denotes the finite-dimensional $(T+1)n_Y$-vector $Y^t \equiv (Y'_{t,t}, Y'_{t+1,t}, \ldots, Y'_{t+T,t})'$, we can write

$$Y^t = \tilde{D}s^t, \tag{13}$$

where $\tilde{D}$ denotes a finite-dimensional $(T+1)n_Y \times (T+1)(n_X+n_x+n_i)$ block-diagonal matrix with the matrix D in each diagonal block.

The intertemporal loss function can be written as a function of s^t as the finite-dimensional quadratic form

$$\frac{1}{2}s^{t\prime}\Omega s^t, \tag{14}$$

where Ω is a symmetric positive semidefinite block-diagonal $(T+1)(n_X+n_x+n_i)$ matrix with its $(\tau+1)$-th diagonal block being $\delta^\tau D'WD$ for $0 \le \tau \le T$.[6]

Then, the policy problem is to find the OPP $\hat{s}^t$ that minimizes (14) subject to (12). The Lagrangian for this problem is

$$\frac{1}{2}s^{t\prime}\Omega s^t + \Lambda^{t\prime}(Gs^t - g^t), \tag{15}$$

where Λ^t is the $(T+1)(n_X+n_x)$-vector of Lagrange multipliers of (12). The first-order condition is

$$s^{t\prime}\Omega + \Lambda^{t\prime}G = 0.$$

Combining this with (12) gives the linear equation system

$$\begin{bmatrix} G & 0 \\ \Omega & G' \end{bmatrix} \begin{bmatrix} s^t \\ \Lambda^t \end{bmatrix} = \begin{bmatrix} g^t \\ 0 \end{bmatrix}.$$

The solution to this linear system gives the OPP $\hat{s}^t$, which in turn determines the OPP of the target variables, $\hat{Y}^t \equiv \tilde{D}\hat{s}^t$. In particular, the method of OPPs amounts to finding a whole projection path for

[6] Svensson (2005) shows how this loss function shall be modified to incorporate commitment in a timeless perspective; we abstract from these issues here.

the instrument and doing so in one step, as opposed to deriving an instrument rule.[7]

A finite-dimensional projection model has several advantages beyond ease of computation. One is that it is very easy to incorporate any restrictions on the projections. Any equality restriction on X^t, x^t, i^t, or Y^t can be written

$$Rs^t = \bar{s}^t, \tag{16}$$

where the number of rows of the matrix R and the dimension of the given vector $\bar{s}^t$ equal the number of restrictions. This makes it easy to incorporate any restriction on the instrument projection—for instance, that it shall be constant or of a particular shape for some periods. Then it is possible to compute restricted OPPs, OPPs that are subject to some restrictions, for particular purposes.

2. A Real-World Demonstration of OPPs

This section provides a real-world demonstration of OPPs, using the FRB/US model.

2.1 The World in Early 1997

We use the economy in early 1997 as our backdrop. To illustrate the importance of judgment, we use two different views of the state of the economy at that time. The first is the contemporaneous view from the February 1997 Greenbook forecast and the FRB/US model of that time.[8] The second is the "backcast" of this period as seen from the November 1999 Greenbook.

The contemporaneous forecast of February 1997 was selected for a number of reasons. First, in the view of the Federal Reserve Board's

[7]Robustness can be addressed by looking at "distorted judgment" in a way suggested by, for instance, Hansen and Sargent (2003 and forthcoming) and Tetlow and von zur Muehlen (2001), through the addition of worst-case judgment to the baseline forecast and optimizing conditional on that judgment. One would, of course, consider such a scenario as part of a suite of scenarios, including the OPP for the best-guess forecast, not as a replacement for the best-guess forecast.

[8]We follow the convention internal to the Federal Reserve of dating the forecast as of the date of the FOMC meeting. The Greenbook *document* corresponding to the February decision—Federal Reserve Board (1997a)—was actually completed in late January.

Table 1. February 1997 Greenbook Forecast[1]

	1995	1996	1997	1998
Real GDP	3.3	3.1	2.3	2.1
Unemployment rate[2]	5.6	5.3	5.1	5.0
Non-farm business productivity	−0.1	0.8	0.8	0.8
PCE inflation	2.1	2.5	2.2	2.8
Employment cost index[3]	2.6	3.1	3.5	3.7

1. Four-quarter or twelve-month growth as applicable, except as noted.
2. Monthly average value in the final quarter of the year shown.
3. Private-industry workers, December–December.

staff, the economy was straining at capacity constraints. According to the Greenbook (Federal Reserve Board 1997a, part 1, I-2):

> Labor markets, of course, are already tight, and the latest statistics have confirmed the uptilt in compensation increases last year. With the unemployment rate projected to edge down to 5 percent and with the minimum wage jumping again later this year, we see labor cost inflation continuing to escalate . . . [O]ur forecast has edged further in the direction of a more cyclical pattern of inflationary overshooting, which typically has been followed by a period of weakness.

