

## **THE EVOLUTION OF US MONETARY POLICY: 2000 - 2007**

Michael T. Belongia  
Otho Smith Professor of Economics  
University of Mississippi  
Box 1848  
University, MS 38677  
[mvpt@earthlink.net](mailto:mvpt@earthlink.net)

Peter N. Ireland  
Department of Economics  
Boston College  
140 Commonwealth Avenue  
Chestnut Hill, MA 02467  
[peter.ireland@bc.edu](mailto:peter.ireland@bc.edu)

August 2015

Abstract: This paper estimates a VAR with time-varying parameters to characterize the changes in Federal Reserve policy that occurred from 2000 through 2007 and assess how those changes affected the performance of the U.S. economy. The results point to a gradual shift in the Fed's emphasis over this period, away from stabilizing inflation and towards stabilizing output. A persistent deviation of the federal funds rate from the settings prescribed by the estimated monetary policy rule appears more important, however, in causing inflation to overshoot its target in the years leading up to the Great Recession.

JEL Codes: C32, E31, E32, E37, E52, E58.

## **Introduction**

The years from 2000 through 2007 lie between two remarkable, but very different, episodes in United States economic history. The period from the mid-1980s through 2000 exhibited extraordinary macroeconomic stability and came to be known popularly as the “Great Moderation.”<sup>1</sup> December 2007, on the other hand, marked the official beginning of the “Great Recession,” a period of economic and financial turmoil of a kind not seen in the U.S. since the Great Depression. The timing of these events, and the sharp contrast between them, suggest that something fundamental must have changed between 2000 and 2007.

The statistical analysis presented here is directed at assessing the role that monetary policy may have played as a possible source of that change. Our focus on monetary policy is motivated by two interrelated sets of considerations. First, a host of studies, including Clarida, Gali, and Gertler (2000), Gali, Lopez-Salido, and Valles (2003), Lubik and Schorfheide (2004), and Boivin and Giannoni (2006), present evidence linking the improved performance of the U.S. economy during the Great Moderation to better monetary policymaking, beginning with Paul Volcker’s arrival as Federal Reserve Chair in 1979. In particular, these studies find that, in the early 1980s, monetary policy began to place more emphasis on stabilizing inflation and less on stabilizing output and employment. These studies go on to argue that this shift in the Federal Reserve’s focus removed monetary policy itself as a source of business cycle fluctuations and helped the economy respond more efficiently to a range of non-monetary disturbances. If these arguments are correct, a shift in emphasis back to smoothing fluctuations in the real economy around 2000 may have created conditions conducive to the reemergence since then of monetary disturbances as a source of inefficient fluctuations.

Investigating the role that monetary policy might have played in switching from the economic activity observed prior to 2000 to that after 2007 is also motivated by the analysis

---

<sup>1</sup> Kim and Nelson (1999), McConnell and Perez-Quiros (2000), and Stock and Watson (2002) establish 1984 as the starting date for this period, and while there is, as yet, no similar consensus as to when the Great Moderation came to a close, it suffices for now to note that over the 16 years that followed, steady growth in aggregate income and employment was interrupted by only one, relatively minor, recession lasting from March through November 1991.

presented in Taylor (2009). Specifically, Taylor argues that the Federal Reserve set the stage for the financial crisis of 2007 and the Great Recession that followed by deviating persistently from the interest rate rule that he had introduced earlier (in Taylor [1993]) to describe more systematic policy over the period from 1987 through 1992. Taylor's subsequent (2009) comparison between the actual trajectory of the federal funds rate from 2000 through 2007 and the values prescribed by his rule suggests that monetary policy had been too accommodative over most of this period, fueling a boom-bust cycle in housing and other interest-sensitive sectors of the economy.<sup>2</sup>

Our own preliminary look at the data lends some support to Taylor's claims. Figure 1 plots quarterly series over 1960 through 2007 for three variables: Inflation, the output gap, and the federal funds rate.<sup>3</sup> These graphs confirm that the Federal Reserve responded to what was, in retrospect, a relatively brief and mild recession in 2001 with an extended period of very low interest rates. Moreover, the Fed kept its target for the funds rate at exceptionally low levels even after inflation began to rise in 2004. Together, these observations can be interpreted in at least two ways. The data could reflect a possible shift in the emphasis of monetary policy away from stabilizing inflation and towards stabilizing output. Alternatively, rather than reflecting a deliberate decision to switch the focus of monetary policy, the data could reflect a persistent deviation by policymakers away from systematic behavior of any kind, perhaps signaling a shift

---

<sup>2</sup> Barnett (2012, pp.133-134) also blames the housing boom on overly expansionary monetary policy in the years following 2001, arguing that Federal Reserve officials might have noticed this error had they used appropriate measures of money instead of the federal funds rate to gauge the stance of their policies. Barnett adds that a subsequent policy tightening, signaled by a slowdown in the growth rates of his preferred, Divisia monetary aggregates, helped trigger the chain of mortgage defaults that led to the financial crisis. That restrictive monetary policy preceded the onset of recession in 2007 is an argument also made by Hetzel (2009, 2012) as well as economists affiliated with "market monetarism;" the latter reach this conclusion by comparing the paths of nominal GDP and potential GDP. With our focus on monetary policy, this paper abstracts from the housing crisis, credit derivatives, and other possible causes of the Great Recession. One treatment of non-monetary explanations of the decline and subsequent slow recovery can be found in Stock and Watson (2012).

<sup>3</sup> The inflation rate is measured by year-over-year percentage changes in the deflator for personal consumption expenditures, excluding food and energy. The output gap is measured as the percentage-point difference between actual real GDP and the Congressional Budget Office's estimate of potential output. All series are drawn from the Federal Reserve Bank of St. Louis' FRED database.

from a rules-based framework to one relying more on discretionary actions.<sup>4</sup> Either interpretation, however, would suggest a potentially important departure from the desirable features of policy that held sway during the Great Moderation.

These considerations are reinforced by the additional data plotted in Figure 2. Shown in the graph are the actual path for the federal funds rate and the values implied by one version of the Taylor Rule.<sup>5</sup> The data indicate that the funds rate was above the value implied by the rule through the latter half of the 1990s, potentially explaining the negative output gap and low inflation observed over the same interval. In the early 2000s, however, the funds rate was persistently below the value implied by the rule; consistent with Taylor's (2009) own analysis, this is suggestive of an overly-expansionary stance of policy as well as the rising inflation that appears to be associated with it. But the graph, by itself, leaves open the deeper questions of whether monetary policy after 2000 is better described by changing weights on inflation versus output in a Taylor-type rule or by a greater willingness on the part of Federal Reserve officials to deviate from the behavior prescribed by such a rule and how, more exactly, these policy changes affected the paths of inflation and output.

To answer these questions, we use the data shown in figure 1 to estimate a vector autoregression with time-varying parameters and stochastic volatility using Bayesian methods introduced and outlined by Cogley and Sargent (2005) and Primiceri (2005). This model is capable of capturing a range of ways in which monetary policy can change and, in particular, distinguishes between whether the central bank adjusted the strength of its systematic

---

<sup>4</sup> Here, the contrast we wish to draw between "rules" and "discretion" comes closest to the distinction as it is made by Taylor (1993, pp.198-199): the former refers to the policymaker's systematic response to changes in the economy as summarized by a small number of state variables, such as inflation and the output gap, whereas the latter alludes to less predictable actions motivated, perhaps, by the policymaker's own judgment. In Barro and Gordon's (1983) theoretical framework, by contrast, a "discretionary" policymaker sets inflation too high in an effort to exploit a Phillips curve trade-off, but still behaves in perfectly predictable manner; Ireland (1999) presents statistical analysis designed to test whether Federal Reserve policy appears to be discretionary in this, alternative, sense.

