MEASURING INFLATION PRESSURE AND MONETARY POLICY RESPONSE: A GENERAL APPROACH APPLIED TO US DATA 1966 - 2001

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Measuring Inflation Pressure and Monetary Policy Response: A General Approach Applied to US Data 1966 – 2001

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Abstract

Quantifying Inflation Pressure and Monetary Policy Response in the United States

We propose a methodology for constructing operational indices of inflation pressure, the monetary authority's effort to reduce this pressure, and the degree to which inflation pressure is alleviated. We begin with model independent definitions of these concepts. When our definitions are applied to a specific model we obtain model-specific functional forms for these indices. We apply our methodology to a micro-founded aggregate model with rational expectations. GMM estimates of the model are used to obtain quarterly time series of our indices for the United States from 1966 to 2001.

Journal of Economic Literature Classification No.: E50, E58

Keywords: monetary policy, inflation pressure, stabilization policy

1. Introduction

The formulation of effective monetary policy requires that we understand both the successes and failures of current and past policies. Because policies can only be properly evaluated in the context of the economic conditions that prevailed at the time they are implemented, in order to conduct empirical studies of the effectiveness of monetary policy, we need quantitative measures of the policy stance of the monetary authority that separately characterize the economic environment and the responses of the policy authority to that environment. Ideally, such measures should have the following four attributes. First, they should be summary statistics so that they an be used as independent variables in empirical analyses.[1] Second, they should have strong theoretical foundations so that is clear what is being measured. Third, they should not be dependent on country-specific features of monetary institutions so that they can serve as useful tools for conducting cross-country comparisons of monetary effectiveness, not just for assessing monetary policy in a single country. Fourth, they should have simple intuitive interpretations so that they can be used by the public, not just by practioners, to evaluate how well the monetary authority is achieving its objectives, just as other widely used measures of economic performance such as real GDP, the consumer price index, and the unemployment rate are used to evaluate how well a government is doing.

In this article, we focus on policies relating to price stabilization. We introduce three indices that can be used to assess the impact of systematic monetary policy on inflation, taking into account the environment in which the policy was implemented.[2] Our summary statistics measure (i) inflation pressure, (ii) the degree to which inflation

[1] Although useful for other reasons, impulse response functions do not satisfy this desiderata.

[2] Various measures of monetary policy stance have been employed in earlier studies. For example, the federal funds rate has been used by Bernanke (1990), Bernanke and Blinder (1992), and Boivin and Giannoni (2006); Christiano and Eichenbaum (1992) used non-borrowed reserves; and Strongin (1995) used the ratio of non-borrowed reserves to total reserves. None of these measures provides information about the strength of the policy response relative to the economic conditions that existed at the time the policy was implemented.

pressure is alleviated, and (iii) the overall effectiveness of monetary policy in reducing inflationary expectations.

Our first index measures inflation pressure as the change in the inflation rate that would have been observed if the monetary authority had held its interest rate instrument constant. Our index of inflation pressure therefore describes the environment that the monetary authority faced and to which it responded in a given period.[3] The policy response of the monetary authority can be measured as the ratio of the actual change in inflation to the change that would have occurred if the interest rate had been held constant. We subtract this ratio from one to obtain our second index, which we refer to as an index of effective price stabilization. Our effective price stabilization index measures the proportion of inflation pressure that was alleviated by the policy implemented by the monetary authority. Inflation pressure can be thought of as arising from two sources, an excess demand for goods (positive output gap) and expectations of future price increases (inflationary expectations). Interest rate increases reduce inflation pressure when they lead to reductions in the demand for goods and/or inflationary expectations. Our index of policy effectiveness compares the magnitude of inflation pressure prior to the policy change with the inflation pressure that remains after the policy change. Comparing the magnitude of ex ante and ex post inflation pressure provides a measure of the degree to which inflationary expectations were affected by the policy that was implemented.

The measures of inflation pressure needed to calculate our indices are not directly observable. They must therefore be imputed from a theoretical model. In order to obtain estimates of inflation pressure, we apply a two-step methodology that Weymark (1995, 1998) used to measure exchange market pressure. First, we propose model-independent definitions of each index. We then apply these definitions to a theoretical model and derive model-specific index formulae which provide a functional

[3] Note that our general definition is extremely flexible in that it does not specify any particular timing between the implementation of the interest rate change and its impact on the economy. Our definition can accommodate a wide range of forward-looking and pre-emptive policy actions on the part of the central bank.

relationship between inflation pressure and economic variables that are directly observable. We then estimate our model and use the estimation results to calculate our indices of inflation pressure and monetary policy response for the United States from 1966 to 2001.

Although the definitions of the indices we have proposed are model-independent, the functional forms of the estimated indices are model-sensitive. We employ a quarterly version of Clarida, Galí, and Gertler's (1999) aggregate rational-expectations model to derive our indices. In order to check whether the measures we have estimated are reasonable, we compare monetary policy as described by our indices with Greenspan's (2004) narrative account of Federal Reserve policy. Based on this analysis, we conclude that our indices provide a very plausible measure of Federal Reserve policy and of the economic conditions that the Federal Reserve faced. To further illustrate the application of our indices, we undertake a comparison of the Federal Reserve's policy under its five most recent chairmen.

Both the concept of inflation pressure and the methods we use to construct inflation pressure indices are new to the literature. Measures of monetary policy effectiveness, on the other hand, exist in various forms in earlier studies. Most of the earlier studies focus on impact of monetary policy shocks (i.e., non-systematic monetary policy) on output.[4] An exception is Boivin and Giannoni (2006) who use impulse response functions to assess the impact of both systematic and non-systematic monetary policy. The measure of monetary policy effectiveness that we introduce here is novel in that it captures the impact of systematic monetary policy on inflation in the form of a summary statistic that has a simple, intuitively appealing interpretation.

The remainder of this article is organized as follows. Section 2 provides the model-independent index definitions. In Section 3, we use Clarida, Galí, and Gertler's (1999)

[4]See, for example, Bernanke (1990), Bernanke and Blinder (1992), Bernanke and Mihov (1998), Christiano and Eichenbaum (1992), Romer and Romer (1989), and Strongin (1995), among others. Although Romer and Romer (2004) are interested in the impact of monetary policy on prices as well as output, they also employ a measure of monetary policy that is purged of all endogenous components.

aggregate rational-expectations model to illustrate the derivation of our summary statistics. The quarterly model, which we use to estimate our indices for the United States, and the index formulae that are consistent with this model are presented in Section 4. A description of the estimation procedures applied to the quarterly model and the results obtained are also provided in this section. Time series of our indices are presented and interpreted in Section 5. In Section 6 we demonstrate how our indices can be used to characterize the nature and effectiveness of monetary policy in the United States. Concluding comments may be found in Section 7.

2. Three Indices: Model-Independent Definitions

The effectiveness of monetary policy is typically judged in terms of observed inflation outcomes, with little consideration given to the environment in which this outcome was achieved. Yet the economic environment is a critical determinant of the outcomes that monetary policy can reasonably be expected to achieve. Interest rate increases are likely to be less effective in reducing inflation in countries with strong demand pressures and/or a long history of poor inflation performance. In this section, we introduce three operational concepts that can be used to obtain quatitative representations of the monetary authority's policy stance. Our indices distinguish between the environment facing the policy authority and the policy authority's response to the economic environment.

2.1 Inflation Pressure

Definition: Inflation Pressure measures the change in the inflation rate that would have been observed in a given period if the monetary authority had held its monetary instrument constant at the previous period's level.

Inflation pressure, as it is defined above, characterizes the inflationary conditions produced by forces outside the direct control of the monetary authority. Our concept of Inflation Pressure can be more clearly understood with the help of the following simple model:

$$y_t = f(i_t, x_t^e, u_t), \qquad f_i' < 0 \tag{1}$$

$$\pi_t = g(y_t, x_t^e, e_t), \qquad g'_y > 0 \tag{2}$$

where y_t is the output gap in period t, i_t is the interest rate in period t, x_t^e is a vector of private agents' expectational variables, and π_t is the inflation rate in period t. The arguments u_t and e_t represent random disturbances to the economy.

Equations (1) and (2) are general, though simple, representations of the aggregate demand and Phillips curve equations that are typically employed in the monetary policy literature. Together, (1) and (2) imply a negative relationship between inflation and the interest rate

$$\pi_t = h(i_t, x_t^e, e_t, u_t), \qquad h'_i < 0. \tag{3}$$

From (3) it is evident that if central banks can control i_t, then interest rate changes can be used to offset the impact of x_t^e, e_t, and u_t on inflation. This inverse relationship between inflation and interest rates is the basis for the counter-cyclical interest rate policies that form the cornerstone of modern monetary policy.

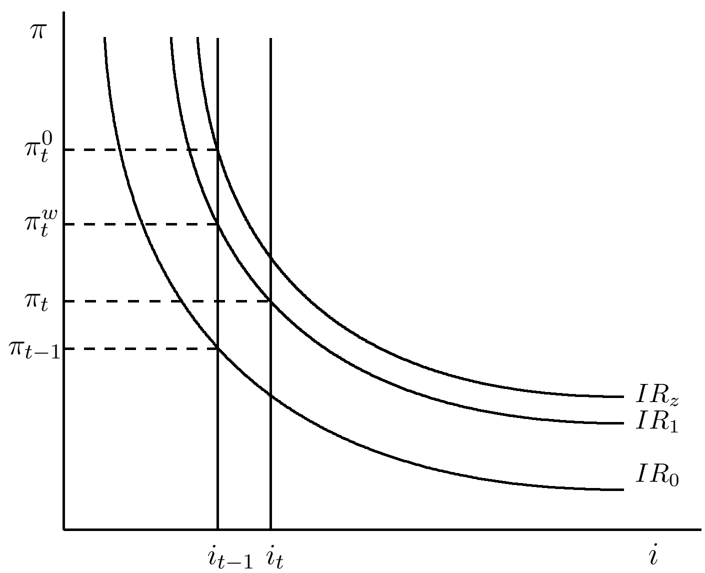

FIGURE 1

According to (3) there is a trade-off between inflation and the interest rate, for given x_t^e, e_t, and u_t. This trade-off is illustrated graphically in Figure 1 by the curves IR_0, IR_1, and IR_z. The lowest curve, IR_0, represents the trade-off that existed in period $t-1$. The difference in the position of IR_0 and highest curve, IR_z, represents the shift in the trade-off caused by u_t and e_t (we assume for simplicity that there are no exogenous expectational shocks). Our index of inflation pressure measures the rate of inflation that these shocks would have generated if the monetary authority had held $i_t = i_{t-1}$. Using the notation in Figure 1, we define our Inflation Pressure (IP) index as

$$IP_t \;=\; \pi_t^0 \;-\; \pi_{t-1} \tag{4}$$

where π_t^0 denotes the inflation rate that would have been observed in period t if the monetary authority had held $i_t = i_{t-1}$.

Note that when agents form expectations rationally, x_t^e depends on i_t, causing the trade-off between π_t and i_t to shift (from IR_z to IR_1 in Figure 1). By defining inflation pressure as the change in inflation that would have been observed with $i_t = i_{t-1}$, we capture the potential impact of exogenous shocks (which may include exogenous changes in expectations) to the economy on inflation. This ensures that π_t^0 reflects only the impact of exogenous disturbances e_t and u_t, and any exogenous change in expectations that may have occurred in period t. Because (4) measures inflation pressure that existed before the monetary authority changed interest rates in response to that pressure, we refer to IP_t as *ex ante* inflation pressure.

2.2 Effective Price Stabilization

Definition: The Effective Price Stabilization index is the proportion of ex ante inflation pressure that was relieved by the monetary policy that was implemented in a given period.

The IR curves shown in Figure 1 represent feasibility constraints that the monetary authority faces. When an interest rate policy is implemented, the monetary authority chooses a combination of inflation and interest rate that is a point on the feasibility constraint. In an economy populated with forward-looking rational agents, changes in the monetary instrument will alter inflation expectations causing the feasibility constraint to shift. Under the assumption that there is a negative relationship between the interest rate and inflationary expectations, an interest rate increase would cause the feasibility constraint to shift inwards. In Figure 1, we show the feasibility constraint shifting inwards, from IR_z to IR_1 when the policy authority increases the interest rate from i_{t-1} to i_t. The degree of price stabilization therefore depends not only on the interest rate change, but also on the response of private expectations to this policy initiative. Formally, the Effective Price Stabilization index is defined as

$$EPS_t = \frac{\pi_t^0 - \pi_t}{PI_t} = 1 - \frac{\pi_t - \pi_{t-1}}{\pi_t^0 - \pi_{t-1}} \tag{5}$$

An index value of 1 indicates the monetary authority succeeded in holding inflation constant. An index value of 0 indicates that the monetary authority was unsuccessful in alleviating any of the underlying inflation pressure. Index values between 0 and 1 reflect the proportion of inflation stabilization achieved by the monetary authority's policy initiative. Index values outside the [0,1] interval can also be interpreted. An EPS_t value greater than unity, indicates that monetary policy decreased (increased) inflation at a time when ex ante inflation pressure was positive (negative). Negative EPS_t values, on the other hand, indicate that monetary policy exacerbated inflation pressure, causing the change in the observed inflation rate to exceed ex ante inflation pressure in absolute magnitude.