Real GDP growth in 1996 was measured at a bit over 3 percent per year, well above most estimates of the growth rate of potential output.[9] The unemployment rate, which had started 1996 at 5.6 percent, finished it at 5.3 percent, below most estimates of the NAIRU. Meanwhile, growth in personal consumption expenditures (PCE) prices was climbing, to 2.5 percent for the twelve months ending December 1996, up from 2.1 percent a year earlier. Not surprisingly, then, the staff saw unsustainable growth, given a constant federal funds rate, over the projection period ending in 1998:Q4. Table 1 summarizes the emerging data of that time and the forecast.

[9] For example, the Congressional Budget Office was projecting potential output growth in 1996 of about 2-1/4 percent, measured on a GDP basis (see Congressional Budget Office 1997). See Orphanides and Williams (2002) for a detailed examination of retrospective and real-time estimates of NAIRU measures.

The projected wage-price spiral is evident in the sharp acceleration in wage inflation (the employment cost index). And while productivity growth had increased recently, it had only climbed from dismal rates in 1995 to modest rates in 1996; similar modest rates were projected into the future. The warning in the Greenbook's statement that tighter monetary policy was likely to be necessary was also reflected in the Bluebook, the Federal Reserve staff's main document for analyzing monetary policy options for the FOMC (Federal Reserve Board 1997b, 6–7):

> By the end of the Greenbook forecast, the disequilibrium in policy and in the economy has become quite evident—the economy is producing beyond its sustainable potential and the stance of monetary policy is too easy to correct the situation and forestall a continuous rise in core inflation.

The second reason for selecting the February 1997 forecast is that the judgment contained therein would turn out to be wrong: unbeknownst to the Board's staff, a productivity boom was under way in the United States that would obviate the need for a tightening of monetary policy, at least for a while. The staff and the Committee were aware that productivity had been unusually high in 1996, but the staff took the recent data to have been a temporary phenomenon.[10] Over the next year, the persistence of productivity growth became evident, and the staff consequently revised its forecast. Accordingly, the view expressed in the November 1999 Greenbook was quite different (Federal Reserve Board 1999, part 1, I-1):

> The key changes in our forecast relate to a revised outlook for labor productivity . . . [T]he combination of revisions to the NIPA [National Income and Product Accounts] and a reassessment of the contribution to potential output from growth of the capital stock has led us to raise our estimate of trend growth in recent years and . . . in the period ahead.

[10] Still, there was enough evidence of something going on that the staff included some alternative scenarios in the Bluebook to illustrate the possibility that higher productivity growth might persist.

The upward revision to the estimates of past and projected trend growth meant substantially less incipient inflation pressures than had previously been anticipated. For our purposes, this sets up an interesting contrast of what the policy prescription would have been in real time with what it would have been in retrospect, nearly three years later.

2.2 The Greenbook Extension

Using the February 1997 Greenbook provides a third advantage: it was the first Greenbook that was extended beyond its normal forecast period to provide a baseline for policy analysis experiments in the Bluebook. (The extension procedure would become routine somewhat later.) And while the extension of that time was not stored electronically, the Bluebook document offers guidance on how to reconstruct the original extension. We do this for this paper. Reproducing the extension, in turn, has two benefits. First, it provides a reasonably lengthy period in common with the November 1999 Greenbook—the period from 1997:Q1 to 2001:Q4—that we can use to compare OPP experiments, with and without the benefit of some hindsight. Second, it demonstrates the procedure in use at the Federal Reserve Board for creating extensions and the judgment encompassed therein.

Good judgment is of obvious benefit for policy design. For us, however, the veracity of the judgment at the time is less important than demonstrating its significance to OPPs in general, and the differences from alternative policies, in particular.

The Greenbook forecast is conditioned on an assumed path for the federal funds rate, the Federal Reserve's policy instrument. Following the convention of the day, the February 1997 Greenbook held fixed the funds rate at the prevailing value of 5-1/4 percent until the end of the forecast period in 1998:Q4. This gave the Committee a sense of what a "no-change policy" would imply.

In all cases, the Greenbook extension maintains all the assumptions of the Greenbook forecast itself for the forecast period. This is done by computing the judgment—that is, the residuals to the FRB/US model—that is necessary to replicate the Greenbook forecast. Thereafter, the fundamental views of the forecast are maintained wherever possible by extending several years into the future the model residuals as of the end of the regular forecast period. In principle, any assumptions regarding the economic outlook could have been incorporated in the extension by adjusting the model residuals and exogenous variables in an appropriate way over the extension period. But the staff have tended to focus on determinants of the medium-term outlook, including the stance of fiscal policy, foreign economic conditions, oil prices, productivity growth, and the exchange rate.

The medium-term outlook also included a view on the general state of the economy and what that state implies for monetary policy.[11] As noted, the view in early 1997 was that the economy had reached an unsustainable level of output with incipient inflation pressures. For the extension, this elicited an increase in the funds rate to stabilize the economy and contain inflation, albeit not necessarily at an inflation rate that FOMC members would find desirable. Risks in the forecast and its extension can be (and were) handled by reconstructing baseline forecasts with alternative assumptions and recomputing policy scenarios conditional on the alternative baseline.