<sup>5</sup> Many versions of the Taylor Rule exist. To be somewhat agnostic in this analysis, the values reported in Figure 2 were generated by the same data and procedures used by the Federal Reserve Bank of St. Louis and reported on page 10 of its monthly Monetary Trends publication, assuming an inflation target of two percent per year.

responses to inflation and output or whether it deviated from that systematic behavior to a greater or lesser extent. Thus, we can use estimates from this model to judge, more specifically, how Federal Reserve policy changed, moving from the period of the Great Moderation to the period leading up to the Great Recession.

Such judgments are possible because the equation for the interest rate in the model takes the same general form as the Taylor (1993) rule, but with fewer constraints imposed on the dynamics with which the Federal Reserve adjusts its target for the funds rate in response to changes in the economy. Thus, our analysis joins with others in the literature that describe Federal Reserve behavior by estimating interest rate rules with time-varying parameters. Most of these earlier studies, including Jalil (2004), Boivin (2006), Kim and Nelson (2006), McCulloch (2007), Trecroci and Vassalli (2011), Li (2012), Jung and Katayama (2014), and Lakdawala (2015), were directed towards the more basic question of whether the coefficients of an estimated Taylor rule varied over time in ways that are more complex than a one-time sample split around 1979 might initially suggest. Others, such as Bayoumi and Sgherri (2004), Mandler (2007), and Ang, Boivin, Dong, and Loo-Kung (2011), went further to consider the effects that time-variation in Taylor Rule parameters have had on the persistence of inflation, the predictability of the federal funds rate, or the behavior of longer-term bond rates. Here, we add to this literature by focusing mainly on how Federal Reserve policy changed over the period from 2000 through 2007. By estimating our version of the Taylor Rule within a simultaneous-equation system, however, we can investigate a broader issue: How changes in monetary policy during this period affected both inflation and output as well. Our results allow us to ask, for example, whether macroeconomic conditions leading up to the Great Recession might have evolved differently if the Fed had not changed the weights it put on inflation versus output in the estimated rule or if it had not deviated from the behavior prescribed by that rule.

In fact, our results do point to both a gradual shift in Federal Reserve policy away from stabilizing inflation and towards stabilizing output between 2000 and 2007 *and* to important departures from rule-like behavior during that time. According to the estimated model, these changes in policy – but especially the latter – caused inflation and output to be higher than

they otherwise would have been when the Great Recession began. These results and others discussed below raise the question of whether the United States has, after an interlude spanning the mid-1980s through the 1990s, entered a period of renewed monetary instability after 2000. They underscore, as well, the advantages that accrue to economic performance when central bankers respond systematically to movements in inflation and output within the context of a monetary policy rule and avoid persistent deviations from that rule.

### **The Model**

The model – a vector autoregression (VAR) with time-varying parameters and stochastic volatility – is adapted from Primiceri’s (2005). The variables used to estimate the model are those shown in figure 1 and differ somewhat from the ones originally used by Primiceri. Our measure of inflation  $\Pi_t$ , based on the deflator for core personal consumption expenditures, and the short-term nominal interest rate  $R_t$ , based on the federal funds rate, are those that the Federal Reserve has focused on more closely in its conduct of monetary policy. In contrast, Primiceri employed the GDP deflator and the three-month U.S. Treasury bill rate in his work, mainly so as to extend the sample period back farther in time. Our use of the output gap  $G_t$  to measure real economic activity replaces the unemployment rate from Primiceri’s study. Use of the output gap makes the model’s description of monetary policy a version of the Taylor (1993) Rule, but with more flexible dynamics that enter through time-varying coefficients on the current and lagged values of inflation and the output gap as well as lags of the federal funds rate itself. Finally, as shown in figure 1, the quarterly data used here run through 2007, which allows the analysis to focus specifically on changes in Federal Reserve policy that may have occurred between 2000 and the onset of the Great Recession.

The three variables are collected in a 3x1 vector

$$y_t = \begin{bmatrix} \Pi_t & G_t & R_t \end{bmatrix}'$$

which is assumed to follow a second-order VAR with time-varying coefficients and a time-varying covariance matrix for its innovations. The model's reduced form is

$$y_t = c_t + B_{1,t}y_{t-1} + B_{2,t}y_{t-2} + u_t, \quad (1)$$

where  $c_t$  is a 3x1 vector of time-varying constant terms,  $B_{i,t}$ , for  $i = 1$  and  $i = 2$ , are 3x3 matrices of time-varying autoregressive coefficients, and  $u_t$  is a 3x1 vector of heteroskedastic shocks with time-varying covariance matrix  $\Omega_t$ . By stacking the constant terms and autoregressive coefficients into the 21x1 vector

$$B_t = \text{vec} \left( \begin{bmatrix} c'_t \\ B'_{1,t} \\ B'_{2,t} \end{bmatrix} \right)$$

and decomposing the covariance matrix  $\Omega_t$  as

$$\Omega_t = A_t^{-1} \Sigma_t \Sigma_t' (A_t')^{-1}, \quad (2)$$

where the 3x3 matrix

$$A_t = \begin{bmatrix} 1 & 0 & 0 \\ -\alpha_{g\pi,t} & 1 & 0 \\ -\alpha_{r\pi,t} & -\alpha_{rg,t} & 1 \end{bmatrix}$$

is lower triangular with ones along its diagonal and the 3x3 matrix

$$\Sigma_t = \begin{bmatrix} \sigma_{\pi,t} & 0 & 0 \\ 0 & \sigma_{g,t} & 0 \\ 0 & 0 & \sigma_{r,t} \end{bmatrix}$$

is diagonal, the reduced form (1) can be rewritten more conveniently as

$$y_t = X_t' B_t + A_t^{-1} \Sigma_t \varepsilon_t, \quad (3)$$

where

$$X_t = I_3 \otimes \begin{bmatrix} 1 & \Pi_{t-1} & G_{t-1} & R_{t-1} & \Pi_{t-2} & G_{t-2} & R_{t-2} \end{bmatrix},$$

$E\varepsilon_t\varepsilon_t' = I_3$ , and  $I_3$  denotes the 3x3 identity matrix.