2.3 Policy Effectiveness

Definition: The index of Policy Effectiveness measures degree to which inflation pressure was reduced by the implementation of monetary policy.

The term ex post inflation pressure refers to the inflation pressure that remains after a policy change has been implemented.

Definition: Ex post inflation pressure is the change in the inflation rate that would have occurred under the monetary policy actually implemented in a given period, if the policy authority had unexpectedly maintained its policy instrument at the same level as in the previous period.[5]

In Figure 1, the monetary policy implemented in period t is the increase in the

[5] The concept of ex post inflation pressure is analogous to the concept of exchange market pressure introduced in Weymark (1995, 1998).

interest rate from i_{t-1} to i_t. Graphically, ex post inflation pressure is represented by the vertical distance between the initial feasibility constraint IR_0 and the feasibility constraint associated with the monetary policy that was implemented IR_1. Ex post inflation pressure in period t is therefore given by the vertical distance $\pi_t^w - \pi_{t-1}$ that is associated with the period t interest rate i_t.

It is apparent from Figure 1 that the magnitude of the interest rate change required to achieve a given inflation rate depends on the degree to which the feasibility constraint shifts in response to changes in interest rates. When inflationary expectations are very sensitive to interest rate changes, relatively small changes can bring about much larger inflation reductions than when expectations are unresponsive. We therefore measure policy effectiveness as the ratio of ex post inflation pressure to ex ante inflation pressure. Formally, we define the index of Policy Effectiveness (PE) as

$$PE_t = \frac{\pi_t^w - \pi_{t-1}}{IP_t} = \frac{\pi_t^w - \pi_{t-1}}{\pi_t^0 - \pi_{t-1}} \qquad (6)$$

An index value of 0 indicates that the policy was effective in removing all inflation pressure from the economy. When $PE_t = 1$, on the other hand, monetary policy is ineffective in moderating the degree of inflation pressure. Index values between 0 and 1 are indicative of partial reduction in inflation pressure.

When ex ante inflation pressure is positive, an index value greater than 1 indicates that monetary policy magnified inflation pressure. In this case, an index value greater than unity is indicative of policy ineffectiveness. When IP is negative, however, an index value greater than unity has a more positive interpretation. PE values that exceed unity when ex ante inflation pressure is negative occur when the policy implemented reduces inflation pressure by more than the amount that would have occurred in the absence of this policy initiative. In this case, a PE value greater than unity reflects an effort on the part of the policy authority to bring about a long-run reduction in the mean of the price level. In periods of positive ex ante inflation pressure, negative PE values are characteristic of a highly effective price reduction policy; in this case, the monetary authority is able to achieve disinflation in the face of positive inflation pressure.

3. Illustration of the Methodology

All three indices introduced in Section 2 include at least one variable that is not directly observable. In particular, the concepts of ex post and ex ante inflation pressure are counter-factuals which must be imputed. In this section we demonstrate how to derive the expressions for these unobservable variables from a theoretical model.

In subsequent sections, we use a quarterly model to estimate our indices for the United States. Because the index formulae we obtain from the quarterly model are very complex, we use a much simpler aggregate model to illustrate the method by which we obtain our indices. Although our methodology is not model dependent, we feel that it is important to illustrate the application of our methodology in the context of a familiar model whose properties are well-known to as many potential readers as possible. For this reason we use Clarida, Galí, and Gertler's (*JEL* 1999) aggregate rational-expectations model to illustrate the derivation of measures of inflation pressure and monetary policy response.

3.1 A Simple Aggregate Model

Our illustrative economy is characterized by the following equations:

$$y_t = -\beta_1[i_t - \mathrm{E}_t\pi_{t+1}] + \beta_2\mathrm{E}_t y_{t+1} + u_t \tag{7}$$

$$\pi_t = \alpha_1\mathrm{E}_t\pi_{t+1} + \alpha_2 y_t + e_t \tag{8}$$

$$i_t = \rho i_{t-1} + (1-\rho)[\gamma_\pi\mathrm{E}_t\pi_{t+1} + \gamma_y\mathrm{E}_t y_{t+1}] \tag{9}$$

where y_t is the output gap in period t, i_t is the nominal interest rate, and π_t is the inflation rate in period t. The variable $\mathrm{E}_t\pi_{t+1}$ denotes the expectation that rational agents form in period t about the level of inflation that will prevail in period $t+1$. Similarly, $\mathrm{E}_t y_{t+1}$ is the rational, one-period-ahead expectation of the output gap. The random disturbances u_t and e_t are assumed to be independently distributed and to have zero means.

3.2 Derivation of Index Formulae

The first step in deriving model-consistent measures of ex ante inflation pressure and monetary policy response, is to obtain the rational expectations solution for our model. We begin by postulating the following minimal state variable (MSV) solutions for y_t and π_t

$$y_t = q_1 u_t + q_2 e_t + q_3 i_{t-1} \tag{10}$$

$$\pi_t = \delta_1 u_t + \delta_2 e_t + \delta_3 i_{t-1}. \tag{11}$$

Under the assumption that the information sets available to agents at time t contain all lagged variables as well as contemporaneous observations of i_t, y_t, and π_t, (10) and (11) imply the following one-period-ahead expectations

$$\mathrm{E}_t y_{t+1} = q_3 i_t \tag{12}$$

$$\mathrm{E}_t \pi_{t+1} = \delta_3 i_t. \tag{13}$$

Substituting (9), (12) and (13) into (7) and (8) yields

$$y_t = [-\beta_1 + \beta_1\delta_3 + \beta_2 q_3]\Lambda^{-1}\rho i_{t-1} + u_t \tag{14}$$

$$\pi_t = \{\alpha_1\delta_3 + \alpha_2[-\beta_1 + \beta_1\delta_3 + \beta_2 q_3]\}\Lambda^{-1}\rho i_{t-1} + \alpha_2 u_t + e_t \tag{15}$$

where $\Lambda = 1 - (1-\rho)\gamma_\pi\delta_3 - (1-\rho)\gamma_y q_3$.

3.2.1 Ex Ante Inflation Pressure

According to our definition, ex ante inflation pressure measures the inflation rate that would have been observed in a given period if the policy authority had held the interest rate constant at the level observed in the previous period. When the actual value of ρ is less than unity (i.e., $0 \leq \rho < 1$), ex ante inflation pressure therefore measures a fully-anticipated one-period deviation from the observed (average) interest rate rule given in (9). Ex ante inflation pressure in period t can be obtained from (15) by setting $\rho = 1$ in period t. According to our model, holding $i_t = i_{t-1}$ generates the following inflation process

$$\pi_t^0 = [\alpha_2\beta_1(\delta_3^0 - 1) + \alpha_1\delta_3^0 + \alpha_2\beta_2 q_3^0]i_{t-1} + \alpha_2 u_t + e_t \tag{16}$$

where the superscripts on δ_3 and q_3 indicate that the values of these coefficients were obtained by setting $\rho = 1$ in period t.[6] The variable π_t^0 is a counterfactual, and as such is not directly observable. In order to impute π_t^0 from our model, we need to solve for the undetermined coefficients in (16). In addition, because the random disturbances, u_t and e_t, are not observable, we need to use the model to derive the relationship between the unobservable shocks and the changes in observable endogenous variables that occur in response to these shocks.

Comparing (14) and (15) with (10) and (11), respectively, we obtain $\delta_1 = \alpha_2$, $\delta_2 = q_1 = 1$, $q_2 = 0$. With $\rho_t = 1$, δ_3 and q_3 are given by

$$\delta_3^0 = \frac{-\alpha_2\beta_1}{(1-\alpha_1)(1-\beta_2)-\alpha_2\beta_1} \tag{17}$$

$$q_3^0 = \frac{-\beta_1(1-\alpha_1)}{(1-\alpha_1)(1-\beta_2)-\alpha_2\beta_1}. \tag{18}$$

In order to recover the disturbances u_t and e_t from (10) and (11), we need to solve for the undetermined coefficients in these two equations under the interest rate policy actually implemented. The coefficients δ_1, δ_2, q_1, and q_2 are independent of the magnitude of ρ and are therefore identical in value to those obtained above for $\rho_t = 1$. The remaining coefficients, δ_3 and q_3, are not independent of ρ and must therefore be recalculated. It turns out that even in this simple model, δ_3 and q_3 are non-linear functions of each other whose solution requires the application of numerical methods. Obtaining the solutions for δ_3 and q_3 would require estimation of (7)–(9). However, as these numerical solutions are not necessary for the purposes of this illustration, we postpone the application of numerical methods until Section 5, where we estimate our indices for the United States using quarterly data. Under the assumption that solutions for δ_3 and q_3 exist, we may express u_t and e_t as

$$u_t = y_t - q_3 i_{t-1} \tag{19}$$

[6]Note that in the simple model we have specified, π_t is a function of current and past ρ values only. By setting $\rho_t = 1$ and expressing the RE solution for π_t in terms of i_{t-1}, we implicitly set all past ρ values at their actual (observed) values and ensure that (16) measures the impact of a one-period deviation from the actual policy rule on inflation.

$$e_t \;=\; \pi_t \;-\; \alpha_2 y_t \;+\; [\alpha_2 q_3 - \delta_3] i_{t-1}. \tag{20}$$

Substituting (19) and (20) into (16) yields the operational formula for measuring ex ante inflation pressure that is consistent with our illustrative model:

$$\pi_t^0 \;= \pi_t \;+\; \Big\{[\alpha_1 + \alpha_2\beta_1]\delta_3^0 \;-\; \alpha_2\beta_2 q_3^0 \;-\; \delta_3 \;-\; \alpha_2\beta_1\Big\}\, i_{t-1}. \tag{21}$$

By definition, the IP index can then be obtained as

$$IP_t \;=\; \pi_t^0 \;-\; \pi_{t-1}.$$

3.2.2 Ex Post Inflation Pressure

Ex post inflation pressure is the inflation pressure that remains after the monetary policy response has taken effect. In Figure 1, ex post inflation pressure in period t is given as the vertical distance between the two feasibility constraints, IR_0 and IR_1, at i_{t-1}. Using the notation in Figure 1, ex post inflation pressure is given by $\pi_t^w - \pi_{t-1}$. Clearly, π_t^w is a counter-factual which is not directly observable. However, we can use our theoretical model to derive an operational formula for ex post inflation pressure that can be calculated on the basis of oberved changes in inflation and interest rate levels.

As a first step, we substitute (7) into (8) to obtain the semi-reduced form for π_t:

$$\pi_t \;=\; \alpha_1 \mathrm{E}_t\pi_{t+1} \;-\; \alpha_2\beta_1 i_t + \alpha_2\beta_1 \mathrm{E}_t\pi_{t+1} \;+\; \alpha_2\beta_2 \mathrm{E}_t y_{t+1} \;+\; \alpha_2 u_t \;+\; e_t. \tag{22}$$

In the context of our model, ex post inflation pressure in period t is measured as the change in inflation that would have been generated by u_t, e_t, and i_{t-1}, given the expectations that were formulated under the policy actually implemented (i.e., under i_t). Replacing i_t with i_{t-1} in (22) yields

$$\pi_t^w \;=\; \alpha_1 \mathrm{E}_t\pi_{t+1} \;-\; \alpha_2\beta_1 i_{t-1} + \alpha_2\beta_1 \mathrm{E}_t\pi_{t+1} \;+\; \alpha_2\beta_2 \mathrm{E}_t y_{t+1} \;+\; \alpha_2 u_t \;+\; e_t. \tag{23}$$

It follows immediately from (22) and (23) that π_t^w can be measured as

$$\pi_t^w \;=\; \pi_t \;+\; \alpha_2\beta_1 \Delta i_t. \tag{24}$$

4. The Quarterly Model

In order to obtain quarterly indices of inflation pressure and the Federal Reserve's policy stance, we employ a quarterly empirical specification that is a variation of models employed in earlier work by Clarida, Galí and Gertler (2000), Fuhrer (2002), and Rudebusch (2002). The fact that similar equations have been estimated by others provides us with benchmarks against which to compare our estimations results.[7]

4.1 The Empirical Model

Our quarterly empirical model is composed of the following equations:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 \mathrm{E}_t y_{t+1} - \beta_3 [i_{t-1} - \mathrm{E}_t \bar{\pi}_{t+3}] + \eta_t \tag{25}$$

$$\pi_t = \alpha_0 + \alpha_1 \mathrm{E}_t \bar{\pi}_{t+3} + (1-\alpha_1)[\alpha_2 \pi_{t-1} + \alpha_3 \pi_{t-2} + \alpha_4 \pi_{t-3} + \alpha_5 \pi_{t-4}] + \alpha_6 y_{t-1} + \varepsilon_t \tag{26}$$

$$i_t = \gamma_0 + \rho i_{t-1} + (1-\rho)[\gamma_\pi \mathrm{E}_t \bar{\pi}_{t+3} + \gamma_y y_t] \tag{27}$$

$$\bar{\pi}_{t+3} = \frac{1}{4}[\pi_t + \pi_{t+1} + \pi_{t+2} + \pi_{t+3}] \tag{28}$$

where $\gamma_0 = (1-\rho)[r^* - \gamma_\pi \pi^*]$.