We will have more to say about the extension and its properties in the next section. We close this subsection by noting that since the funds rate path in the extension is not likely to be optimal, in the OPP exercises below we should expect to see a markedly different path. To provide some context, we will also include some scenarios with funds rate settings directed by a simple Taylor rule, just as in Taylor (1993), except that core PCE inflation is used instead of the GDP price deflator. Besides being simple and familiar, the Taylor rule was and is held up as an example of an instrument rule that, although not necessarily optimal, should work reasonably well in a wide variety of circumstances. Moreover, in accordance with the real-time nature of the present analysis, in early 1997 the rule was novel and was garnering a great deal of attention.

[11] Except where extra-model information would suggest otherwise, variables that have typically exhibited trends in history are extrapolated out at trend rates in the extension period. Variables that have been stationary are assumed to settle on values at or near their forecast ending values except when stabilizing on such values would be inconsistent with the views incorporated in the forecast.

2.3 The FRB/US Model

The FRB/US model is the workhorse model of the Federal Reserve Board's staff. As such, it serves in a variety of capacities: conducting forecasts, carrying out policy experiments, generating alternative Greenbook simulations, conducting stochastic simulations to measure uncertainty, and constructing the Greenbook extension, to name a few. And while the model is not used to produce the official Greenbook forecast—that is done judgmentally—the model provides a check on the Greenbook forecast, both formally through the model forecasts themselves, and informally through explorations of the model's properties and examinations of the Greenbook extension.[12]

Fundamentally, the model is of New Keynesian design. It includes a specific expectations block and, with it, a fundamental distinction between intrinsic model dynamics (dynamics that are immutable to policy) and expectational dynamics (which policy can affect). In most instances, the intrinsic dynamics of the model were designed around representative agents choosing optimal paths for decision variables while facing polynomial adjustment costs. The notion of polynomial adjustment costs, a straightforward generalization of the well-known quadratic adjustment costs, allowed, for example, the flow of investment to be costly to adjust, and not just the capital stock. This idea, controversial at the time, has recently been adopted in the broader academic community.[13]

The model has a neoclassical steady state with growth and rich channels through which monetary policy operates. Monetary impulses originate from the model's instrument, the federal funds rate, and then transmit—in large part through expectations—to longer-term interest rates, asset prices, and wealth, and from there to expenditure decisions of firms and consumers. The model is estimated using NIPA data, with most equations estimated over the period since the early 1960s.

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[12] The Greenbook extension provides a path for the funds rate beyond the Greenbook forecast period that is used to inform the path for longer-term bond rates that condition the Greenbook forecast.

[13] Christiano, Eichenbaum, and Evans (2005), for example, allow the flow of investment to be costly to adjust, which is the same thing as having higher-order adjustment costs for the stock of capital.

FRB/US is a large model. In 1997, it contained some 300 equations and identities, of which perhaps 50 were behavioral. About half of the behavioral equations of that vintage of the model were modeled using formal specifications of optimizing behavior containing explicit estimates of forward expectations and adjustment costs.[14]

Two versions of expectations formation were envisioned: rational expectations and VAR-based expectations. Rational expectations means that agents are assumed to understand and take fully into account the entire structure of the model, including monetary policy formulation, in arriving at their decisions. VAR-based expectations follows a parable quite like the Phelps-Lucas "island paradigm": the model's agents live on different islands where they have access to a limited set of core macroeconomic variables, knowledge they share with everyone in the economy. The core macroeconomic variables are the output gap, the inflation rate, and the federal funds rate, as well as beliefs on the long-run target rate of inflation and what the equilibrium real rate of interest will be in the long run. In addition, they have information that is germane to their island, or sector. Consumers, for example, augment their core VAR model with information about potential output growth and the ratio of household income to GDP.

There is not the space here for a complete description of the model. Readers interested in detailed descriptions of the model are invited to consult papers on the subject, including Brayton and Tinsley (1996), Brayton, Levin, et al. (1997), Brayton, Mauskopf, et al. (1997), and Reifschneider, Tetlow, and Williams (1999). Tetlow and Ironside (2004) describe the real-time evolution of the model and the time variation in optimized Taylor-type rules that are implied.

The FRB/US model is a near-linear model. The illustrative linear (or linearized) framework used above to explain OPPs can thus be seen as a good linear approximation to the FRB/US model. The model is solved using a terminal condition that projections of the variables are equal to their target or steady-state values at a given horizon T. Thus, the FRB/US model is solved as a finite-horizon problem. This is a practical step, and it is not restrictive for OPP purposes. Optimal policy in the FRB/US model makes all variables

[14]In price and volume decisions, polynomial adjustment costs ruled. In financial markets, intrinsic adjustment costs were assumed to be zero.

approach their target or steady-state values at sufficiently long horizons. Then, the horizon T can be set to a reasonably large number such that the finite-horizon solution is insensitive to local perturbations of the terminal date.[15] The finite-horizon approximation outlined above can then be seen as a linearization of the finite-horizon problem for the FRB/US model. Indeed, the near-linear FRB/US model can be represented as a near-linear equation system instead of (12),

$$f(s^t, g^t) = 0, \tag{17}$$

where the function $f(\cdot, \cdot)$ is a vector-valued function of dimension $(T+1)(n_X + n_x)$. The OPP is then the projection s^t that minimizes (14) subject to (17).