Let

$$\alpha_t = \begin{bmatrix} \alpha_{g\pi,t} & \alpha_{r\pi,t} & \alpha_{rg,t} \end{bmatrix}'$$

and

$$\sigma_t = \begin{bmatrix} \sigma_{\pi,t} & \sigma_{g,t} & \sigma_{r,t} \end{bmatrix}'$$

be 3x1 vectors collecting the elements of  $A_t$  and  $\Sigma_t$  not equal to zero or one. The dynamics of the time-varying parameters are governed by

$$B_t = B_{t-1} + v_t, \quad (4)$$

$$\alpha_t = \alpha_{t-1} + \xi_t, \quad (5)$$

and

$$\log \sigma_t = \log \sigma_{t-1} + \eta_t, \quad (6)$$

where all of the serially uncorrelated innovations are assumed to be jointly normally distributed, with

$$E \begin{bmatrix} \varepsilon_t \\ v_t \\ \xi_t \\ \eta_t \end{bmatrix} \begin{bmatrix} \varepsilon_t' & v_t' & \xi_t' & \eta_t' \end{bmatrix} = \begin{bmatrix} I_3 & 0_{3 \times 21} & 0_{3 \times 3} & 0_{3 \times 3} \\ 0_{21 \times 3} & Q & 0_{21 \times 3} & 0_{21 \times 3} \\ 0_{3 \times 3} & 0_{3 \times 3} & S & 0_{3 \times 3} \\ 0_{3 \times 3} & 0_{3 \times 3} & 0_{3 \times 3} & W \end{bmatrix}, \quad (7)$$

and  $0_{m \times n}$  denotes an  $m \times n$  matrix of zeros. In (7),  $Q$  is 21x21,  $S$  is 3x3, and  $W$  is 3x3 and diagonal, so that the standard deviations in  $\sigma_t$  evolve as independent, geometric random walks. Following Primiceri (2005), it is assumed that  $S$  is block-diagonal, with one non-zero element in the first column of the first row and three distinct non-zero elements in the second

and third columns of the second and third rows. Hence,  $Q$  has 231 distinct elements,  $S$  has four distinct non-zero elements, and  $W$  has three non-zero elements.

The Cholesky factorization of the symmetric, positive definite covariance matrix  $\Omega_t$  shown in (2) always exists and is unique; hence, the model can be written in the form of (3) without loss of generality. However, under the additional identifying assumption – made throughout much of the literature that works with VARs – that inflation and the output gap respond to monetary policy shocks only after a one-period lag, the third equation in (3) has a structural interpretation as the central bank’s monetary policy rule. Multiplying (3) by  $A_t$  puts this policy rule in its most easily interpretable form,

$$R_t = \alpha_{r\pi,t} \Pi_t + \gamma_{1,r\pi,t} \Pi_{t-1} + \gamma_{2,r\pi,t} \Pi_{t-2} + \alpha_{rg,t} G_t + \gamma_{1,rg,t} G_{t-1} + \gamma_{2,rg,t} G_{t-2} + \gamma_{1,rr,t} R_{t-1} + \gamma_{2,rr,t} R_{t-2} + \sigma_{r,t} \varepsilon_{rt}, \quad (8)$$

where the coefficients on the lagged values of inflation, the output gap, and the interest rate are those from the third rows of the matrices  $\Gamma_{i,t} = A_t B_{i,t}$  for  $i = 1$  and  $i = 2$  and  $\varepsilon_{rt}$ , the third element of the vector  $\varepsilon_t$  from (3), is the identified monetary policy shock. The policy rule in (8) takes the same general form as Taylor’s (1993), in that it prescribes a setting for the federal funds rate with reference to the changing values of inflation and the output gap. However, (8) also allows for considerable flexibility in the dynamic response of the funds rate to changes in inflation and the output gap and, through the inclusion of lagged interest rate terms on the right-hand side, captures as well the central bank’s tendency to smooth interest rate movements out over time. Deviations in the actual federal funds rate away from the value dictated by the current and lagged values of inflation, the output gap, and the interest rate get picked up as monetary policy shocks in (8). Finally, (8) allows for time-variation in all of the response coefficients and in the standard deviation  $\sigma_{r,t}$  of the monetary policy shocks.

Therefore, by expanding the time-varying estimation beyond that of a Taylor Rule’s coefficients in isolation this specification is ideally-suited for distinguishing between a variety of changes to monetary policy that might have occurred over the period 2000 through 2007. In

particular, this more generalized estimation permits drawing distinctions between changes in the emphasis that the Federal Reserve placed on its stabilization objectives for output versus inflation and the extent to which Federal Reserve officials became more willing to tolerate deviations from their systematic behavior. And, because the parameters of (8) are estimated within the multivariate system (3), the model also can be used to trace out the implications that these changes in monetary policy had, over the same period, on inflation and the output gap.

### **Estimation Strategy**

Going back to the earliest work by Litterman (1979), Bayesian techniques have proven quite useful in estimating and interpreting vector autoregressive time series models, as these methods offer theoretically coherent and computationally convenient ways of coping with the large numbers of parameters appearing even in VARs with coefficients that do not vary over time. More recently, Cogley and Sargent (2005) and Primiceri (2005) have outlined more powerful Markov Chain Monte Carlo techniques for simulating the posterior distributions for the still larger number of parameters in systems like that described here in equations (3)-(7). Following the same approach taken by Cogley and Sargent and Primiceri, prior distributions for these parameters are calibrated with the help of classical estimates obtained by applying a training sample consisting of the first ten years of data to a constant-parameter version of (3):

$$y_t = X_t' B + A^{-1} \Sigma \varepsilon_t.$$

In particular, an estimate  $\hat{B}$  of the parameter vector  $B$  is obtained by applying ordinary least squares, individually, to each equation in this system, and estimates  $\hat{\alpha}$  and  $\hat{\sigma}$  of the parameter vectors  $\alpha$  and  $\sigma$  are found by applying the same Cholesky factorization shown in (2) to the covariance matrix of least-squares residuals. Standard least-squares formulas provide an estimate of  $\hat{V}_B$  for the covariance matrix of  $\hat{B}$ , while Lutkepohl's (2006, Ch.9,

p.373) Proposition 9.5 derives an expression for  $\hat{V}_\alpha$ , the covariance matrix for  $\hat{\alpha}$ . These magnitudes help fix normal priors for the initial values

$$B_0 \sim N(\hat{B}, 4\hat{V}_B),$$

$$\alpha_0 \sim N(\hat{\alpha}, 4\hat{V}_\alpha),$$

and

$$\log \sigma_0 \sim N(\log \hat{\sigma}, I_3),$$

similar to those used by Primiceri (2005), which then imply, through (4)-(7), normal priors for all three sets of time-varying coefficients.

For  $Q$ , the two diagonal blocks  $S_1$  and  $S_2$  of  $S$ , and each diagonal element  $w_{i,i}$ ,  $i = 1, 2, 3$ , of  $W$ , inverse Wishart priors are calibrated as

$$Q \sim IW(40k_Q^2\hat{V}_B, 40),$$

$$S_1 \sim IW(2k_S^2\hat{V}_{\alpha,1}, 2),$$

$$S_2 \sim IW(3k_S^2\hat{V}_{\alpha,2}, 3),$$

and

$$w_{i,i} \sim IW(2k_W^2, 2)$$

for  $i = 1, 2, 3$ , where  $\hat{V}_{\alpha,1}$  and  $\hat{V}_{\alpha,2}$  are the diagonal blocks of  $\hat{V}_\alpha$  and the settings  $k_Q = 0.01$ ,  $k_S = 0.1$ , and  $k_W = 0.01$  are again taken directly from Primiceri (2005).