4.2 Formulae for Quarterly Ex Ante and Ex Post Inflation Pressure

The quarterly model has a much more complex lag structure than the illustrative model employed in Section 3. As a consequence, the implementation of our general definition of ex ante inflation pressure in the context of this model requires careful treatment of the timing of key variables.

Our quarterly model specifies a two period control lag between the interest rate and inflation. We therefore construct our quarterly ex ante inflation pressure index by

[7] Some compromises were necessary in order to ensure that the model remained analytically tractable and, at the same time, yielded reasonable estimation results. For purposes of tractability, we economized on the number of lagged variables wherever possible and included the contemporaneous output gap in (27), rather than the expectation of a future output gap as in (9).

computing the inflation rate that would have been observed in period t if the interest rate in period $t-2$ had been held constant at its period $t-3$ level. As before, when we conduct this counterfactual experiment for a given period, we assume that the interest rate in all other periods was generated by the policy authority's estimated interest rate response function. Consequently, our measure of inflation pressure captures the impact on inflation of a very specific one-period deviation from the interest rate rule. In the context of the model, we set $\rho = 1$ in period $t-2$ and $\rho = \hat{\rho}$, where $\hat{\rho}$ is the estimated coefficient value, for all other time periods.[8]

Applying the methodology described in Section 3 to the quarterly model yields the following formulae for computing ex ante inflation:

$$\begin{aligned}\pi_t^0 \; &= \; \Gamma_0^0 + \Gamma_1^0 i_{t-3} + \Gamma_2^0 y_{t-2} + \Gamma_3^0 \pi_{t-2} + \Gamma_4^0 \pi_{t-3} + \Gamma_5^0 \pi_{t-4} \\ &\quad + \Gamma_6^0 \pi_{t-5} + \Gamma_7^0 \eta_{t-1} + \Gamma_8^0 \varepsilon_{t-1} + \Gamma_9^0 \varepsilon_t \end{aligned} \tag{29}$$

where

$$\eta_t \;=\; (q_7 \delta_8 - \delta_7 q_8)^{-1} X_t^{\eta} \tag{30}$$

$$\varepsilon_t \;=\; (q_7 \delta_8 - \delta_7 q_8)^{-1} X_t^{\varepsilon} \tag{31}$$

The coefficients Γ_i^0, $i = 1, ..., 9$,in (29) are complex composites of the parameter estimates in (26)–(28). The variables X_t^{η} and X_t^{ε} are comprised of weighted sums of current and/or lagged changes in the interest rate, inflation rate, and output level. Details of the derivation of (29)–(31) and the definitions of the relevant composite coefficients and composite variables in these equations may be found in Appendix 1.

[8]Note that because (25)–(28) include lagged variables, our quarterly measure of ex ante inflation pressure for any given period captures not only the impact of current exogenous disturbances, but also the impact of past policy actions as they are reflected in the values of lagged endogenous variables. In the context of quarterly empirical model, our ex ante index of inflation pressure measures the inflation rate that would have been observed in period t, *taking policies in period* $t-4$ *and earlier as given*, if there had been no change in the interest rate between periods $t-3$ and $t-2$. However, to the extent that past policy actions contribute to the inflationary environment that the policy authority faces in any given period, our ex ante inflation pressure index still provides a useful benchmark against which to measure the strength and effectiveness of the monetary authority's policy response.

Ex post inflation pressure, $\pi_t^w - \pi_{t-1}$, measures the inflation pressure that remains subsequent to the implementation of monetary policy (measured as interest rate changes). Given the two period control lag in our model, ex post inflation pressure in period t is measured in terms of the observed change in inflation in period t and the observed change in the interest rate from period $t-3$ to period $t-2$. The formula for ex post inflation pressure that is consistent with our quarterly model is

$$\pi_t^w - \pi_{t-1} \; = \Delta\pi_t \; + \; \alpha_6 \beta_3 \Delta i_{t-2}. \tag{32}$$

In order to calculate our inflation pressure indices we need estimates of the coefficients in our model as well as the rational expectations solutions for the endogenous variables π_t, y_t, and i_t. The estimation procedures we employ are described in the following section. The complexity of the expectational structure of our model does not permit us to obtain closed-form rational expectations solutions for π_t, y_t, and i_t. Details of the numerical methods used to obtain the rational expectations solutions for these variables are given in Appendix 2.

4.3 Estimation Method

Two types of expectational variables appear in our model, they reflect the expectations formed by private agents about future inflation and the future output gap. From a purely empirical perspective, we could use ordinary least squares (OLS) to estimate our model if data for these expectational variables were available. For example, Rudebusch (2002) uses the Michigan survey of inflation expectations to estimate a quarterly version of (8) by OLS. However, whether it is appropriate to use such survey data to estimate a rational expectations model is still an open question.

An alternative way of estimating our model, which does not require the use of survey data for the expectational variables, is to use the generalized method of moments (GMM), which utilizes the moment restrictions implied by rational expectations. In recent work, Clarida, Galí and Gertler (2000) and Rudebusch and Fuhrer (2002) used GMM to estimate single equations containing expectations that were assumed to have been formed rationally. Following the example of these earlier studies, we use GMM to estimate our rational expectations model. Details of our GMM estimation are given in Appendix 3.

4.4 Data and Estimation Results

Following Fuhrer and Rudebusch (2002), the sample period for the estimation extends from 1966:1 to 2001:4. We utilize quarterly data from various sources. The output gap is defined as $y_t \equiv q_t - q_t^*$ where $q_t \equiv 100 \ln Q_t$ with Q_t defined as chain-weighted real GDP, and q_t^* is the log of real potential output compiled by the Congressional Budget Office (CBO). To check the sensitivity of our results to alternative output gap formulations, we also consider an alternative measure of the output gap based on a Hodrick-Prescott (HP) filtered q_t. Inflation is defined as $\pi_t \equiv 100(\ln P_t - \ln P_{t-1})$ where P_t is the GDP chain-weighted price index. For the interest rate i_t, we use a quarterly average of the federal funds rate.

Our estimates were obtained using single-equation GMM. We chose to estimate the equations individually rather than using multipl-equation GMM to estimate the component equations jointly for a number of reasons. First, as pointed out in Hayashi (2000, p.273), joint estimation can be hazardous. While it theoretically provides asymptotic efficiency, it may suffer more from the small-sample bias in practice. Single equation GMM is less vulnerable to problems of misspecification. Second, parameter estimates in related studies, including Clarida, Galí and Gertler (2000) and Rudebusch and Fuhrer (2002), were obtained using single equation GMM. Using single equation GMM therefore facilitates the comparison of our estimates with those obtained in earlier studies.

In estimating the Fed's interest rate rule (27) we followed Clarida, Galí and Gertler's (2000) example and split the data set into two subsamples: (i) Pre-Volcker (1966:1–1979:2) and (ii) Volcker-Greenspan (1979:3–2001:4). Because the size of our data set is quite modest, we chose not to allow for structural breaks when estimating the quarterly Phillips curve (25) and aggregate demand equation (26). These two equations were therefore estimated using the full sample. Our estimation results are presented in Table 1.

The signs of all of our unrestricted parameter estimates are consistent with theory and also with the results obtained in earlier studies. Note however that Clarida, Galí, and Gertler (2002) found γ_π to be below unity for the pre-Volcker period and greater than unity after that. The results reported in Table 1 show that the γ_π estimates are greater than unity for both Pre-Volcker and Volcker-Greenspan periods. This is consistent with Inoue and Shintani (2004) who find that the hypothesis that γ_π exceeds unity cannot be rejected for Pre-Volcker period. The results obtained using the HP filtered data are quite similar to those obtained using the CBO's output gap and are therefore not reported here.

Fuhrer and Rudebusch (2002) have shown that GMM estimators may exhibit finite sample bias, causing asymptotic standard errors to be unreliable indicators statistiacal significance. We have dealt with this problem by employing Inoue and Shintani's (2003) block bootstrap procedure, which is designed to improve the finite sample property of the standard error in GMM estimations with correlated errors. The 90% confidence intervals generated by this bootstrap procedure are reported in Table 1.

5. Estimated Indices for the United States

Using the coefficient estimates in Table 1, the RE solution associated with these estimates from Table A2.1 of Appendix 2, and (29)–(31), yields the following operational formulae for ex ante inflation pressure π_t^0.

Pre-Volcker:

$$\begin{aligned}\pi_t^0 \;=\;& 0.2219 + 0.0105 i_{t-1} + 0.0292 i_{t-2} - 0.0406 i_{t-3} \\ & - 0.0417 y_t + 0.0691 y_{t-1} + 0.0262 y_{t-2} + 1.0064 \pi_t \\ & + 0.4991 \pi_{t-1} + 0.2769 \pi_{t-2} - 0.0032 \pi_{t-3} - 0.0026 \pi_{t-4} \qquad (33)\end{aligned}$$

Table 1

GMM Estimates

Parameters	Estimates	90% Confidence Interval	
Output Equation [1966:1 - 2001:4]			
β_0	0.216	(0.041,	0.346)
β_1	0.442	(0.407,	0.489)
β_2	0.569	(0.512,	0.614)
β_3	0.070	(0.007,	0.112)
Inflation Equation [1966:1 - 2001:4]			
α_0	-0.041	(-0.102,	0.031)
α_1	0.473	(0.357,	0.599)
α_2	0.669	(0.592,	0.774)
α_3	-0.013	(-0.097,	0.047)
α_4	0.109	(0.034,	0.153)
α_5	0.253	(0.206,	0.344)
α_6	0.043	(0.019,	0.073)
Pre-Volcker Policy Function [1966:1-1979:2]			
γ_0	-1.111	(-1.721,	-0.408)
ρ	0.585	(0.490,	0.690)
γ_π	1.508	(1.169,	1.886)
γ_y	0.572	(0.453,	0.775)
Volcker-Greenspan Policy Function [1979:Q3-2001:Q4]			
γ_0	0.163	(-0.463,	0.455)
ρ	0.800	(0.698,	1.011)
γ_π	2.020	(0.296,	5.304)
γ_y	0.467	(-0.271,	3.297)

Notes: Instruments are y_{t-1}, y_{t-2}, y_{t-3}, y_{t-4}, π_{t-1}, π_{t-2}, π_{t-3}, π_{t-4} and a constant.

Volcker-Greenspan:

$$\begin{aligned}\pi_t^0 \;=\;& 0.1309 \;+\; 0.0327 i_{t-1} \;+\; 0.0548 i_{t-2} \;-\; 0.0912 i_{t-3} \;-\; 0.0389 y_t \\ & -\, 0.0699 y_{t-1} \;-\; 0.0020 y_{t-2} \;+\; 1.0092 \pi_t \;-\; 0.5508 \pi_{t-1} \\ & +\, 0.0012 \pi_{t-2} - \; 0.0031 \pi_{t-3} \;+\; 0.3567 \pi_{t-4} \;-\; 0.0016 \pi_{t-5}. \end{aligned} \tag{34}$$

The formula for ex post inflation pressure, $\pi_t^w - \pi_{t-1}$, which applies to the entire sample period is given by

$$\pi_t^w - \pi_{t-1} \;= \Delta \pi_t \;+\; 0.0003 \Delta i_{t-2}. \tag{35}$$

The time series of index values that we obtain using the definitions introduced in Section 2 and the formulae in (33)–(35) are given in Tables 2, 3, and 4.