OPPs can and have been done with both VAR-based- and rational-expectations versions of the model. An important point to glean from these examples is that in comparison with most models, the various versions and vintages of the FRB/US model are complicated. It follows that if the method of OPPs can work for this model under these circumstances, it can work for a wide variety of other applications.

In what follows in this paper, we restrict the analysis to the version with VAR-based expectations, in large part because this is what was used almost exclusively for Greenbook and Bluebook work in 1997. Today, it is still the VAR-based-expectations version of the model that is used for forecasting. For policy analysis, when the staff believes the experiment in question does not deviate too much from what has been typical in the past, so that the average historical experience captured in the VAR can be thought of as representative of the likely response under the experiment, the VAR-based-expectations version is again used. The rational-expectations version is used for problems in which agents are likely to have the information and motivation to formulate a detailed understanding of events, or for policies that are systematic enough that agents could be expected to learn about their consequences.[16]

[15] That is, one need only extend the horizon until such a point that the extension no longer affects the simulated results over the horizon of interest. This is a "type III iteration" in the parlance of Fair and Taylor (1983).

[16] Examples of where foresight is regarded as critical include certain kinds of fiscal-policy interventions, since they involve legislative commitments to future actions that are costly to undo and for which it pays for agents to make the effort

2.4 Two OPPs

In designing OPPs in the present context, one is faced with choices regarding the specification of the loss function, (9), which amounts to fixing weights in the matrices W and Ω and targets for the inflation rate and the unemployment rate. One could, in principle, choose the weights on the loss function using a quadratic approximation of the true social welfare function, as described in Woodford (2003). However, this would be prohibitively difficult to do in a model as large and as complicated as the FRB/US model. Moreover, as Levin and Williams (2003) have argued, leveraging the microfoundations of a model in this way can make the selected policy even more susceptible to model uncertainty than would otherwise be the case. For this exercise we choose equal weights on each of the (squared) deviation of inflation from its target rate (the inflation gap), the deviation of the unemployment rate from the estimated NAIRU (the unemployment gap), and the change in the federal funds rate.[17] The target for the unemployment rate is set equal to the staff estimate of NAIRU at the time of 5.6 percent. The choice of a target rate of inflation is more problematic. The Federal Reserve does not have an official target rate of inflation. As we show below, while the judgmental path for the federal funds rate in the extension period was chosen with some notion of stabilizing the economy in mind, it was not done so to render "price stability." Under these circumstances, we arbitrarily choose a rate of 2 percent, measured in terms of PCE inflation, for the target rate.[18] Hence this corresponds to a periodic loss function,

$$L_{t+\tau,t} = (\pi_{t+\tau,t} - \pi^*)^2 + (u_{t+\tau,t} - u^*_{t+\tau,t})^2 + (i_{t+\tau,t} - i_{t+\tau-1,t})^2, \quad (18)$$

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to learn the implications of the legislation. Another example would be monetary policy rules that are used so systematically that agents can be expected to learn them.

[17]The presence in the loss function of the inflation rate less its target rate and the unemployment rate less the NAIRU (or the output gap) is conventional. The use of the change in the funds rate as an argument to the loss function is a simple acknowledgement of the empirical observation that central banks the world over seem to smooth instrument settings over time. This phenomenon may represent efforts to hedge against model uncertainty, an inherent taste of central bankers, or something else. See Sack and Wieland (2000) for a survey on Federal Reserve interest-rate smoothing.

[18]Besides being a reasonable, mainstream choice, as we shall see, a 2 percent target corresponds with a scenario called "stable inflation" in the Bluebook.