Starting from these priors, the remaining sample of quarterly data, running from 1970:1 through 2007:4, is used within a Gibbs sampling procedure to draw blocks of parameter values from their conditional posterior distributions. The multi-move algorithm outlined by Carter and Kohn (1994) and Fruhwirth-Schnatter (1994) generates draws for the sequence of coefficients in  $B_t$ ; following Cogley and Sargent (2005), we reject those implying explosive VAR dynamics. Primiceri's (2005) equation-by-equation method provides draws for

the sequence of parameters in  $\alpha_t$ . Draws for the volatility parameters in  $\sigma_t$  are made using Kim, Shephard, and Chib's (1998) algorithm, which approximates the true, log-chi-square distribution for each of these coefficients with a mixture of seven normal distributions. Within this algorithm, the state variable indicating which normal distribution each volatility parameter is chosen from is selected before sampling a value for the volatility parameter itself; the importance of this ordering of steps is discussed by Del Negro and Primiceri (2014). Finally, updated draws for the parameters in  $Q$ ,  $S$ , and  $W$  are taken from their inverse Wishart conditional posterior distributions. After cycling through this procedure 100,000 times in a burn-in period, we base all the results reported below on the 50,000 draws of each parameter that follow.

### Estimation Results

Figures 3 and 4 focus on the time-varying parameters of the monetary policy rule (8). Figure 3 tracks the evolution of the medians of the posterior distributions for the “impact coefficients”  $\alpha_{r\pi,t}$  and  $\alpha_{rg,t}$ , measuring the contemporaneous responses of the federal funds rate to movements in inflation and the output gap. Figure 4 does the same for the measure of “interest rate smoothing” given by the sum  $\gamma_{1,rr,t} + \gamma_{2,rr,t}$  of the coefficients on the lagged interest rate terms and the “long-run coefficients”

$$(\alpha_{r\pi,t} + \gamma_{1,r\pi,t} + \gamma_{2,r\pi,t}) / (1 - \gamma_{1,rr,t} - \gamma_{2,rr,t})$$

and

$$(\alpha_{rg,t} + \gamma_{1,rg,t} + \gamma_{2,rg,t}) / (1 - \gamma_{1,rr,t} - \gamma_{2,rr,t}),$$

which measure the total increase in the funds rate that would, in theory, follow a permanent one-percentage-point increase in inflation or the output gap under the policy rule (8). In each figure, the graphs in the left-hand column present results covering the entire sample period beginning in 1970, while those on the right zoom in on the period since 1990 so as to highlight changes that have occurred more recently.

The graphs do show a steady decline in the policy response of the funds rate to changes in inflation, both on impact and in the long run, extending back to 1990. And while the immediate response of policy to movements in the output gap fluctuates in a narrow range over the entire sample period, the long-run response follows a clearer upward trend, again going all the way back to 1990. In particular, the long-run coefficient on the inflation rate falls from 1.31 in 1990:1 to 1.25 in 2001:1 and 1.21 in 2007:4, while the long-run coefficient on the output gap rises from 0.66 in 1990:1 to 0.74 in 2000:1 and 0.79 in 2007:4. These changes, though not enormous, do point to a noticeable shift in the emphasis of monetary policy, responding less to inflation and more to output. Moreover, these results indicate that this shift in emphasis appears to have started much earlier than our preliminary look at the data suggested.

Figure 5 plots the changing posterior medians for the shock volatility parameters; once again, graphs on the left extend back to 1970 while those on the right begin in 1990. The graph at the bottom left, tracking the evolution of the volatility of the identified monetary policy shock over the full sample, shows quite clearly that, according to the estimated model, Federal Reserve policy has changed over time mainly in terms of the willingness policymakers have shown at different points in time to depart from the interest rate settings implied by a Taylor-type interest rate rule of the form in (8). Monetary volatility was extremely high during the early-to-mid 1970s and even higher during the period of the Volcker disinflation; compared to those very high levels, the standard deviation of monetary policy shocks has been low and stable since 1985. Figures 6-8, which reproduce figures 3-5 after adding lines demarcating the 16th and 84th percentiles of the posterior distributions, reinforce these conclusions by showing that while there is considerable uncertainty regarding the magnitudes of the response coefficients in (8), the evidence for large changes in the volatility of monetary policy shocks is quite strong. Using a larger VAR, a different identification scheme, and a model that allows for abrupt regime-switching rather than the slow parameter drift captured here, Sims and Zha (2006) arrives at a similar conclusion: the data point rather decisively to changes in the volatility of monetary policy shocks, rather than to changes in coefficients of the monetary

policy rule, as capturing the most important changes to occur in Federal Reserve behavior across the decades.

The graph at the bottom right of figure 5 reveals that, while remaining quite low compared to the longer-term historical standards set during the 1970s and early 1980s, the volatility of monetary policy shocks did move higher in the years just before, during, and after the recession of 2001. Figure 9, which plots medians from the distributions of the VAR shocks themselves, confirms that over this period, the identified monetary policy disturbances were large and most frequently expansionary, associated with settings for the federal funds rate below that prescribed by the rule in (8). Thus, while the results are consistent with the view that the Federal Reserve has shifted its emphasis away from inflation stabilization and towards objectives for output, they point strongly to an increased willingness of Federal Reserve officials to depart from rule-like behavior as the most striking feature of policy in the years since 2000.

### **Simulation Experiments**

To assess how these changes in policy have affected U.S. economic performance, figure 10 reports results from two experiments in which the estimated model is used to describe counterfactual scenarios. In the first, the coefficients of the policy rule (8) beginning in 2000:1 and ending in 2007:4 are drawn, not from their own posterior distributions but instead from the posterior distributions from 1990:1. Thus, this experiment is designed to explore what would have happened to inflation, the output gap, and the funds rate if the systematic behavior of monetary policy from 2000 through 2007 placed higher weight on inflation stabilization and lower weight on output stabilization, as it did in 1990 as according to figures 3 and 4. The graphs from the left-hand column in figure 10 suggest that this shift in policy would have done very little to change the course of history: although the median paths for all three variables under the counterfactual do differ slightly from paths taken by the actual data, those differences are so slight that the two lines in each graphs cannot be distinguished.

The second experiment attempts, instead, to change history by simply “turning off” the monetary shocks that, according to the estimated model, occurred over the period from 2001:1

through 2007:4. Here, the graphs from the right-hand column of figure 10 show more important differences between the actual time series and the median paths implied by the counterfactual simulations. Without monetary policy shocks, the median path for the federal funds rate runs much higher than the actual path over a five-year period running from 2001 through 2005. The counterfactual path never falls below 2 percent and, for much of this period, in fact, exceeds the actual setting for the funds rate by more than 150 basis points.

The top graph on the right-hand side of figure 10, meanwhile, displays the model's implications for how these monetary shocks affected inflation. In the absence of expansionary shocks, the median path for inflation under the counterfactual lies between 25 and 40 basis points below the inflation rate that actually prevailed. Moreover, instead of overshooting what has become the Federal Reserve's official long-run target of two percent, as it did by the end of 2004, inflation under the counterfactual converges to, then remains very close to, two percent all the way through the end of the sample. The graph in the middle of the right-hand column suggests that the negative output gap that persisted in the years following the 2001 recession would have been 25 to 40 basis points smaller in absolute value. In this sense, the Fed appears to have successfully "bought" higher output at the cost of creating more inflation. Note from the bottom graph, however, that the actual path for the funds rate moves approximately 100 basis points *above* the path without monetary shocks beginning in the second half of 2006. At least in hindsight, deviations from the rule in (8) over this period – keeping interest rates too low for too long even as the economy continued to recover and inflation began to rise, then raising rates by too much, too quickly when inflation eventually rose above target – bear a troubling resemblance to the discretionary, "go-stop" dynamics that Hetzel (2012) associates with Federal Reserve policy before 1979.