6. A Quantitative Characterization of Federal Reserve Policy

Our objective in deriving theory-based indices of inflation pressure and monetary policy response is to provide measures that allow for a quantitative characterization of (i) the economic environment facing the policy authority and (ii) the policy authority's response to that environment. Although the definitions of our indices are model-independent, the index formulae, which entail counterfactual calculations, are necessarily model-specific. The model we have used to derive and estimate our index formulae was chosen for several reasons. First, forward-looking micro-founded aggregate models of this type have been used to study a wide variety of monetary policy issues in recent years. Our model is therefore familiar and its properties are well-understood. Second, because the calculation of our counterfactual inflation pressure index is quite complex, the model employed needs to be simple enough to yield tractable index formulae but also rich enough to capture the forward-looking aspects of modern monetary policy. Finally, the indices we have proposed have no counterparts in the literature that can be used for purposes of comparison. It is therefore important that the parameter estimates upon which the calculated index values are based can be shown to be reasonable. The equations that comprise our model have

Table 2

Quarterly Indices for the United States

Pre-Volcker (1966:1 – 1979:2)

	$\Delta\pi_t$	IP	EPS	PE		$\Delta\pi_t$	IP	EPS	PE
1966:1	−0.35	−0.31	−0.13	1.13	1973:1	0.56	0.63	0.11	0.89
2	1.30	1.42	0.08	0.92	2	1.26	1.37	0.08	0.92
3	0.29	0.41	0.29	0.71	3	0.96	1.15	0.17	0.84
4	−0.36	−0.25	−0.42	1.42	4	−0.72	−0.57	−0.26	1.26
1967:1	−1.79	−1.70	−0.06	1.06	1974:1	1.25	1.50	0.17	0.84
2	0.79	0.94	0.16	0.84	2	0.84	0.93	0.10	0.90
3	1.09	1.19	0.08	0.91	3	3.17	3.35	0.06	0.94
4	0.75	0.86	0.12	0.87	4	−0.04	0.21	1.18	−0.15
1968:1	0.11	0.19	0.44	0.56	1975:1	−2.90	−2.71	−0.07	1.07
2	−0.05	0.04	2.39	−1.36	2	−3.52	−3.52	0.00	1.00
3	−0.81	−0.68	−0.18	1.18	3	1.61	1.64	0.02	0.98
4	1.91	2.09	0.08	0.92	4	−0.32	−0.19	−0.70	1.71
1969:1	−1.70	−1.65	−0.03	1.03	1976:1	−2.62	−2.49	−0.05	1.05
2	1.57	1.70	0.08	0.92	2	−0.04	0.10	1.46	−0.48
3	0.36	0.51	0.30	0.71	3	1.28	1.46	0.13	0.87
4	−0.65	−0.43	−0.51	1.50	4	1.41	1.62	0.13	0.87
1970:1	0.36	0.54	0.35	0.66	1977:1	−0.30	−0.13	−1.26	2.26
2	0.06	0.22	0.71	0.29	2	−0.11	0.00	21.85	−21.09
3	−2.40	−2.30	−0.05	1.05	3	−0.90	−0.80	−0.12	1.12
4	2.01	2.22	0.10	0.90	4	1.05	1.25	1.16	0.84
1971:1	0.87	0.92	0.06	0.94	1978:1	0.06	0.26	0.77	0.24
2	−0.75	−0.65	−0.14	1.15	2	1.15	1.22	0.06	0.94
3	−1.24	−1.15	−0.08	1.09	3	−0.81	−0.72	−0.13	1.13
4	−0.82	−0.60	−0.37	1.37	4	0.93	1.03	0.10	0.90
1972:1	2.66	2.84	0.06	0.94	1979:1	−0.31	−0.18	−0.79	1.77
2	−3.49	−3.46	−0.01	1.01	2	1.33	1.51	0.12	0.88
3	1.49	1.60	0.07	0.93					
4	0.83	0.97	0.15	0.86					

Table 3

Quarterly Indices for the United States

Volcker (1979:3 – 1987:2)

	$\Delta\pi_t$	IP	EPS	PE		$\Delta\pi_t$	IP	EPS	PE
1979:3	−0.89	−0.95	0.07	0.93					
4	−0.09	−0.15	0.40	0.59					
1980:1	0.93	1.01	0.08	0.93	1984:1	1.45	1.55	0.07	0.93
2	0.16	0.44	0.64	0.38	2	−1.46	−1.46	0.00	1.00
3	−0.20	−0.19	−0.08	1.05	3	−0.19	−0.11	−0.74	1.73
4	1.64	1.24	−0.32	1.31	4	−0.36	−0.22	−0.63	1.62
1981:1	−0.47	−0.67	0.30	0.71	1985:1	1.46	1.52	0.04	0.97
2	−3.02	−2.54	−0.19	1.18	2	−1.62	−1.82	0.11	0.89
3	0.64	0.65	0.01	0.99	3	−0.50	−0.58	0.12	0.88
4	−0.46	−0.38	−0.20	1.19	4	0.69	0.69	0.00	1.00
1982:1	−1.66	−1.78	0.07	0.93	1986:1	−1.25	−1.22	−0.03	1.03
2	−0.44	−0.75	0.41	0.61	2	0.31	0.40	0.22	0.78
3	0.35	0.52	0.32	0.68	3	0.63	0.64	0.02	0.98
4	−1.38	−1.37	0.00	1.00	4	0.35	0.32	−0.08	1.08
1983:1	−0.92	−1.21	0.24	0.77	1987:1	0.71	0.73	0.02	0.98
2	0.38	0.28	-0.35	1.34	2	−0.76	−0.71	−0.06	1.06
3	−0.20	−0.18	−0.13	1.14					
4	−0.03	0.07	1.42	−0.42					

Table 4

Quarterly Indices for the United States

Greenspan (1987:3 – 2001:4)

	$\Delta\pi_t$	IP	EPS	PE		$\Delta\pi_t$	IP	EPS	PE
1987:3	0.08	0.15	0.43	0.57					
4	0.34	0.40	0.16	0.85					
1988:1	−0.53	−0.48	−0.10	1.10	1995:1	1.06	1.23	0.14	0.86
2	1.34	1.37	0.02	0.98	2	−1.24	−1.08	−0.15	1.15
3	0.65	0.68	0.04	0.96	3	0.16	0.30	0.49	0.52
4	−1.58	−1.53	−0.03	1.03	4	0.11	0.20	0.45	0.56
1989:1	1.00	1.09	0.08	0.92	1996:1	0.51	0.58	0.11	0.89
2	−0.14	−0.07	−0.90	1.88	2	−1.10	−1.08	−1.02	1.02
3	−1.09	−1.01	−0.08	1.08	3	0.60	0.65	0.08	0.92
4	0.07	0.09	0.21	0.80	4	−0.37	−0.32	−0.15	1.15
1990:1	1.53	1.46	−0.05	1.05	1997:1	1.30	1.38	0.06	0.94
2	0.09	0.04	−1.03	2.00	2	−1.08	−1.06	−0.02	1.02
3	−0.74	−0.75	0.01	0.99	3	−0.63	−0.59	−0.07	1.07
4	−0.36	−0.29	−0.22	1.22	4	0.27	0.35	0.23	0.77
1991:1	1.14	1.22	0.06	0.94	1998:1	−0.39	−0.37	−0.07	1.07
2	−1.79	−1.83	0.02	0.98	2	−0.04	0.02	3.15	−2.16
3	−0.24	−0.29	0.16	0.85	3	0.38	0.44	0.13	0.87
4	−0.46	−0.42	−0.08	1.09	4	−0.31	−0.29	−0.07	1.07
1992:1	0.91	0.97	0.06	0.94	1999:1	0.69	0.72	0.05	0.95
2	−0.76	−0.78	0.02	0.98	2	−0.24	−0.25	0.05	0.96
3	−0.97	−0.96	−0.01	1.02	3	−0.31	−0.29	−0.07	1.07
4	1.21	1.27	0.05	0.95	4	0.45	0.48	0.06	0.94
1993:1	0.80	0.88	0.09	0.91	2000:1	1.35	1.44	0.06	0.94
2	−1.18	−1.10	−0.07	1.07	2	−0.73	−0.71	−0.04	1.04
3	−0.31	−0.19	−0.61	1.61	3	−0.65	−0.57	−0.14	1.14
4	0.41	0.50	0.17	0.83	4	0.40	0.51	0.21	0.80
1994:1	−0.18	−0.09	−1.08	2.08	2001:1	1.58	1.67	0.06	0.94
2	−0.22	−0.15	−0.49	1.49	2	−1.20	−1.17	−0.03	0.58
3	0.53	0.68	0.21	0.79	3	−0.23	−0.27	0.12	0.89
4	−0.51	−0.37	−0.39	1.39	4	−2.70	−2.79	0.03	0.97

been estimated at quarterly frequency by a number of authors, providing us with useful benchmarks for our parameter estimates.

In this section we illustrate how the indices we have proposed can be used to assess the effectiveness of monetary policy. We begin by comparing monetary policy as described by our indices with Greenspan's (2004) narrative account of Federal Reserve policy. This application serves two purposes: (1) it allows us to verify that the indices we have estimated are generally consistent with Greenspan's view of the Federal Reserve's policy stance, and (2) it enables us to demonstrate how our indices can be used to enhance our understanding of the nature and impact of monetary policy. In our second illustration we use our indices to compare the Federal Reserve's policy under its five most recent chairmen.

6.1 Federal Reserve Policy: 1979:3–2001:4

Over the past two decades the Federal Reserve implemented policies that supported not only the longest period of expansion since World War II, but also a return to price stability. Greenspan (2004) attributes this success to the use of pre-emptive monetary policies in an environment conducive to the pursuit of price stability. According to Greenspan, political support for price stability, greater global competition, and productivity increases, were all important contributors to the success of the Fed's price stabilization efforts. The view that economic conditions contributed significantly to the Fed's success in controlling inflation is supported by the ex ante inflation measures given in Table 4. In particular, our IP index shows that over the period 1987:3–2001:1, there were 30 quarters of negative ex ante inflation pressure. This means that inflation would have fallen roughly fifty per cent of the time even if the Fed had not implemented any interest rate changes.

Greenspan highlights three occasions on which the Fed eased monetary policy in order to prevent liquidity crises from taking hold. These events were the stock-market crash in October 1987, the Russian debt default in the third quarter of 1998, and the terrorist attack on the United States in September 2001. In each of these cases the change in Fed policy is clearly discernible in the data.

The two quarters leading up to the 1987 stock-market crash span Volcker's last quarter and Greenspan's first quarter as Fed chairman. The negative value of the EPS index for 1987:2 indicates that monetary policy under Volcker magnified the impact of exogenous forces on inflation, causing inflation to fall 6 per cent more that it would have without an increase in the interest rate. In 1987:3, IP was positive; the Fed tightened monetary policy removing 43 per cent of ex ante inflation pressure. The change in Fed chairmanship appears to have had a significant impact on inflation expectations. The PE value of 0.57 indicates that the monetary policy implemented by the Fed brought about a 43 per cent drop in inflation expectations. The rise of the IP index from 0.15 in 1987:3 to 0.40 1987:4 and the reduction of the EPS index from 0.43 to 0.16 over the same period, reflects a general easing of monetary policy in response to the stock-market crash.

As in the case of the 1987 stock-market crash, the loosening of monetary policy in response to the 1998 Russian debt default shows up clearly in our indices as an abrupt change in the direction of policy. In the two quarters preceding the default, the Fed had engaged in a concerted effort not only to reduce inflation, but to reduce the average price level. In the first two quarters of 1998, IP was -0.37 and 0.02, respectively. In 1989:1 the Fed's contractionary policy magnified the drop in ex ante inflation by 7 per cent; in 1989:2, IP was mildly positive, but tight monetary policy resulted in a 4 per cent drop in inflation. The steep increase in IP, from 0.02 in 1998:2 to 0.44 in 1998:3, and the relatively small EPS value of 0.13 support Greenspan's contention that the Fed was more concerned with averting a potential liquidity crisis than with controlling inflation in the third quarter of 1998.

According to our indices, ex ante inflation pressure was negative in the two quarters preceding the September 2001 terrorist attack. The EPS index value of -0.03 indicates that monetary policy magnified the deflationary impact of exogenous disturbances in 2001:2. The Fed's policy response to the September 11th crisis is captured, in part, by the rise of the EPS index to 0.12. It is worth emphasizing that the

EPS index measures the effectiveness of the policy response rather than the absolute magnitude of the policy initiative. The Federal Funds rate dropped 83 basis points during the third quarter of 2001 and a further 136 basis points in the fourth quarter of that year. The fact that these substantial interest rate reductions eliminated only 12 per cent of deflationary pressure in 2001:3 and 3 per cent of deflationary pressure in 2001:4 gives a good indication of the magnitude of the contractionary forces that the Fed was attempting to combat. The PE ratio shows that while the reduction in interest rates in 2001:3 was effective in reducing deflationary expectations by 11 per cent, the much larger reduction in interest rates that took place the following quarter only reduced deflationary expectations by 3 per cent.

In his article, Greespan comments that even though the Fed found it necessary to counteract deflationary pressures from time to time, it never wavered from its commitment to achieve long-run price stability. The indices that we have estimated provide objective evidence of the validity of this statement. Our indices show that the Fed, under Greenspan, consistently reisted inflation pressure and, with the exception of the periods of crisis mentioned above, capitalized on deflationary pressures whenever the opportunity presented itself.

6.2 Monetary Policy under Five Federal Reserve Chairmen

In order to compare the policy stance of the Federal Reserve under different chairmen, we split the sample into sub-periods corresponding to the periods of tenure of the five most recent Federal Reserve chairmen. For each sub-period we calculated average values for the output gap, changes in observed inflation, and ex ante inflation pressure (IP). For inflation and ex ante pressure we also calculated the associated standard deviations. These figures are to be found in columns two through five in Table 5. The Fed's average monetary policy response for each sub-period is given in columns 6 and 7.[9] In these two columns we distinguish between the Fed's response to reductions in

[9] In a few cases, outliers were excluded to prevent the averages from misrepresenting the Fed's overall policy stance in a particular period. The quarters excluded from the calculation of average EPS and PE values in Yable 5 are: 1977:2 (Burns), 1990:2 (Greenspan), and 1998:2 (Greenspan).

ex ante inflation pressure ($\Delta\pi_t^0 < 0$) and its response to increases in ex ante inflation pressure ($\Delta\pi_t^0 > 0$). The last two columns in Table 5 provide average measures of the impact of Fed policy on inflation expectations (PE).