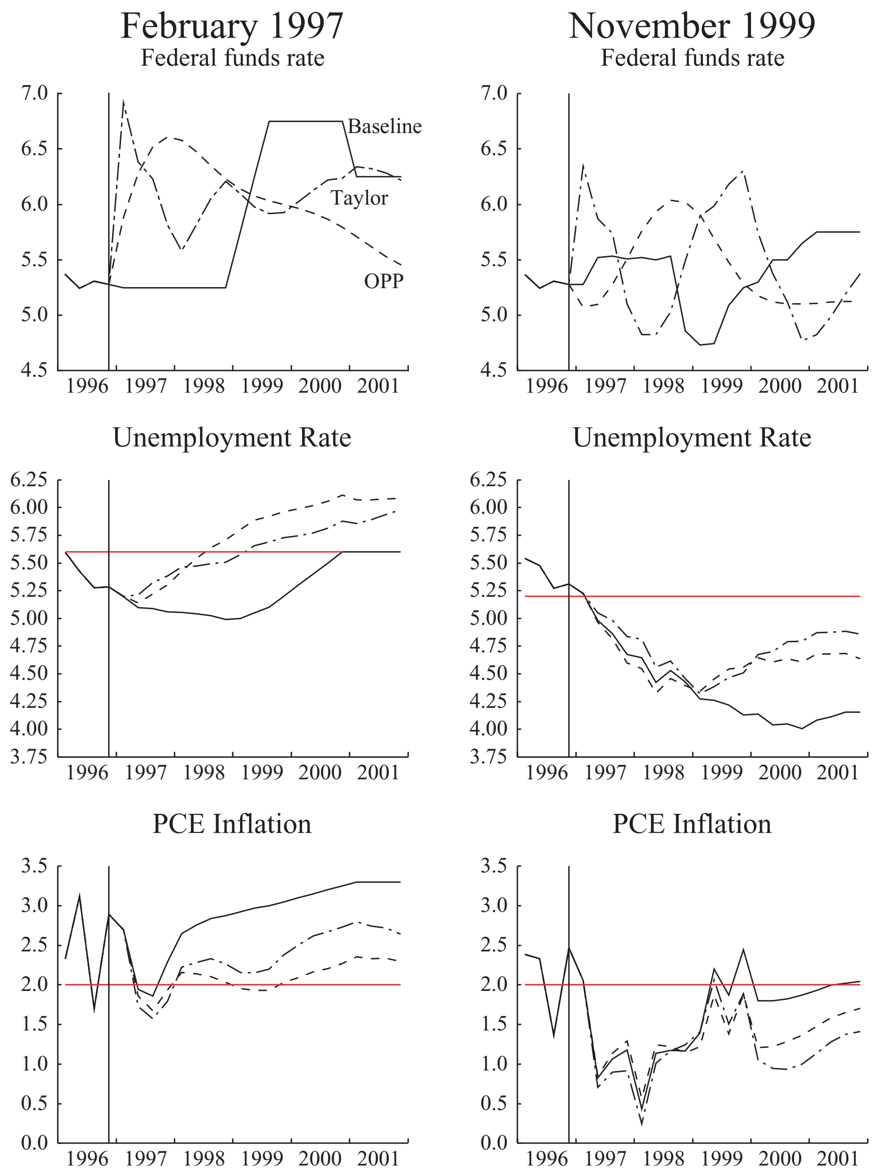
where π_t denotes annualized quarterly PCE inflation in quarter t, measured in percent, the inflation target π^* equals 2 percent per year, u_t denotes the unemployment rate measured in percent, and u_t^* denotes the natural unemployment rate. The discount factor in the intertemporal loss function is set at $\delta = 0.99$ per quarter.

The same exercise is carried out based on the November 1999 Greenbook, using the baseline of that time, and that model vintage. Now, since part of the period we study has us looking back at the 1997 to 1999 period, the "judgment" is quite different. In the intervening years, the staff had come to recognize the productivity boom during the mid-1990s. In addition, myriad other forces had impinged on the economy, including the 1998 Asian crisis and the Russian debt default. The policymaker's loss function also differs, albeit only slightly: in the nearly three years between the two Greenbooks under study, the staff reduces its estimate of the NAIRU, u_t^*, to 5.2 percent instead of the previous 5.6 percent. Accordingly, it is the lower figure that enters into equation (18) for the November 1999 exercise.

The results are best shown graphically, which we do in figure 1. The left column of the figure shows the results for the February 1997 Greenbook, while the right column shows the results for the November 1999 Greenbook. In each case, the baseline projection is shown by the solid line, the OPP is the dashed line, and the Taylor-rule projection is the dashed-dotted line. A vertical line marks 1996:Q4, the last quarter before our projections. Let us focus on the left column for the time being.

As already discussed, the February 1997 Greenbook baseline projection holds the funds rate at its inherited level until the conclusion of the forecast period in 1998:Q4; thereafter the funds rate path was adjusted judgmentally to contain excess demand and stabilize the inflation rate. In particular, the funds rate rises 50 basis points in each of the first three quarters of 1999 to reach 6-3/4 percent, where it stays until the end of 2000. Thereafter, the funds rate is reduced to 6-1/4 percent, where it remains for the duration of the scenario. With these increases in the funds rate coming as late as they do, the middle-left panel shows a near-continuous decline in the unemployment rate under the baseline policy until mid-1999, after which time it gradually returns to the staff NAIRU of 5.6 percent. And, the staff warned in the Greenbook of the time, the result is a steady rise in inflation rate, to about 3.3 percent.

Figure 1. Optimal Policy Projections with the FRB/US Model (Selected Historical Extended Greenbook Forecasts)



The OPP calls for an immediate increase in the funds rate, by about 125 basis points over the first three quarters of 1997, and reaches its peak of a little over 6-1/2 percent in early 1998. Thereafter, it slides slowly back down toward its original level. These increases in the funds rate are sufficient to reverse the decline in unemployment that would otherwise be projected to occur, bringing the unemployment rate above the NAIRU by the middle of 1998. The prescribed increases in the funds rate, while not particularly large by historical standards, are timely. By acting early, the OPP keeps inflation very close to the target rate of 2 percent, as shown in the bottom-left panel.

The OPP simplifies the construction of, and adds rigor to, the process that was actually carried out for the February 1997 Bluebook. The appendix to this paper shows selected pages from that Bluebook. The dotted line in the appendix chart shows a path for the funds rate, determined by trial-and-error methods, that brings core PCE inflation to the same 2 percent target level we use in OPP. The path for the funds rate shown there shows broadly the same characteristics as the OPP path, although the path is not an optimal one.