## **Conclusion**

Although the Federal Reserve never had announced that it follows a rule to guide monetary policy decisions, Taylor (1993) described a framework the Fed might use to determine its target value for the federal funds rate. Despite its simplicity, this rule appeared to track

quite well actual Federal Reserve policy decisions over the period from 1987 through 1992 that was the focus of Taylor's original study. Moreover, the rule's parsimony meant that it could be incorporated easily into even the simplest of New Keynesian models, which focus on the behavior of the same three variables – inflation, the output gap, and the short-term nominal interest rate – that appear in the rule itself. For both of these reasons, the Taylor Rule has become a benchmark for assessing and evaluating how Federal Reserve policy has changed over longer periods of time, well beyond the short sample first considered by Taylor.

Here, we estimate a version of the Taylor Rule that allows for time variation in both the coefficients measuring the Federal Reserve's systematic policy responses to inflation and output and in the volatility of an identified monetary policy shock, which we interpret as reflecting the Fed's willingness, at any given point in time, to deviate from the interest rate setting prescribed by the rule. This allows us to characterize, more sharply than previous studies have, the changes to Federal Reserve policy that occurred between 2000 and 2007, a period spanning the end of the Great Moderation and the beginning of the Great Recession. Moreover, by estimating this time-varying rule within a vector autoregressive framework, we also are able to investigate how these changes affected the behavior of inflation and output over the same period.

The results suggest, first, that the Fed did place increasing weight on stabilizing output, and correspondingly less weight on stabilizing inflation from 2000 through 2007, continuing trends that extend, according to our estimates, all the way back to the early 1990s. We also find evidence, however, of persistent deviations from the estimated policy rule that had more important implications for the behavior of output and, especially, inflation. Counterfactual simulations run with the estimated model suggest that the purely rules-based path for the funds rate would have allowed inflation to converge to the Federal Reserve's two percent target without overshooting and also would have avoided the abrupt tightening of monetary policy that occurred just prior to the onset of the Great Recession. These results are supportive of Taylor's (2009) claim that monetary policy was too expansionary for too long following the earlier recession of 2001. More broadly, the results reinforce a basic message from modern

macroeconomics: That economic performance improves when central banks adopt and adhere closely to monetary policy rules.

## References

Ang, Andrew, Jean Boivin, Sen Dong, and Rudy Loo-Kung. "Monetary Policy Shifts and the Term Structure." Review of Economic Studies 78 (April 2011): 429-457.

Barnett, William A. Getting It Wrong: How Faulty Monetary Statistics Undermine the Fed, the Financial System, and the Economy. Cambridge: MIT Press, 2012.

Barro, Robert J. and David B. Gordon. "A Positive Theory of Monetary Policy in a Natural Rate Model." Journal of Political Economy 91 (August 1983): 589-610.

Bayoumi, Tamim and Silvia Sgherri. "Monetary Magic? How the Fed Improved the Flexibility of the U.S. Economy." Working Paper WP/04/24. Washington: International Monetary Fund, February 2004.

Boivin, Jean. "Has U.S. Monetary Policy Changed? Evidence from Drifting Coefficients and Real-Time Data." Journal of Money, Credit, and Banking 38 (August 2006): 1149-1173.

Boivin, Jean and Marc P. Giannoni. "Has Monetary Policy Become More Effective?" Review of Economics and Statistics 88 (August 2006): 445-462.

Carter, C.K. and R. Kohn. "On Gibbs Sampling for State Space Models." Biometrika 81 (August 1994): 541-553.

Clarida, Richard, Jordi Gali, and Mark Gertler. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." Quarterly Journal of Economics 115 (February 2000): 147-180.

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

Del Negro, Marco and Giorgio Primiceri. "Time Varying Structural Vector Autoregressions and Monetary Policy: A Corrigendum." Staff Report 619. New York: Federal Reserve Bank of New York, October 2014.

Fruhworth-Schnatter, Sylvia. "Data Augmentation and Dynamic Linear Models." Journal of Time Series Analysis 15 (March 1994): 183-202.

Gali, Jordi, J. David Lopez-Salido, and Javier Valles. "Technology Shocks and Monetary Policy: Assessing the Fed's Performance." Journal of Monetary Economics 50 (May 2003): 723-743.

Hetzel, Robert L. "Monetary Policy in the 2008-2008 Recession." Federal Reserve Bank of Richmond Economic Quarterly 95 (Spring 2009): 201-233.

\_\_\_\_\_. The Great Recession: Market Failure or Policy Failure? Cambridge: Cambridge University Press, 2012.

Ireland, Peter N. "Does the Time-Consistency Problem Explain the Behavior of Inflation in the United States?" Journal of Monetary Economics 44 (October 1999): 279-291.

Jalil, Munir A. "Monetary Policy In Retrospective: A Taylor Rule Inspired Exercise." Manuscript. San Diego: University of California, San Diego, August 2004.

Jung, Yong-Gook and Munechika Katayama. "Uncovering the Fed's Preferences." Manuscript. Detroit: Wayne State University, April 2014.

Kim, Chang-Jin and Charles R. Nelson. "Has the U.S. Economy Become More Stable? A Bayesian Approach Based on a Markov-Switching Model of the Business Cycle." Review of Economics and Statistics 81 (November 1999): 608-616.

\_\_\_\_\_. "Estimation of a Forward-Looking Monetary Policy Rule: A Time-Varying Parameter Model Using Ex Post Data." Journal of Monetary Economics 53 (November 2006): 1949-1966.

Kim, Sangjoon, Neil Shephard, and Siddhartha Chib. "Stochastic Volatility: Likelihood Inference and Comparison With ARCH Models." Review of Economic Studies 65 (July 1998): 361-393.

Lakdawala, Aeimit. "Changes in Federal Reserve Preferences." Manuscript. East Lansing: Michigan State University, April 2015.

Li, Han. "Empirical Studies of Monetary Policy." Economics Ph.D. Thesis. Lawrence: Kansas University, May 2012.

- Litterman, Robert B. "Techniques of Forecasting Using Vector Autoregressions." Working Paper 115. Minneapolis: Federal Reserve Bank of Minneapolis, November 1979.
- Lubik, Thomas A. and Frank Schorfheide. "Testing for Indeterminacy: An Application to U.S. Monetary Policy." American Economic Review 94 (March 2004): 190-217.
- Lutkepohl, Helmut. New Introduction to Multiple Time Series Analysis. Berlin: Springer-Verlag, 2006.
- Mandler, Martin. "The Taylor Rule and Interest Rate Uncertainty in the U.S. 1955-2006." Manuscript. Giessen: University of Giessen, March 2007.
- McConnell, Margaret M. and Gabriel Perez-Quiros. "Output Fluctuations in the United States: What Has Changed Since the Early 1980's?" American Economic Review 90 (December 2000): 1464-1476.
- McCulloch, J. Huston. "Adaptive Least Squares Estimation of the Time-Varying Taylor Rule." Manuscript. Columbus: Ohio State University, June 2007.
- Primiceri, Giorgio E. "Time Varying Structural Vector Autoregressions and Monetary Policy." Review of Economic Studies 72 (July 2005): 821-852.
- Sims, Christopher A. and Tao Zha. "Were There Regime Switches in U.S. Monetary Policy?" American Economic Review 96 (March 2006): 54-81.
- Stock, James H. and Mark W. Watson. "Has the Business Cycle Changed and Why?" NBER Macroeconomics Annual 17 (2002): 159-218.
- \_\_\_\_\_. "Disentangling the Channels of the 2007-09 Recession." Brookings Papers on Economic Activity (Spring 2012): 81-135.
- Taylor, John B. "Discretion Versus Policy Rules in Practice." Carnegie-Rochester Conference Series on Public Policy 39 (December 1993): 195-214.
- \_\_\_\_\_. Getting Off Track: How Government Actions and Interventions Caused, Prolonged, and Worsened the Financial Crisis. Stanford: Hoover Institution Press, 2009.
- Trecroci, Carmine and Matilde Vassalli. "Monetary Policy Regime Shifts: New Evidence From Time-Varying Interest Rate Rules." Economic Inquiry 48 (October 2010): 933-950.