For Volcker and Greenspan we calculated averages for specific subsamples as well as for the sample period as a whole. In Volcker's case, the negative average output gap was sometimes accompanied by inflation and at other times by deflation.[10] Distinguishing between periods when the US economy experienced stagflation and periods in which inflation and the output gap were both negative on average allows us to determine whether there was a significant difference in the Fed's response to these two situations. The data shows that the average rate of inflation was positive during the first three years of Greenspan's tenure and negative thereafter. The average output gap, on the other hand was positive for the first three years, negative for the succeeding six years, and once again positive for the final four years. Over the fourteen years included in our sample the Fed, under Greenspan's direction, dealt with a typical expansion in which both output and inflation were increasing, a typical recession in which both output and inflation fell, and a period in which output increases were accompanied by reduction in inflation. The sub-samples we have identified correspond to each of these distinct circumstances.

One of the most striking aspects of the averages reported in Table 5 is the similarity of the Fed's policy response over the 35 year period under study. The EPS index measures the proportion of inflationary (or deflationary) pressure removed by

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In the case of Greenspan, the outliers were exluded in calculating the average index values for the relevant subsamples, but not for the overall average. Including 1977:2 in Burns' average results in EPS and PE values of 1.33 and -0.34, respectively, for $\Delta\pi_t^0 > 0$. For Greenspan, including 1990:2 in the first subsample yields EPS=-0.02 and PE=1.02 for $\Delta\pi_t^0 > 0$; including 1998:2 in the third subsample yields EPS=0.44 and PE=0.55 for $\Delta\pi_t^0 > 0$.

[10] Periods in which inflation was predominantly positive were initially identified by inspection. Following that an iterative procedure was applied to determine whether the addition or subtraction of marginal quarters increased or reduced the average (in absolute terms). The same procedure was employed to distinguish between periods in which the output gap was predominantly positive or negative during Greenspan's chairmanship.

TABLE 5

Inflation Pressure and Monetary Policy Response

Chairman	Output Gap: y_t	$\Delta\pi_t$		IP = $\Delta\pi_t^0$		Policy Response: EPS		Effectiveness: PE	
	mean	mean	sdev	mean	sdev	$\Delta\pi_t^0 > 0$	$\Delta\pi_t^0 < 0$	$\Delta\pi_t^0 > 0$	$\Delta\pi_t^0 < 0$
Martin (1966:1–1969:4)	3.80	0.19	1.08	0.27	1.10	0.40	−0.22	0.60	1.22
Burns (1970:1–1978:1)	−0.64	0.05	1.65	0.19	1.68	0.30†	−0.26	0.70†	1.26
Miller (1978:2–1979:2)	1.51	0.46	0.96	0.57	0.96	0.09	−0.46	0.91	1.45
Volcker: (1979:3–1980:4)	−1.38	0.26	0.89	0.24	0.82	0.13	0.13	0.86	0.87
(1981:1–1985:3)	−3.78	−0.44	1.10	−0.45	1.10	0.25	−0.05	0.64	1.05
(1985:4–1987:2)	−0.78	0.10	0.78	0.12	0.77	0.04	−0.05	0.96	1.05
(1979:3–1987:2)	−2.67	−0.19	1.02	−0.19	1.01	0.15	−0.02	0.85	1.02
Greenspan: (1987:3–1990:2)	0.60	0.15	0.92	0.18	0.90	0.13†	−0.28	0.87†	1.27
(1990:3–1996:3)	−1.72	−0.10	0.83	−0.04	0.85	0.17	−0.21	0.83	1.21
(1996:4–2001:4)	1.30	−0.12	0.96	−0.08	1.00	0.11†	−0.04	0.94†	1.04
(1987:3–2001:4)	−0.15	−0.06	0.89	−0.01	0.91	0.21	−0.15	0.79	1.15

† Outliers were excluded from the calculation of the indicated averages as described in footnote 4.

monetary policy. The average EPS values show that under all five chairmen, the Fed countered positive inflationary pressures and magnified deflationary pressures. According to our indices it was only during Volcker's first year as Chairman that the Fed dampened the impact of deflationary pressure. It is also interesting to note that monetary policy appears not to have had much effect on the volatility of inflation.

Volcker and Greenspan are now generally credited with having taken a tough stand against inflation. However, our EPS indices show that monetary policy under Martin and Burns was also effective in counteracting inflation pressure. Monetary policy under Martin and Burns removed, respectively, 27 and 19 per cent of positive ex ante inflation pressure on average. The average EPS index value of 0.09 shows that monetary policy under Miller was much less effective in combating inflation than under the previous two Chairmen. However, according to the IP index, inflation pressure during Miller's tenure as Fed Chairman was 3 times higher than it had been during the previous eight years. Miller was therefore confronted with much stronger inflationary pressures than his predecessor was. The relatively large negative EPS value of −1.46 indicates that Miller did try to use periods of deflationary pressure to bring about significant reductions in inflation. However, these efforts were not very successful because, as is evident from the data in Table 2, the deflationary episodes were considerably weaker than the inflationary pressures that developed during this period.

The PE index measures the degree to which expectational changes contributed to the Fed's success in combating inflationary pressures. The PE index suggests that the Fed's lack of success under Miller may in part be attributable to an inability to convince economic agents of the Fed's commitment to price stability. The PE index indicates that under Martin and Burns the Fed's policy initiatives, in times of positive ex ante pressure, brought about reductions in inflationary expectations of 40 and 30 per cent, respectively.[11] Under Miller, inflationary expectations fell only by 9 per cent.

[11]The reason that the average EPS and PE indices sum to one in most periods is because, based on our estimates, there is no significant difference betweeen ex post inflation pressure and observed inflation. This may be characteristic of the US economy, but it may also be a result of the high

The PE index also shows that contractionary policies implemented during deflationary periods had a stronger impact on expectations during Miller's chairmanship than under his predecessors, but as there were only two quarters of relatively weak negative pressure, this did not contribute a great deal to the achievement of price stability.

The output gap and inflation pressure averages in Table 5 show that Volcker had to deal with a combination of declining output and rising prices (stagflation) during his first year as chairman. The fact that the estimated EPS index is 0.13 for both positive and negative inflation pressure indicates that inflation and deflation met with approximately the same degree of resistance from the Fed during this period. According to our estimates, monetary policy increased the level and volatility of inflation on average. This lack of success may have been caused by the Fed's operating procedure which, at the time, was directed at targeting non-borrowed reserves.[12]

There is general agreement that it was during the first half of the 1980s that the Fed made the most significant progress towards bringing the inflationary process that had started in the late 1960s under control. Our estimates of policy response and policy effectiveness support this view. However, our indices of inflation pressure indicate that the reduction of inflation during this period was due not only to the effectiveness of the Fed's policies, but also to exogenous deflationary forces. The average IP index value of -0.45 for the period 1981:1–1985:4 is an indication that there were significant deflationary forces present in the economy at that time.[13] The estimated EPS indices indicate that the Fed's response to inflation pressure was very effective, removing 25 per cent of inflation pressure on average. It was also during this period that Volcker began to capitalize on periods of deflationary pressure, causing

degree of forward-lookingness that the model we have employed attributes to economic agents.

[12]The Fed changed its operating procedure from targeting non-borrowed reserves to targeting borrowed reserves in late 1982. In so doing the Fed essentially switched its focus from direct money stock control to controlling the Federal Funds rate.

[13]Because we calculated the IP index quarter by quarter, it would not be correct to interpret this average as indicating that inflation would have fallen by 45 per cent if the Fed had held the interest rate constant at its 1980:4 level.

inflation to fall 5 per cent more on average than it would have in response to economic conditions alone. The strength of the Fed's commitment to restoring price stability is clearly evident in this period, as is the cost of those policies in the form of an output gap of -3.78. The pay-off for this commitment is also clearly discernible in the PE index, which shows that the Fed's policies reduced inflation expectations by 36 per cent. It is apparent that in the final six quarters of Volcker's term, the US economy was undergoing significant expansion; a substantial reduction in the (negative) output gap was accompanied by moderate (positive) inflation pressure. The EPS index shows that although the Fed continued to use periods of negative inflation pressure to push the mean level of prices downwards, the response to positive inflation pressure was considerably weaker than it had been in previous years. This suggests that the Fed was reluctant to dampen the economic recovery that was underway in the latter half of the 1980s.

The stockmarket crash of October 1987 not withstanding, the US economy, during Greenspan's first three years as chairman, was characterized by predominantly positive output gaps and positive inflation pressure. Our estimates show that the policies implemented by the Fed at this time were similar in effectiveness to those that Volcker implemented in the preceding period. In both cases, monetary policy resulted in an observed inflation rate that was 17 per cent below the estimated ex ante inflation pressure. However, because the volatility of inflation pressure had increased, Greenspan had to respond more strongly to quarter-by-quarter inflation pressure than Volcker did to achieve similar results. Our EPS index shows that in addition to removing 13 per cent of positive inflation pressure on average, monetary policy magnified deflationary forces by an average of 28 per cent over the period 1987:3–1990:2. For the six years following the recession that started in July 1990, the output gap was predominantly negative. Our indices show that Greenspan used this period to make further progress towards price stabilization. By implementing somewhat stronger contractionary policies when inflation pressure was positive and continuing to contract strongly in deflationary quarters, the Fed increased the magnitude of the deflation by 150 per cent. the PE index shows that the Fed's policies reduced inflationary expectations by 17 per cent during this period. In the last 5 years of our sample, the output gap was on average positive and, owing to productivity increases, inflation pressure was negative. Greenspan's response to both negative and positive inflation pressure was less aggressive than in previous years. Nevertheless, these policies served to magnify ex ante deflationary pressure by 50 per cent, bringing inflation (as measured by the GDP deflator) down to 2.13 per cent by the end of 2001.

7. Concluding Comments

The operational indices that we have introduced and calculated in this article are intended as quantitative tools that can be used to characterize the stance of monetary policy and to evaluate the effectiveness of policy responses. As a first step in illustrating our methodology and the calculation of our indices, we have used a theoretical model that is suitable for estimation at quarterly frequencies. The equations that comprise our model have been estimated at quarterly frequency by a number of authors, providing us with useful benchmarks for our parameter estimates.

Although our index defintions are general, the index formulae, and therefore our estimated indices, are model-sensitive. Because the indices we have proposed are novel, they have no counterparts in the literature that can be used for purposes of comparison. To check whether the measures we estimated are reasonable, we compared monetary policy as described by our indices with Greenspan's (2004) narrative account of Federal Reserve policy. Based on this analysis, we conclude that our indices provide a very plausible measure of Federal Reserve policy and of the economic conditions that the Federal Reserve faced. The degree to which our estimated indices are robust to reasonable variations in the underlying model is an issue that we plan to address in future reasearch.

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Appendix 1

Derivation of Quarterly Ex Ante Inflation Pressure

In order to derive the ex ante inflation formula (29)–(31) that is consistent with our model, we begin by substituting (25) into (26):

$$\begin{aligned}\pi_t \;=\; & \alpha_0 + \alpha_1 \mathrm{E}_t\bar{\pi}_{t+3} + (1-\alpha_1)[\alpha_2\pi_{t-1} + \alpha_3\pi_{t-2} + \alpha_4\pi_{t-3} + \alpha_5\pi_{t-4}] \\ & + \alpha_6\{\beta_0 + \beta_1 y_{t-2} + \beta_2 \mathrm{E}_{t-1}y_t - \beta_3[i_{t-2} - \mathrm{E}_{t-1}\bar{\pi}_{t+2}] + \eta_{t-1}\} + \varepsilon_t \quad \text{(A.1)}\end{aligned}$$

where, from (28),

$$E_t\bar{\pi}_{t+3} = \frac{1}{4}\left[\pi_t + E_t\pi_{t+1} + E_t\pi_{t+2} + E_t\pi_{t+3}\right]. \quad \text{(A.2)}$$

In order to obtain expressions for the expectational components of (A.2), we conjecture the following MSV solutions for π_t and y_t:

$$y_t \;=\; q_0 + q_1 i_{t-1} + q_2 y_{t-1} + q_3 \pi_{t-1} + q_4 \pi_{t-2} + q_5 \pi_{t-3} + q_6 \pi_{t-4} + q_7 \eta_t + q_8 \varepsilon_t \quad \text{(A.3)}$$

$$\pi_t \;=\; \delta_0 + \delta_1 i_{t-1} + \delta_2 y_{t-1} + \delta_3 \pi_{t-1} + \delta_4 \pi_{t-2} + \delta_5 \pi_{t-3} + \delta_6 \pi_{t-4} + \delta_7 \eta_t + \delta_8 \varepsilon_t \quad \text{(A.4)}$$

$$i_t \;=\; \mu_0 + \mu_1 i_{t-1} + \mu_2 y_{t-1} + \mu_3 \pi_{t-1} + \mu_4 \pi_{t-2} + \mu_5 \pi_{t-3} + \mu_6 \pi_{t-4} + \mu_7 \eta_t + \mu_8 \varepsilon_t \quad \text{(A.5)}$$