Returning to figure 1, in order to provide some context, the dashed-dotted lines show projections under the Taylor rule.[19] By construction, a Taylor-rule policy responds to the big picture of the economy, but eschews the judgment that is the subject of this paper. Thus, it is useful for comparative purposes. The dashed-dotted line in the upper-left panel shows that the Taylor rule calls for an even sharper tightening of policy in the short run than does the OPP policy. Thereafter, it advocates a more equivocal policy for some time, with oscillations up and down in the funds rate. This reflects the myopic nature of the rule—picking the funds rate period by period based only on current conditions—as opposed to the multiperiod forward-looking optimal planning of OPPs. Thus, the Taylor rule must reverse what turn out to be excessive movements in previous settings of the funds rate. In the end, the Taylor rule's policy prescription ends up with unemployment and inflation that

[19]For the Taylor-rule simulation, the equilibrium real federal funds rate, r^*, is set equal to 3.1 percent, the value that the real rate converges on in the extension shown in the baseline simulation as shown in the upper-right panel of the chart in the appendix.

are closer to target than the baseline policy, but still well off target levels.

Now let us turn to the November 1999 baseline shown in the right column. It is obviously not possible for a policymaker acting in real time to have the scope of information that the November 1999 backcast of the period from 1997:Q1 to 1999:Q3 includes. Our objective here is diagnostic; we revisit this period in history to see what better judgment—as captured by the historical data and the backcast of unobservable variables that those data engendered—does to policy prescriptions. The solid line, once again, shows the forecast (for 1999:Q4 and beyond) as well as the revised historical data (from 1997:Q1 to 1999:Q3). Notice the dip in the funds rate, in the upper-right panel, from late 1998 until early 2000, reflecting the FOMC's response to the Asia crisis and its effects on global financial markets.[20] Beginning as before in 1997:Q1, the actual funds rate rose 25 basis points early in 1997. With the benefit of hindsight, the OPP would have called for a modest easing in the stance of policy in the early going. The subsequent increases in the funds rate, although superficially similar to those for the February 1997 scenario, are smaller and shorter lived. In any event, one of the interesting historical aspects of the two baseline scenarios is the remarkable difference in inflation projections that are supported by relatively similar patterns of excess demand as captured by the unemployment rates. This change in view was a reflection of the new-found appreciation by the staff of the productivity boom and its effects on marginal costs and hence on inflation. In the end, this results in a situation—as seen from the perspective of the November 1999 Greenbook—in which excess demand for labor must be tolerated for a time in order to bring inflation up toward the target of 2 percent from the low levels seen in 1997 and 1998.

The Taylor rule is oblivious to all this. It responds only to contemporaneous excess demand (which differs only in small ways in early 1997 between the two scenarios) and inflation (which differs even less). Consequently, the policy prescription from the Taylor rule is quite similar for the two baselines, even though they differ

[20]In daily data, the *intended* funds rate would move in 25 basis points increments, given the FOMC's practice to move it in such discrete increments. Historically, however, the Federal Reserve was not always able to keep the funds rate at its intended level. And, in any case, in our figures the funds rate is expressed as a quarterly average of daily observations.

Table 2. Losses Under Alternative Funds Rate Paths[1]

	February 1997		November 1999	
	Loss	Incr.[2]	Loss	Incr.[2]
OPP policy	0.20	–	1.69	–
Taylor rule	0.66	0.46	2.27	0.58
Extended Greenbook	1.06	0.86	2.28	0.59

1. Losses calculated from 1997:Q1 to 2001:Q4, average per quarter.
2. Increase in loss compared with the OPP.

in important ways. The myopia of the Taylor rule causes it to oscillate back and forth between tightening and easing in the November 1999 baseline.

To provide a summing up of the performance of these rules, table 2 computes the loss as calculated using (14) and (18), for the baseline projection and the two counterfactual experiments, for both the February 1997 and November 1999 cases. In all cases the losses are computed over the same period of twenty quarters from 1997:Q1 to 2001:Q4 and divided by the number of quarters, so the losses reported are average loss measured per quarter. To add some perspective, the columns marked "Incr." show the increase in loss compared with the OPP loss, which can be interpreted as the maximum increase in the average (per quarter) squared inflation gap, unemployment gap, or federal funds change, that the policymaker would be willing to incur for the privilege of using the OPP policy instead of the policy shown.[21]

The two left columns show the results for the February 1997 model. They demonstrate that both the baseline and the Taylor-rule projections produce substantially inferior performance, in proportionate terms, in comparison with the OPP. In both cases, the policymaker would be willing to suffer an increase in the average squared inflation gap of about a half percentage point per period or more for the privilege of using the OPP. The result under the baseline projection is hardly surprising, since the path for the funds rate in that instance is a conditioning assumption for the forecast, rather than a

[21]It is because each squared term of the loss function carries the same weight that the increase in loss applies to all terms.

policy prescription—but the Taylor-rule result requires some explanation. What it tells us is that the Taylor rule supplies the broad strokes of a stabilizing policy, but in a large-scale model where there are numerous channels through which shocks are conveyed and policy operates, it provides insufficient breadth to come close to the optimal policy. Advocates of simple rules recognize that such rules are suboptimal (except in special cases) to a complexity of a fully optimal rule. The trade-off for this suboptimality is said to be that such rules are likely to be more robust than many alternatives, a point to which we return presently. Our result for the February 1997 model, however, suggests that the Taylor rule leaves substantial room for improvement.