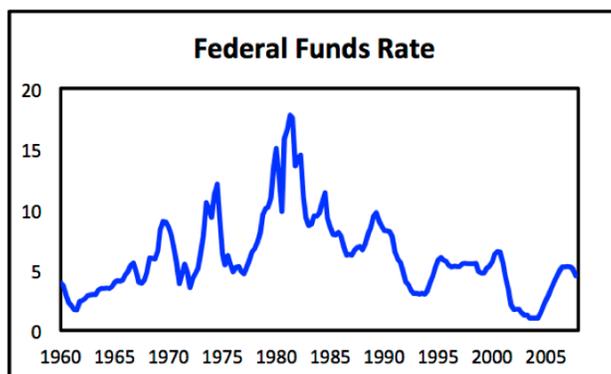
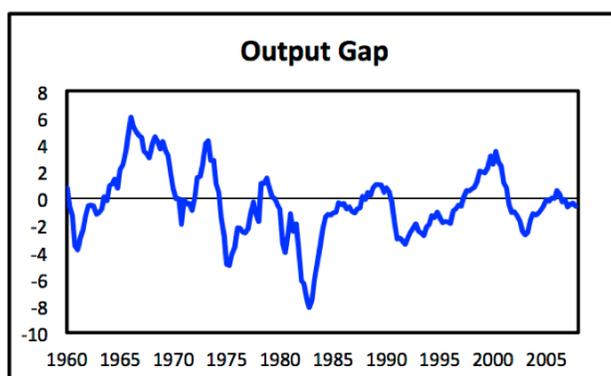
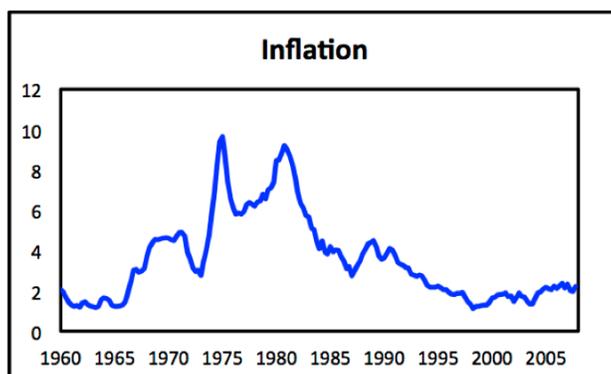


Figure 1. Quarterly U.S. Data. Inflation is measured by year-over-year percentage changes in the deflator for personal consumption expenditures, excluding food and energy. The output gap is measured by the percentage-point difference between real GDP and the Congressional Budget Office's estimate of potential output. Source: Federal Reserve Bank of St. Louis, FRED database.

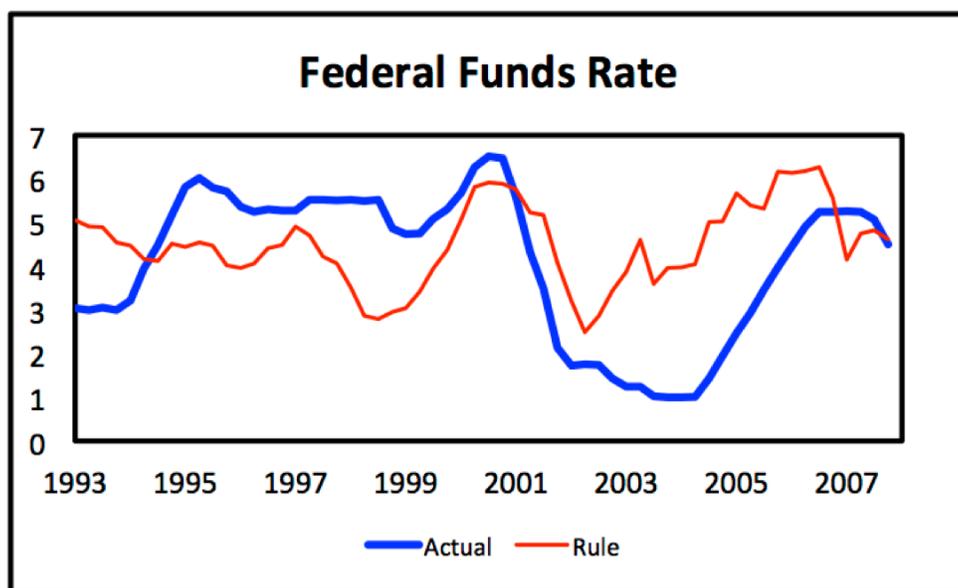


Figure 2. Federal Funds Rate. The graph compares the actual value of the federal funds rate to the value prescribed by a version of the Taylor Rule.

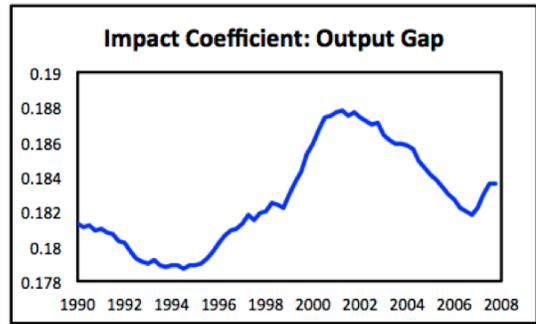
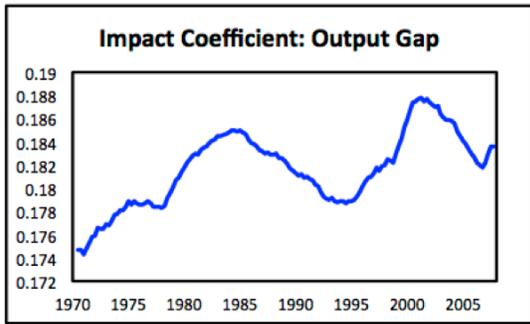
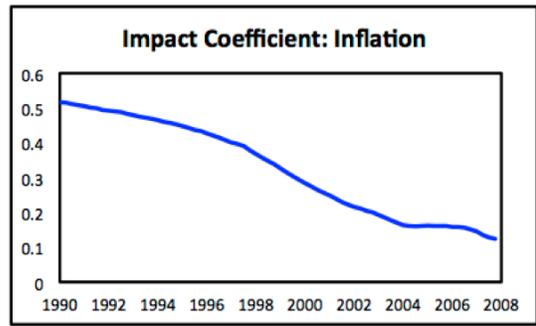
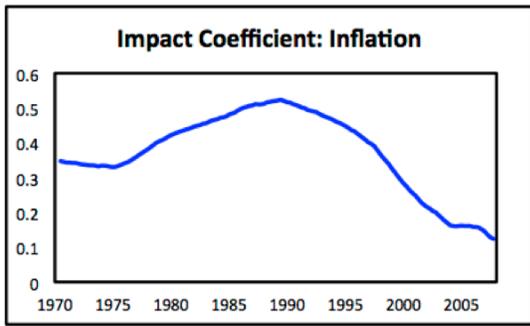


Figure 3. Impact Coefficients from the Estimated Monetary Policy Rule. Each graph plots the median of the posterior distribution of the indicated parameter.