Using (A.3)–(A.5) we obtain the following expressions for $E_{t-1}\bar{\pi}_{t+2}$ and $E_t\bar{\pi}_{t+3}$

$$\mathrm{E}_{t-1}\bar{\pi}_{t+2} \;=\; \frac{1}{4}\left[\phi_0 + \phi_1 i_{t-1} + \phi_2 y_{t-1} + \phi_3 \pi_{t-1} + \phi_4 \pi_{t-2} + \phi_5 \pi_{t-3} + \phi_6 \pi_{t-3}\right] \quad \text{(A.6)}$$

$$\mathrm{E}_{t}\bar{\pi}_{t+3} \;=\; \frac{1}{4}\left[\Omega_0 + \Omega_1 i_{t-1} + \Omega_2 y_{t-1} + \Omega_3 \pi_{t-1} + \Omega_4 \pi_{t-2} + \Omega_5 \pi_{t-3} + \Omega_6 \pi_{t-4}\right] \quad \text{(A.7)}$$

where the composite coefficients ϕ_j and $\Omega_j; j = 0, ..., 6$ are defined as follows:

$$\begin{aligned}
\theta_0 &= 2\delta_0 + \delta_1\mu_0 + \delta_2 q_0 + \delta_3\delta_0 \\
\theta_1 &= \delta_1(1+\mu_1) + \delta_2 q_1 + \delta_3\delta_1 \\
\theta_2 &= \delta_2 + \delta_1\mu_2 + \delta_2 q_2 + \delta_3\delta_2 \\
\theta_3 &= 1 + \delta_3 + \delta_1\mu_3 + \delta_2 q_3 + \delta_3^2 + \delta_4 \\
\theta_4 &= 1 + \delta_4 + \delta_1\mu_4 + \delta_2 q_4 + \delta_3\delta_4 + \delta_5 \\
\theta_5 &= \delta_5 + \delta_1\mu_5 + \delta_2 q_5 + \delta_3\delta_5 + \delta_6 \\
\theta_6 &= \delta_6 + \delta_1\mu_6 + \delta_2 q_6 + \delta_3\delta_6 \\
\theta_7 &= \delta_7 + \delta_1\mu_7 + \delta_2 q_7 + \delta_3\delta_7 \\
\theta_8 &= \delta_8 + \delta_1\mu_8 + \delta_2 q_8 + \delta_3\delta_8 \\
\phi_0 &= \theta_0 + \theta_1\mu_0 + \theta_2 q_0 + \theta_3\delta_0 \\
\phi_1 &= \theta_1\mu_1 + \theta_2 q_1 + \theta_3\delta_1 \\
\phi_2 &= \theta_1\mu_2 + \theta_2 q_2 + \theta_3\delta_2 \\
\phi_3 &= \theta_4 + \theta_1\mu_3 + \theta_2 q_3 + \theta_3\delta_3 \\
\phi_4 &= \theta_5 + \theta_1\mu_4 + \theta_2 q_4 + \theta_3\delta_4 \\
\phi_5 &= \theta_6 + \theta_1\mu_5 + \theta_2 q_5 + \theta_3\delta_5
\end{aligned}$$

$$
\begin{aligned}
\phi_6 &= \theta_1\mu_6 + \theta_2 q_6 + \theta_3\delta_6 \\
\phi_7 &= \theta_1\mu_7 + \theta_2 q_7 + \theta_3\delta_7 \\
\phi_8 &= \theta_1\mu_8 + \theta_2 q_8 + \theta_3\delta_8 \\
\Omega_0 &= \phi_0 + \phi_1\mu_0 + \phi_2 q_0 \\
\Omega_1 &= \phi_1\mu_1 + \phi_2 q_1 \\
\Omega_2 &= \phi_1\mu_2 + \phi_2 q_2 \\
\Omega_3 &= \phi_1\mu_3 + \phi_2 q_3 + \phi_4 \\
\Omega_4 &= \phi_1\mu_4 + \phi_2 q_4 + \phi_5 \\
\Omega_5 &= \phi_1\mu_5 + \phi_2 q_5 + \phi_6 \\
\Omega_6 &= \phi_1\mu_6 + \phi_2 q_6 \qquad \text{(A.8)}
\end{aligned}
$$

Using (A.4), $E_{t-1}y_t$ can be expressed as

$$
\mathrm{E}_{t-1}y_t = q_0 + q_1 i_{t-1} + q_2 y_{t-1} + q_3\pi_{t-1} + q_4\pi_{t-2} + q_5\pi_{t-3} + q_6\pi_{t-4}. \qquad \text{(A.9)}
$$

Substituting (A.7)–(A.9) into (A.1) yields

$$
\begin{aligned}
\pi_t = {} & [\Lambda_0 + \Lambda_1 i_{t-1} + \Lambda_2 y_{t-1} + \Lambda_3\pi_{t-1} + \Lambda_4\pi_{t-2} + \Lambda_5\pi_{t-3} + \Lambda_6\pi_{t-4} \\
& + 4\alpha_6\beta_1 y_{t-2} - 4\alpha_6\beta_3 i_{t-2} + 4\alpha_6\eta_{t-1} + 4\varepsilon_t]\,(4 - \alpha_1\phi_3)^{-1}. \qquad \text{(A.10)}
\end{aligned}
$$

where $\Lambda_j; j = 0, ..., 6$ are defined as follows:

$$
\begin{aligned}
\Lambda_0 &= \alpha_1\Omega_0 + 4\alpha_6\beta_0 + \alpha_6\beta_3\phi_0 + 4\alpha_6\beta_2 q_0 \\
\Lambda_1 &= \alpha_1\Omega_1 + \alpha_6\beta_3\phi_1 + 4\alpha_6\beta_2 q_1 \\
\Lambda_2 &= \alpha_1\Omega_2 + \alpha_6\beta_3\phi_2 + 4\alpha_6\beta_2 q_2 \\
\Lambda_3 &= \alpha_1\Omega_3 + \alpha_6\beta_3\phi_3 + 4\alpha_6\beta_2 q_3 + 4(1-\alpha_1)\alpha_2 \\
\Lambda_4 &= \alpha_1\Omega_4 + \alpha_6\beta_3\phi_4 + 4\alpha_6\beta_2 q_4 + 4(1-\alpha_1)\alpha_3 \\
\Lambda_5 &= \alpha_1\Omega_5 + \alpha_6\beta_3\phi_5 + 4\alpha_6\beta_2 q_5 + 4(1-\alpha_1)\alpha_4 \\
\Lambda_6 &= \alpha_1\Omega_6 + \alpha_6\beta_3\phi_6 + 4\alpha_6\beta_2 q_6 + 4(1-\alpha_1)\alpha_5
\end{aligned}
$$

Then, using (A.3)–(A.5) to express i_{t-1}, y_{t-1}, and π_{t-1} in terms of i_{t-2} we obtain

$$
\pi_t = \Gamma_0 + \Gamma_1 i_{t-2} + \Gamma_2 y_{t-2} + \Gamma_3\pi_{t-2} + \Gamma_4\pi_{t-3} + \Gamma_5\pi_{t-4} + \Gamma_6\pi_{t-5}
$$

$$+ \ \Gamma_7 \eta_{t-1} \ + \ \Gamma_8 \varepsilon_{t-1} \ + \ \left[\frac{4}{4-\alpha_1\phi_3}\right]\varepsilon_t. \quad \text{(A.11)}$$

where

$$\begin{aligned}
\Gamma_0 &= [\Lambda_0 + \Lambda_1\mu_0 + \Lambda_2 q_0 + \Lambda_3\delta_0](4-\alpha_1\phi_3)^{-1} \\
\Gamma_1 &= [\Lambda_1\mu_1 + \Lambda_2 q_1 + \Lambda_3\delta_1 - 4\alpha_6\beta - 3](4-\alpha_1\phi_3)^{-1} \\
\Gamma_2 &= [\Lambda_1\mu_2 + \Lambda_2 q_2 + \Lambda_2\delta_2 + 4\alpha_6\beta_1](4-\alpha_1\phi_3)^{-1} \\
\Gamma_3 &= [\Lambda_1\mu_3 + \Lambda_2 q_3 + \Lambda_2\delta_3 + \Lambda_4](4-\alpha_1\phi_3)^{-1} \\
\Gamma_4 &= [\Lambda_1\mu_4 + \Lambda_2 q_4 + \Lambda_2\delta_4 + \Lambda_5](4-\alpha_1\phi_3)^{-1} \\
\Gamma_5 &= [\Lambda_1\mu_5 + \Lambda_2 q_5 + \Lambda_2\delta_5 + \Lambda_6](4-\alpha_1\phi_3)^{-1} \\
\Gamma_6 &= [\Lambda_1\mu_6 + \Lambda_2 q_6 + \Lambda_2\delta_6](4-\alpha_1\phi_3)^{-1} \\
\Gamma_7 &= [\Lambda_1\mu_7 + \Lambda_2 q_7 + \Lambda_2\delta_7 + 4\alpha_6](4-\alpha_1\phi_3)^{-1} \\
\Gamma_8 &= [\Lambda_1\mu_8 + \Lambda_2 q_8 + \Lambda_2\delta_8](4-\alpha_1\phi_3)^{-1}.
\end{aligned}$$

Ex ante inflation is then given by

$$\begin{aligned}
\pi_t^0 \ = \ & \Gamma_0^0 + \Gamma_1^0 i_{t-3} \ + \ \Gamma_2^0 y_{t-2} \ + \ \Gamma_3^0 \pi_{t-2} \ + \ \Gamma_4^0 \pi_{t-3} \ + \ \Gamma_5^0 \pi_{t-4} \ + \ \Gamma_6^0 \pi_{t-5} \\
& + \ \Gamma_7^0 \eta_{t-1} \ + \ \Gamma_8^0 \varepsilon_{t-1} \ + \ \left[\frac{4}{4-\alpha_1\phi_3}\right]\varepsilon_t \quad \text{(A.12)}
\end{aligned}$$

where the superscripts on the composite Γ coefficients in (A.12) indicate that the rational expectations coefficients δ_i, q_i, and μ_i in (A.3)–(A.5) were obtained under the assumption that $\rho_{t-2} = 1$. The disturbance terms η_{t-1}, ε_{t-1}, and ε_t in (A.12) are not observable and must be obtained by solving (A.3) and (A.4) simultaneously for η_t and ε_t. Expressing (A.3) and (A.4) in matrix form we have:

$$\begin{bmatrix} q_7 & q_8 \\ \delta_7 & \delta_8 \end{bmatrix} \begin{bmatrix} \eta_t \\ \varepsilon_t \end{bmatrix} = \begin{bmatrix} y_t - q_0 - q_1 i_{t-1} - q_2 y_{t-1} - q_3\pi_{t-1} - q_4\pi_{t-2} - q_5\pi_{t-3} - q_6\pi_{t-4} \\ \pi_t - \delta_0 - \delta_1 i_{t-1} - \delta_2 y_{t-1} - \delta_3\pi_{t-1} - \delta_4\pi_{t-2} - \delta_5\pi_{t-3} - \delta_6\pi_{t-4} \end{bmatrix} \quad \text{(A.13)}$$

Solving (A.13) for η_t and ε_t we get

$$\eta_t \ = \ (q_7\delta_8 - \delta_7 q_8)^{-1} X_t^{\eta} \quad \text{(A.14)}$$

$$\varepsilon_t \ = \ (q_7\delta_8 - \delta_7 q_8)^{-1} X_t^{\varepsilon} \quad \text{(A.15)}$$

where

$$X_t^\eta = \delta_8 \{y_t - q_0 - q_1 i_{t-1} - q_2 y_{t-1} - q_3 \pi_{t-1} - q_4 \pi_{t-2} - q_5 \pi_{t-3} - q_6 \pi t - 4\}$$
$$+ q_8 \{-\pi_t + \delta_0 + \delta_1 i_{t-1} + \delta_2 y_{t-1} + \delta_3 \pi_{t-1} + \delta_4 \pi_{t-2} + \delta_5 \pi_{t-3} + \delta_6 \pi t - 4\}$$

$$X_t^\varepsilon = \delta_7 \{-y_t + q_0 + q_1 i_{t-1} + q_2 y_{t-1} + q_3 \pi_{t-1} + q_4 \pi_{t-2} + q_5 \pi_{t-3} + q_6 \pi t - 4\}$$
$$+ q_7 \{\pi_t - \delta_0 - \delta_1 i_{t-1} - \delta_2 y_{t-1} - \delta_3 \pi_{t-1} - \delta_4 \pi_{t-2} - \delta_5 \pi_{t-3} - \delta_6 \pi t - 4\}$$

The formula for ex ante inflation π_t^0 that is consistent with our quarterly model is given by (A.12), (A.14), and (A.15).