The two right columns show the results for the November 1999 model. In this case, the baseline projection is littered with the actual shocks borne over the period from 1997 to 1999. Even with optimal feedback in response to these shocks, significant losses are incurred and so the performances under the alternative projections are likely to be more similar than in our previous case. The results here show that the OPP, operating with the advantage of hindsight over the 1997–99 period, would have outperformed by a significant margin the performance of the Taylor rule or the baseline funds rate path.

The foregoing shows the importance of judgment for the design of policy. It also shows that different judgments can lead to different policies. The question of robustness of policy logically arises. If judgment can be suspect, it stands to reason that different OPPs should be conducted for different, plausible sets of judgment. OPPs for alternative assumptions—including, in the context of these experiments, increasing productivity growth and falling natural unemployment rates, as well as for alternative weights in the loss function—can easily be computed. Together, these alternative OPPs along with the baseline projection can comprise a useful portfolio of policy alternatives for central bankers.

3. Conclusions

This paper shows in theory and in practice how judgment can be optimally incorporated into a rigorous process for monetary policy decision making. The method of optimal policy projections has the advantage of fully incorporating all the knowledge and views that can be formalized of monetary policy decision makers. This method is already in use by the staff of the Federal Reserve Board for presenting policy options to the Federal Open Market Committee.

We demonstrate the efficacy of OPPs using two historical baselines and two vintages of the Federal Reserve Board's FRB/US model. To us, the results are encouraging. Moreover, we would argue that the Federal Reserve's continued use of such exercises—complicated as it is by the use of a large-scale model that is different from the "model" with which the forecast is generated—shows that OPPs are a viable tool for many central banks.

Looking to the future, an important limitation of the procedure is the certainty-equivalence assumption for the results and the consequent underplaying of model-uncertainty issues other than additive judgmental adjustments. The paper mentions the possibility of computing multiple OPPs associated with differing sets of judgments. Also mentioned is the use of min-max procedures in combination with OPPs to formulate defensive strategies against locally worst-case outcomes. These should be worthwhile avenues to pursue. Another possible extension is to show how OPPs can be updated over real time as new data are collected and new judgment is adopted.

Appendix. Excerpt from the February 1997 Bluebook

Long-Run Scenarios

(6) To provide a longer-run perspective on the strategic issues confronting the Committee, this section presents econometric model simulations designed to examine alternative monetary policies as well as the effects of certain shocks to the economy. The three policy scenarios considered first are built around the Greenbook forecast, using the staff's new macroeconometric model to extend that forecast and to derive differences resulting from alternative policies. These scenarios incorporate the same assumptions regarding underlying macroeconomic factors; notably, the full-employment budget for the federal government is on path to balance by early in the next century and the NAIRU is 5.6 percent. Other sets of scenarios consider: (1) a favorable shock to productivity growth, (2) an increase in the NAIRU, and (3) a significant decline in the stock market. The model's dynamic properties are importantly affected by the level and changes

in the public's expectations about key economic variables—such as the rate of inflation likely to prevail in the long run. Because these expectations adapt slowly and nominal wages adjust sluggishly, the sacrifice ratio over a period of five years is about 2—in line with the historical average for the U.S. economy. That is, reducing inflation by 1 percentage point requires unemployment to exceed the NAIRU by the equivalent of 1 percentage point for two years.

(7) The *baseline strategy*, shown by the solid lines in Chart 2, is an extension of the Greenbook forecast. By the end of the Greenbook forecast, the disequilibrium in policy and the economy has become quite evident—the economy is producing beyond its sustainable potential and the stance of policy is too easy to correct the situation and forestall a continuous rise in core inflation.[4] Under the baseline strategy, the Committee caps the rise in inflation by tightening policy after 1998 by enough to bring the unemployment rate quickly up to the NAIRU. This requires the federal funds rate to be raised by around 1-1/2 percentage points, so that the real funds rate overshoots its equilibrium for a time.[5] With this strategy, the Committee would accept whatever rate of inflation that developed while the economy was operating beyond its potential, and, as a consequence, core PCE inflation would ratchet up from an average of 2 to 2-1/2 percent in recent years to a little over 3 percent.