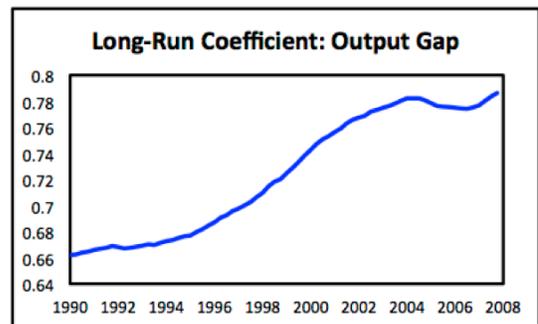
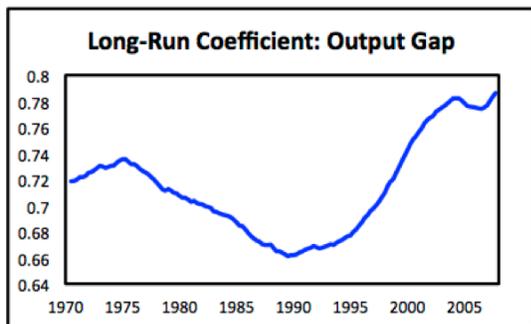
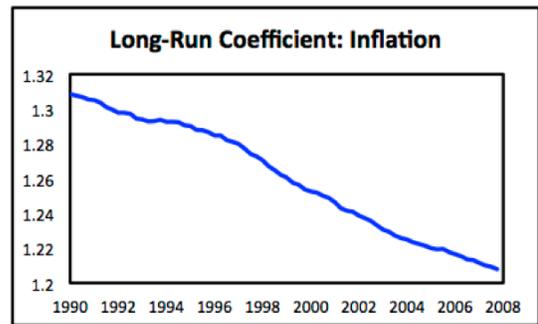
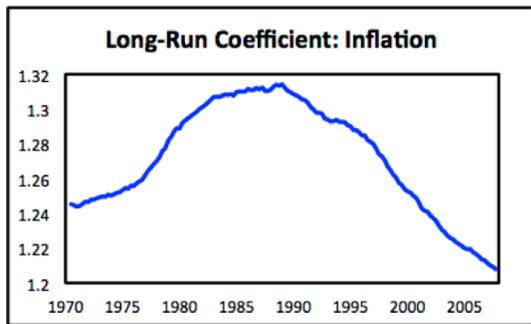
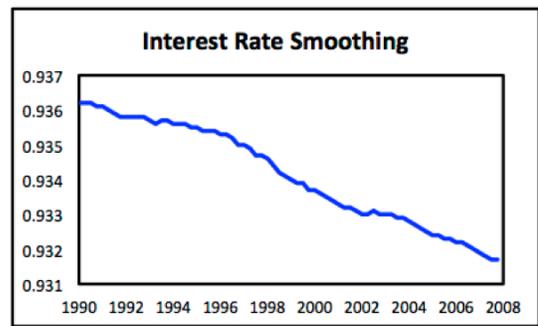
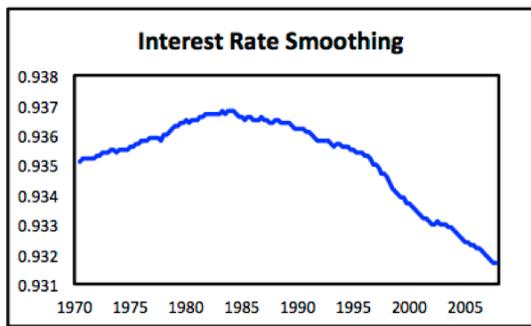


Figure 4. Interest Rate Smoothing and Long-Run Coefficients from the Estimated Monetary Policy Rule. Each graph plots the median of the posterior distribution of the indicated parameter.

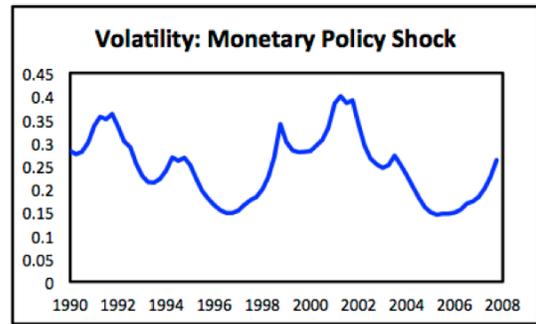
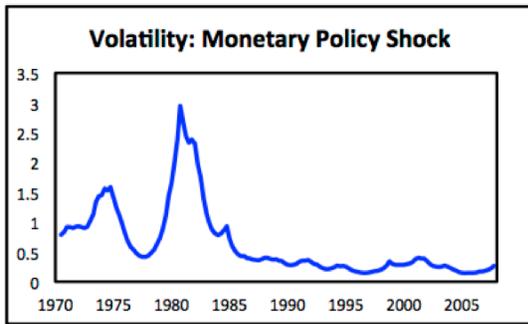
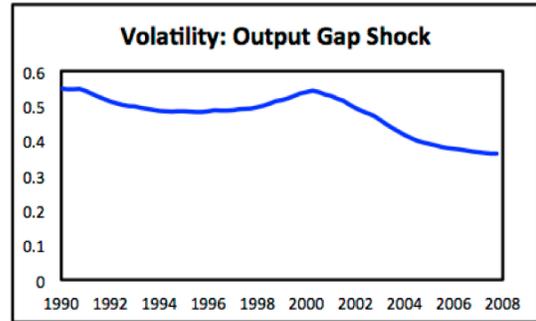
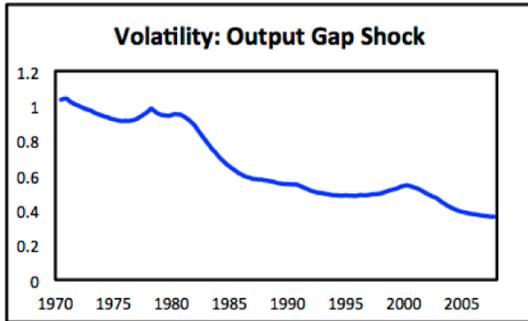
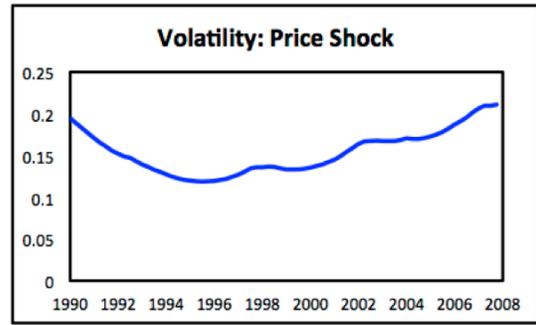
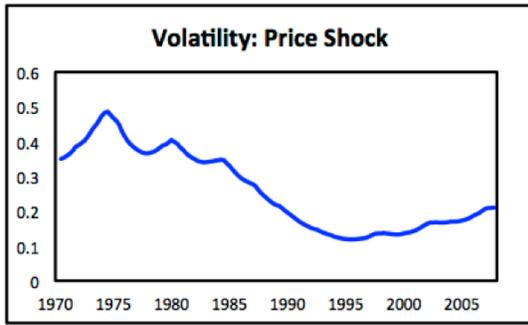


Figure 5. Shock Volatilities. Each graph plots the median of the posterior distribution of the indicated parameter.