In the quarterly model, ex ante inflation pressure is measured as the inflation rate that would have been observed if the monetary authority had held the interest rate constant at its period $t-3$ level in period $t-2$ and then returned to the average policy rule for subsequent periods. Because economic agents are assumed to be fully informed and fully rational, the coefficients in (A.3)—(A.5) that would be obtained under the counterfactual assumption $\rho_{t-2} = 1$ can be expected differ from those obtained under the policy rule that was actually implemented. This was demonstrated in the simple illustrative example in Section 3. Unfortunately, the complexity of the quarterly model prevents us from obtaining closed-form solutions for the coefficients that would be generated by a one-period deviation from the policy rule. We therefore approximate the solution by forming expectations using the coefficients computed under the observed rule. This approximation is unlikely to have any significant impact on the Volcker-Greenspan estimates because the estimated value of $\hat{\rho} = 0.8$ is very close to 1. For the pre-Volcker period, $\hat{\rho} = 0.58$, so the approximation is not quite as good. However, even in this case there should be little effect as we are only failing to adjust the coefficients for a one-period deviation from the estimated policy rule.

Appendix 2

Rational Expectations Computation

A2.1 Computational Formulae

The computational program we employ was developed by Sims (2001). The application of Sims' program requires that we express our RE model in the following form:

$$\Gamma_0 x_t \;=\; \Gamma_1 x_{t-1} \;+\; C \;+\; \Psi z_t \;+\; \Pi\eta_t \tag{A.16}$$

In order to ensure that the computational program identifies the MSV solution we also require that

$$\bar{\Gamma}_0 x_t \;=\; \bar{\Gamma}_1 x_{t-1} \;+\; \bar{C} \;+\; \Psi z_t \;+\; \Pi\eta_t \tag{A.17}$$

$$\Phi_0 \mathrm{E}_t x_{t+1} \;=\; \Phi_1 x_t \;+\; B. \tag{A.18}$$

One configuration of vectors that allows the quarterly model given by (25)–(28) to be expressed in a manner that is consistent with (A.16) is:

$$x_t = \begin{bmatrix} y_t \\ \pi_t \\ \pi_{t-1} \\ \pi_{t-2} \\ \pi_{t-3} \\ i_t \\ \hat{y}_t \\ \hat{\pi}_t \\ \tilde{\pi}_{t+1} \\ \bar{\pi}_{t+2} \end{bmatrix} \qquad x_{t-1} = \begin{bmatrix} y_{t-1} \\ \pi_{t-1} \\ \pi_{t-2} \\ \pi_{t-3} \\ \pi_{t-4} \\ i_{t-1} \\ \hat{y}_{t-1} \\ \hat{\pi}_{t-1} \\ \tilde{\pi}_t \\ \bar{\pi}_{t+1} \end{bmatrix} \qquad z_t = \begin{bmatrix} \eta_t \\ \varepsilon_t \end{bmatrix} \qquad w_t = \begin{bmatrix} u_t \\ v_t \\ \phi_t \\ \theta_t \end{bmatrix}$$

The definitional equations that are associated with these vectors and which must be added to the system are

$$y_t \;=\; \hat{y}_{t-1} \;+\; u_t \tag{A.19}$$

$$\pi_t \;=\; \hat{\pi}_{t-1} \;+\; v_t \tag{A.20}$$

$$\tilde{\pi}_t = \hat{\pi}_t + \phi_t \tag{A.21}$$

$$\bar{\pi}_{t+1} = \tilde{\pi}_{t+1} + \theta_t \tag{A.22}$$

$$\pi_{t-1} = \pi_{t-1} \tag{A.23}$$

$$\pi_{t-2} = \pi_{t-2} \tag{A.24}$$

$$\pi_{t-3} = \pi_{t-3} \tag{A.25}$$

To complete the model specification, the matrices Γ_0, Γ_1, C, Ψ, and Π are then given by:

$$\Gamma_0 = \begin{bmatrix} 1 & \frac{-\beta_3}{4} & 0 & 0 & 0 & 0 & -\beta_2 & \frac{-\beta_3}{4} & \frac{-\beta_3}{4} & \frac{-\beta_3}{4} \\ 0 & (1-\frac{\alpha_1}{4}) & -\alpha_1^*\alpha_2 & -\alpha_1^*\alpha_3 & -\alpha_1^*\alpha_4 & 0 & 0 & \frac{-\alpha_1}{4} & \frac{-\alpha_1}{4} & \frac{-\alpha_1}{4} \\ -(1-\rho)\gamma_y & \frac{-\gamma_\pi^*}{4} & 0 & 0 & 0 & 1 & 0 & \frac{-\gamma_\pi^*}{4} & \frac{-\gamma_\pi^*}{4} & \frac{-\gamma_\pi^*}{4} \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

where $\alpha_1^* = (1-\alpha_1)$ and $\gamma_\pi^* = \gamma_\pi(1-\rho)$.

$$\Gamma_1 = \begin{bmatrix} \beta_1 & 0 & 0 & 0 & 0 & -\beta_3 & 0 & 0 & 0 & 0 \\ \alpha_6 & 0 & 0 & 0 & (1-\alpha_1)\alpha_5 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \rho & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\Psi = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \qquad \Pi = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \qquad C = \begin{bmatrix} \beta_0 \\ \alpha_0 \\ \gamma_0 \end{bmatrix}$$

A2.2 Estimated RE Solutions

The solutions for the undetermined coefficients in (A.3)–(A.4) were obtained by using the GMM estimates of the coefficients in (25)–(28) to perform the computation described above. These estimated RE solutions are reported in Table A2.1.

Appendix 3

Model Estimation and Bootstrapping Results

A3.1 Details of GMM Estimation

To estimate the model using GMM, we rewrite three equations as

$$\begin{aligned} y_t &= \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t+1} - \beta_3 r_{t-1} + \varepsilon_{1t} \\ \pi_t &= \alpha_0 + \alpha_1 \overline{\pi}_{t+3} + \widetilde{\alpha}_2 \pi_{t-1} + \widetilde{\alpha}_3 \pi_{t-2} + \widetilde{\alpha}_4 \pi_{t-3} + \widetilde{\alpha}_5 \pi_{t-4} + \alpha_6 y_{t-1} + \varepsilon_{2t} \\ i_t &= \gamma_0 + \rho i_{t-1} + \widetilde{\gamma}_\pi \overline{\pi}_{t+3} + \widetilde{\gamma}_y y_t + \varepsilon_{3t} \end{aligned}$$

where $r_{t-1} = i_{t-1} - \overline{\pi}_{t+3}$, $\widetilde{\gamma}_\pi = (1-\rho)\gamma_\pi$, $\widetilde{\gamma}_y = (1-\rho)\gamma_y$,

$$\begin{aligned} \varepsilon_{1t} &= \beta_2 \left(E_{t-1} y_{t+1} - y_{t+1}\right) + \beta_3 \left(E_{t-1}\overline{\pi}_{t+3} - \overline{\pi}_{t+3}\right) + \eta_t \\ \varepsilon_{2t} &= \alpha_1 \left(E_{t-1}\overline{\pi}_{t+3} - \overline{\pi}_{t+3}\right) + u_t \\ \varepsilon_{3t} &= \widetilde{\gamma}_\pi \left(E_{t-1}\overline{\pi}_{t+3} - \overline{\pi}_{t+3}\right) \end{aligned}$$

Table A2.1

Estimated Rational Expectations Solutions

PV = Pre-Volcker(1966:Q1-1979:Q2); VG = Volcker-Greenspan(1979:Q3-2002:Q4)

	const	i_{t-1}	y_{t-1}	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}	η_t	ε_t
π_t	δ_0	δ_1	δ_2	δ_3	δ_4	δ_5	δ_6	δ_7	δ_8
PV	1.0835	−0.0197	0.0872	0.5630	0.0744	0.1332	0.1820	0.0645	1.3649
VG	0.3908	−0.0475	0.0846	0.5419	0.0656	0.1261	0.1779	0.0615	1.3344
y_t	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8
PV	4.2053	−0.2240	0.6842	−0.0515	−0.0214	−0.0173	−0.0099	1.5551	−0.0742
VG	2.5929	−0.3895	0.6991	−0.0999	−0.0415	−0.0336	−0.0192	1.5956	−0.1439
i_t	μ_0	μ_1	μ_2	μ_3	μ_4	μ_5	μ_6	μ_7	μ_8
PV	1.3751	0.5058	0.2209	0.2662	0.1024	0.0962	0.0620	0.4545	0.4652
VG	0.7740	0.7230	0.1008	0.1524	0.0580	0.0555	0.0363	0.2016	0.2722

The single equation GMM estimators

$$\begin{aligned}\widehat{\theta}_1 &= \left[\widehat{\beta}_0, \widehat{\beta}_1, \widehat{\beta}_2, -\widehat{\beta}_3\right]' \\ \widehat{\theta}_2 &= \left[\widehat{\alpha}_0, \widehat{\alpha}_1, \widehat{\widehat{\alpha}}_2, \widehat{\widehat{\alpha}}_3, \widehat{\widehat{\alpha}}_4, \widehat{\widehat{\alpha}}_5, \widehat{\alpha}_6\right]' \\ \widehat{\theta}_3 &= \left[\widehat{\gamma}_0, \widehat{\rho}, \widehat{\widehat{\gamma}}_\pi, \widehat{\widehat{\gamma}}_y\right]'\end{aligned}$$

are given by

$$\begin{aligned}\widehat{\theta}_i &= (\mathbf{X}'\mathbf{Z}\widehat{\mathbf{W}}\mathbf{Z}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Z}\widehat{\mathbf{W}}\mathbf{Z}'\mathbf{Y} \\ &= (\sum_{t=1}^{T} X_t Z_t' \widehat{\mathbf{W}} \sum_{t=1}^{T} Z_t X_t')^{-1} \sum_{t=1}^{T} X_t Z_t' \widehat{\mathbf{W}} \sum_{t=1}^{T} Z_t Y_t\end{aligned}$$

where

$$\begin{aligned}Y_t &= y_t \\ X_t &= [1, y_{t-1}, y_{t-2}, y_{t+1}, r_{t-1}]'\end{aligned}$$

for $i = 1$, and

$$\begin{aligned}Y_t &= \pi_t \\ X_t &= [1, \overline{\pi}_{t+3}, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}, \pi_{t-4}, y_{t-1}]'\end{aligned}$$

for $i = 2$, and

$$\begin{aligned}Y_t &= i_t \\ X_t &= [1, i_{t-1}, \overline{\pi}_{t+3}, y_t]'\end{aligned}$$

for $i = 3$, common instruments

$$Z_t = [1, y_{t-1}, y_{t-2}, y_{t-3}, y_{t-4}, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}, \pi_{t-4}]'$$

and an optimal weighting matrix $\widehat{\mathbf{W}}$.

The presence of forward-looking variables implies the serial correlation of at least order 3. We therefore utilized the heteroskedasticity and autocorrelation consistent (HAC) procedure, using a Bartlett kernel with bandwidth $K = 4$ (or lag length 3) to compute the optimal weighting matrix in the GMM criterion and also to compute the standard errors.

A3.2 Bootstrapped Confidence Intervals

The intervals given in Tables A3.1, A3.2, and A3.3 represent 80% confidence bands. They are based on 999 bootstrap repetitions.

Table A3.1

Indices and Bootstrapped Confidence Intervals

1966:1 – 1975:4

	IP	lower	upper	EPS	lower	upper	PE	lower	upper
1966:1	−0.31	−0.38	−0.20	−0.13	−0.35	−0.36	1.13	0.64	1.35
2	1.42	1.34	1.54	0.08	0.04	0.19	0.92	0.81	0.96
3	0.41	0.34	0.51	0.29	0.15	0.53	0.71	0.47	0.85
4	−0.25	−0.33	−0.15	−0.42	−0.77	0.29	1.42	0.71	1.76
1967:1	−1.70	−1.77	−1.59	−0.06	−0.11	−0.01	1.06	1.01	1.11
2	0.94	0.85	1.06	0.16	0.08	0.30	0.84	0.70	0.92
3	1.19	1.11	1.32	0.08	0.02	0.20	0.91	0.80	0.98
4	0.86	0.77	0.98	0.12	0.04	0.26	0.87	0.74	0.96
1968:1	0.19	0.12	0.28	0.44	0.19	0.86	0.56	0.14	0.81
2	0.04	−0.03	0.12	2.39	−0.46	3.89	−1.36	−2.84	1.44
3	−0.68	−0.76	−0.58	−0.18	−0.28	0.08	1.18	0.91	1.28
4	2.09	2.01	2.18	0.08	0.05	0.13	0.91	0.87	0.95
1969:1	−1.65	−1.72	−1.55	−0.03	−0.07	0.04	1.03	0.96	1.07
2	1.70	1.63	1.81	0.08	0.04	0.14	0.92	0.86	0.96
3	0.51	0.44	0.61	0.30	0.19	0.50	0.71	0.51	0.81
4	−0.43	−0.52	−0.32	−0.51	−0.77	0.05	1.50	0.93	1.76
1970:1	0.54	0.46	0.65	0.35	0.24	0.55	0.66	0.45	0.76
2	0.22	0.14	0.33	0.71	0.57	0.93	0.29	0.07	0.43
3	−2.30	−2.37	−2.17	−0.05	−0.08	0.00	1.05	1.01	1.08
4	2.22	2.13	2.37	0.10	0.06	0.16	0.90	0.84	0.94
1971:1	0.92	0.84	1.03	0.06	−0.02	0.17	0.94	0.82	1.02
2	−0.65	−0.74	−0.52	−0.14	−0.26	0.14	1.15	0.87	1.26
3	−1.15	−1.23	−1.01	−0.08	−0.14	0.06	1.09	0.94	1.14
4	−0.60	−0.67	−0.48	−0.37	−0.52	0.03	1.37	0.96	1.52
1972:1	2.84	2.76	2.94	0.06	0.04	0.10	0.94	0.90	0.96
2	−3.46	−3.53	−3.34	−0.01	−0.04	0.02	1.01	0.99	1.04
3	1.60	1.52	1.71	0.07	0.02	0.14	0.93	0.85	0.97
4	0.97	0.90	1.06	0.15	0.08	0.25	0.86	0.75	0.92
1973:1	0.63	0.56	0.71	0.11	0.02	0.29	0.89	0.71	0.98
2	1.37	1.30	1.46	0.08	0.04	0.16	0.92	0.85	0.96
3	1.15	1.07	1.25	0.17	0.11	0.27	0.84	0.74	0.89
4	−0.57	−0.64	−0.47	−0.27	−0.40	0.11	1.26	0.88	1.39
1974:1	1.50	1.41	1.62	0.17	0.12	0.24	0.84	0.76	0.89
2	0.93	0.85	1.04	0.10	0.02	0.22	0.90	0.78	0.98
3	3.35	3.26	3.48	0.06	0.03	0.10	0.94	0.90	0.97
4	0.21	0.12	0.35	1.18	1.01	1.29	−0.15	−0.25	−0.01
1975:1	−2.71	−2.80	−2.56	−0.07	−0.10	0.00	1.07	1.00	1.10
2	−3.52	−3.63	−3.37	0.00	−0.03	0.04	1.00	0.97	1.03
3	1.64	1.54	1.77	0.02	−0.04	0.09	0.98	0.90	1.03
4	−0.19	−0.26	−0.09	−0.70	−1.19	0.50	1.71	0.50	2.22