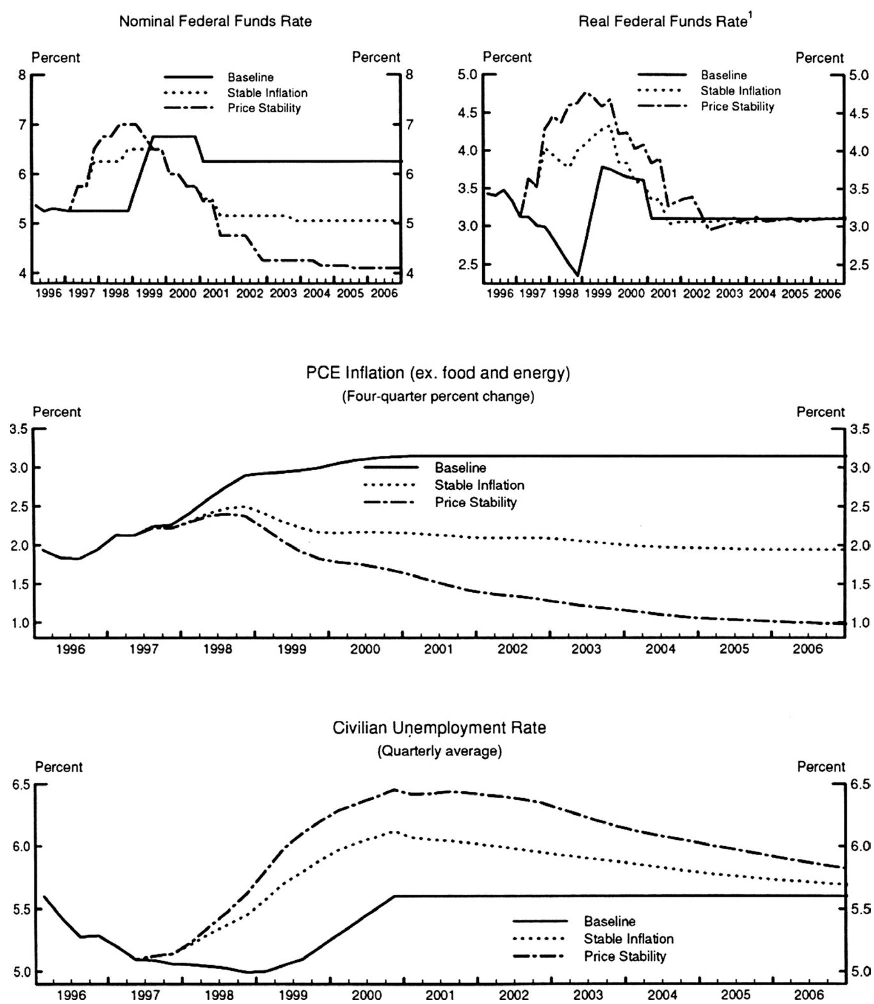
(8) Some pickup in core inflation appears to be unavoidable in the near term given the staff's assessment of the cyclical position of the economy, but the *stable inflation* strategy limits that rise and

[4]In the charts, inflation is measured by the core PCE chain-weight price index, and past movements in this index are used to proxy for inflation expectations in calculations of the real funds rate. This index has a steeper upward trajectory over the next few years than do many other broad measures of prices, because it: (1) excludes food and energy prices, which are moderating; (2) is unaffected by the changes in BLS calculations of the CPI; and (3) unlike a broad GDP price measure, includes import prices, which are damped at first and boosted later by the actual and assumed gyrations of the dollar. We think it gives a clearer view of the underlying inflation tendencies in the various scenarios, but its application in calculating the real interest rate may exaggerate the projected drop in real rates in 1997 and 1998, especially if the public forms its expectations based on a broader set of prices than in this core measure. The real funds rates shown in the charts are higher than those calculated using the CPI, but would be higher through history as well because inflation as measured by the PCE index on average has run $\frac{1}{2}$ percentage point below the CPI.

[5]That equilibrium itself is lower toward the end of the simulation than at present owing primarily to additional fiscal consolidation.

Chart 2

Alternative Strategies for Monetary Policy



1. The real federal funds rate is calculated as the quarterly nominal funds rate minus the four-quarter percent change in the PCE chain-weight price index excluding food and energy.

Note: Data points are plotted at the midpoint of each period.

ultimately brings inflation back down to around its recently prevailing rate. This entails a near-term tightening, with the nominal funds rate rising to 6-1/2 percent by the end of 1998. The effects of the unemployment rate remaining below the NAIRU until early 1999 are tempered in the near term by the sharp slowing in real growth, which keeps inflation expectations damped in the model (similar in result to a "speed effect" in the Phillips curve), and by the rise in the dollar associated with higher interest rates. These effects dissipate, however, and ultimately the real interest rate and the unemployment rate must be kept above their natural levels for some time to offset the underlying inflationary pressures built up as the economy operated above potential from 1996 through 1998.

(9) A strategy involving a sharper tightening of policy over the next two years, with the nominal funds rate rising soon and reaching 7 percent in late 1998, would achieve *price stability* in seven years or so. In this scenario, a higher real funds rate is sustained for longer than under the stable inflation strategy to produce enough slack in the economy to keep downward pressures on wages and prices. The sizable output loss reflects the slow adaptation of expectations noted above. In the absence of empirical evidence that the cost of disinflation from moderate levels is reduced by an aggressive anti-inflation program or by announced inflation targets, we have included no special "credibility" effects from the Committee embarking on a deliberate strategy to achieve price stability. Credibility for price stability does develop—but "in the old fashioned way," by earning it through achieving stable prices. This simulation also makes no allowance for enhanced productivity as price stability is approached.

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