Table A3.2

Indices and Bootstrapped Confidence Intervals

1976:1 – 1985:4

	IP	lower	upper	EPS	lower	upper	PE	lower	upper
1976:1	−2.49	−2.56	−2.39	−0.05	−0.08	−0.02	1.05	1.02	1.08
2	0.10	0.02	0.21	1.46	1.02	2.03	−0.48	−1.08	−0.02
3	1.46	1.38	1.58	0.13	0.08	0.20	0.87	0.80	0.92
4	1.62	1.54	1.73	0.13	0.09	0.19	0.87	0.81	0.91
1977:1	−0.13	−0.21	−0.03	−1.26	−2.42	0.66	2.26	0.34	3.42
2	0.00	−0.07	0.10	21.85	−9.26	12.59	−21.09	−11.73	10.31
3	−0.80	−0.87	−0.70	−0.12	−0.19	0.13	1.12	0.87	1.19
4	1.25	1.17	1.37	0.16	0.10	0.24	0.84	0.76	0.90
1978:1	0.26	0.19	0.38	0.77	0.68	0.92	0.24	0.9	0.33
2	1.22	1.15	1.30	0.06	0.00	0.14	0.94	0.86	1.00
3	−0.72	−0.78	−0.62	−0.13	−0.21	0.14	1.13	0.86	1.21
4	1.03	0.96	1.12	0.10	0.04	0.20	0.90	0.80	0.96
1979:1	−0.18	−0.25	−0.08	−0.79	−1.43	0.65	1.77	0.35	2.42
2	1.51	1.43	1.61	0.12	0.07	0.19	0.88	0.81	0.93
3	−0.95	−1.01	3.14	0.07	−0.06	1.17	0.93	−0.17	1.05
4	−0.15	−0.21	3.93	0.40	−0.43	1.02	0.59	−0.02	1.42
1980:1	1.01	0.91	5.28	0.08	−0.02	0.83	0.93	0.17	1.02
2	0.44	0.31	4.04	0.64	0.49	0.96	0.38	0.04	0.54
3	−0.19	−0.26	3.29	−0.08	−0.85	1.05	1.05	−0.05	1.80
4	1.24	0.98	6.10	−0.32	−0.64	0.74	1.31	0.26	1.64
1981:1	−0.67	−0.76	4.25	0.30	0.09	1.09	0.71	−0.09	0.92
2	−2.54	−2.78	0.52	−0.19	−0.50	3.29	1.18	−2.30	1.49
3	0.65	0.56	4.47	0.01	−0.13	0.86	0.99	0.14	1.14
4	−0.38	−0.46	2.32	−0.20	−0.78	1.15	1.19	−0.15	1.76
1982:1	−1.78	−1.99	−0.96	0.07	0.00	0.25	0.93	0.75	1.00
2	−0.75	−1.08	−0.28	0.41	0.25	0.89	0.61	0.10	0.76
3	0.52	0.39	0.72	0.32	0.19	0.72	0.68	0.28	0.81
4	−1.37	−1.59	−1.27	0.00	−0.06	0.34	1.00	0.66	1.06
1983:1	−1.21	−1.73	−0.98	0.24	0.11	0.55	0.77	0.45	0.90
2	0.28	0.04	0.41	−0.35	−1.60	0.89	1.34	0.11	2.53
3	−0.18	−0.33	−0.08	−0.13	−0.62	0.86	1.14	0.14	1.63
4	0.07	−0.03	0.25	1.42	0.82	1.74	−0.42	−0.72	0.18
1984:1	1.55	1.48	1.52	0.07	0.02	0.45	0.93	0.55	0.98
2	−1.46	−1.52	−0.06	0.00	−0.07	0.12	1.00	0.88	1.07
3	−0.11	−0.18	1.26	−0.74	−3.17	1.16	1.73	−0.16	4.15
4	−0.22	−0.30	0.95	−0.63	−2.24	1.33	1.62	−0.33	3.23
1985:1	1.52	1.43	3.09	0.04	−0.02	0.53	0.97	0.47	1.02
2	−1.82	−2.04	−0.39	0.11	−0.22	0.22	0.89	0.78	1.21
3	−0.58	−0.69	0.74	0.12	0.01	1.48	0.88	−0.48	0.99
4	0.69	0.59	2.10	0.00	−0.16	0.68	1.00	0.32	1.15

Table A3.3

Indices and Bootstrapped Confidence Intervals

1986:1 – 1995:4

	IP	lower	upper	EPS	lower	upper	PE	lower	upper
1986:1	−1.22	−1.28	−0.29	−0.03	−0.80	0.04	1.03	0.96	1.80
2	0.40	0.33	1.15	0.22	0.05	0.73	0.78	0.27	0.95
3	0.64	0.54	1.65	0.02	−0.16	0.63	0.98	0.38	1.16
4	0.32	0.19	1.40	−0.08	−0.79	0.76	1.08	0.24	1.76
1987:1	0.73	0.63	2.00	0.02	−0.12	0.65	0.98	0.35	1.12
2	−0.71	−0.77	0.51	0.43	0.13	0.95	1.06	−0.97	1.17
3	−0.71	−0.77	0.51	0.43	0.13	0.95	0.57	0.05	0.86
4	0.40	0.34	2.02	0.16	0.01	0.84	0.85	0.16	0.99
1988:1	−0.48	−0.54	0.93	−0.10	−0.28	1.33	1.10	−0.33	1.28
2	1.37	1.30	3.26	0.02	−0.03	0.60	0.98	0.40	1.03
3	0.68	0.61	2.76	0.04	−0.06	0.78	0.96	0.22	1.06
4	−1.53	−1.60	0.16	−0.03	−0.12	1.88	1.03	−0.88	1.12
1989:1	1.09	1.02	3.14	0.08	0.02	0.70	0.92	0.30	0.98
2	−0.07	−0.14	1.94	−0.90	−4.38	3.79	1.88	−2.77	5.32
3	−1.01	−1.08	0.61	−0.08	−0.22	1.55	1.08	−0.55	1.22
4	0.09	0.02	1.84	0.21	−0.62	0.97	0.80	0.03	1.66
1990:1	1.46	1.34	3.65	−0.05	−0.14	0.60	1.05	0.40	1.13
2	0.04	−0.06	2.24	−1.03	−3.06	3.83	2.00	−2.74	3.98
3	−0.75	−0.84	1.24	0.01	−0.08	1.36	0.99	−0.36	1.08
4	−0.29	−0.37	1.19	−0.22	−0.53	1.24	1.22	−0.24	1.53
1991:1	1.22	1.13	2.24	0.06	−0.01	0.49	0.94	0.51	1.01
2	−1.83	−1.94	−1.35	0.02	−0.11	0.08	0.98	0.92	1.11
3	−0.29	−0.45	−0.04	0.16	−0.13	0.90	0.85	0.09	1.15
4	−0.42	−0.54	−0.32	−0.08	−0.27	0.38	1.09	0.62	1.27
1992:1	0.97	0.86	1.10	0.06	−0.04	0.21	0.94	0.79	1.04
2	−0.78	−0.91	−0.62	0.02	−0.11	0.20	0.98	0.81	1.11
3	−0.96	−1.09	−0.85	−0.01	−0.10	0.14	1.02	0.86	1.10
4	1.27	1.19	1.52	0.05	−0.01	0.22	0.95	0.78	1.01
1993:1	0.88	0.79	1.10	0.09	−0.01	0.33	0.91	0.67	1.01
2	−1.10	−1.18	−0.99	−0.07	−0.17	0.02	1.07	0.98	1.17
3	−0.19	−0.29	−0.08	−0.61	−1.48	0.35	1.61	0.65	2.48
4	0.50	0.43	0.74	0.17	0.05	0.48	0.83	0.52	0.95
1994:1	−0.09	−0.15	0.17	−1.08	−3.71	1.60	2.08	−0.60	4.71
2	−0.15	−0.21	0.40	−0.49	−1.48	1.43	1.49	−0.43	2.48
3	0.68	0.61	1.32	0.21	0.13	0.60	0.79	0.40	0.87
4	−0.37	−0.44	−0.34	−0.39	−1.02	1.98	1.39	−0.98	2.02
1995:1	1.23	1.16	2.18	0.14	0.09	0.52	0.86	0.48	0.92
2	−1.08	−1.15	−0.64	−0.15	−0.82	−0.07	1.15	1.06	1.83
3	0.30	0.23	0.79	0.49	0.35	0.81	0.52	0.19	0.66
4	0.20	0.14	0.81	0.45	0.23	0.86	0.56	0.14	0.78

Table A3.4

Indices and Bootstrapped Confidence Intervals

1996:1 – 2001:4

	IP	lower	upper	EPS	lower	upper	PE	lower	upper
1996:1	0.58	0.50	1.31	0.11	−0.02	0.61	0.89	0.39	1.02
2	−1.08	−1.15	−0.28	−0.02	−0.92	0.06	1.02	0.95	1.92
3	0.65	0.56	1.55	0.08	−0.06	0.62	0.92	0.38	1.06
4	−0.32	−0.39	0.52	−0.15	−0.41	1.43	1.15	−0.43	1.41
1997:1	1.38	1.31	2.64	0.06	0.01	0.51	0.94	0.49	0.99
2	−1.06	−1.12	−0.07	−0.02	−0.09	0.99	1.02	0.01	1.09
3	−0.59	−0.66	0.23	−0.07	−0.21	1.41	1.07	−0.41	1.21
4	0.35	0.28	1.25	0.23	0.06	0.81	0.77	0.19	0.94
1998:1	−0.37	−0.44	0.35	−0.07	−0.28	1.23	1.07	−0.23	1.28
2	0.02	−0.06	0.65	3.15	−1.11	3.55	−2.16	−2.56	2.12
3	0.44	0.37	1.20	0.13	−0.04	0.74	0.87	0.26	1.04
4	−0.29	−0.36	0.43	−0.07	−0.37	1.15	1.07	−0.15	1.37
1999:1	0.72	0.63	1.69	0.05	−0.09	0.66	0.95	0.34	1.09
2	−0.25	−0.37	0.65	0.05	−0.28	1.12	0.96	−0.12	1.29
3	−0.29	−0.37	0.52	−0.07	−0.34	1.15	1.07	−0.15	1.34
4	0.48	0.41	1.52	0.06	−0.08	0.78	0.94	0.22	1.08
2000:1	1.44	1.37	2.84	0.06	0.01	0.56	0.94	0.44	0.99
2	−0.71	−0.77	0.54	−0.04	−0.16	1.22	1.04	−0.22	1.16
3	−0.57	−0.64	0.51	−0.14	−0.36	1.23	1.14	−0.23	1.36
4	0.51	0.44	1.64	0.21	0.09	0.80	0.80	0.20	0.91
2001:1	1.67	1.60	3.23	0.06	0.01	0.52	0.94	0.48	0.99
2	−1.17	−1.26	−0.03	−0.03	−0.09	1.00	1.03	0.00	1.09
3	−0.27	−0.42	0.72	0.12	−0.22	1.24	0.89	−0.24	1.23
4	−2.79	−2.94	−2.64	0.03	−0.02	0.08	0.97	0.92	1.021