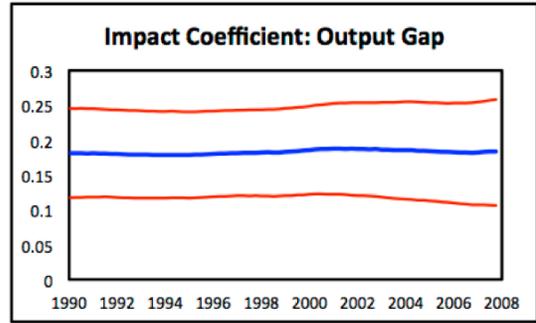
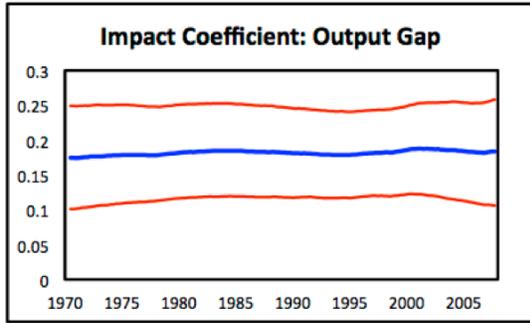
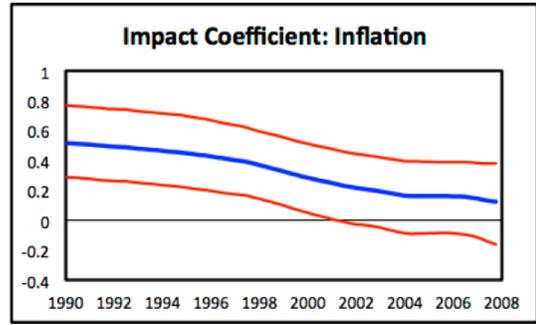
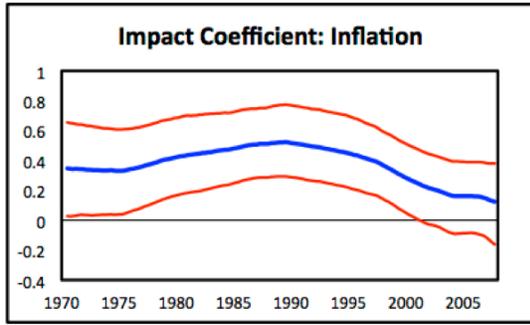


Figure 6. Impact Coefficients from the Estimated Monetary Policy Rule. Each graph plots the median (blue line) and the 16th and 84th percentiles (red lines) of the posterior distribution of the indicated parameter.

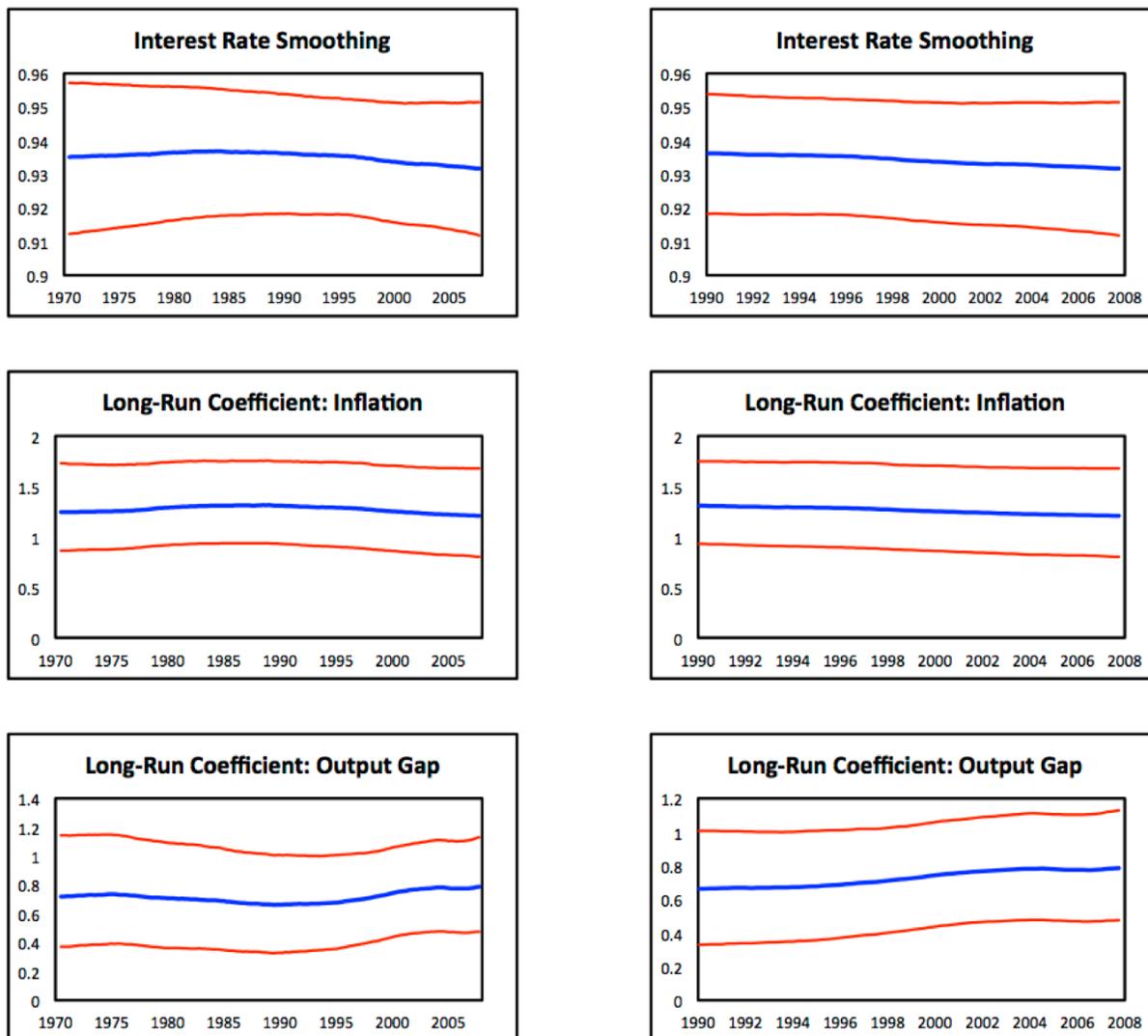


Figure 7. Interest Rate Smoothing and Long-Run Coefficients from the Estimated Monetary Policy Rule. Each graph plots the median (blue line) and the 16th and 84th percentiles (red lines) of the posterior distribution of the indicated parameter.

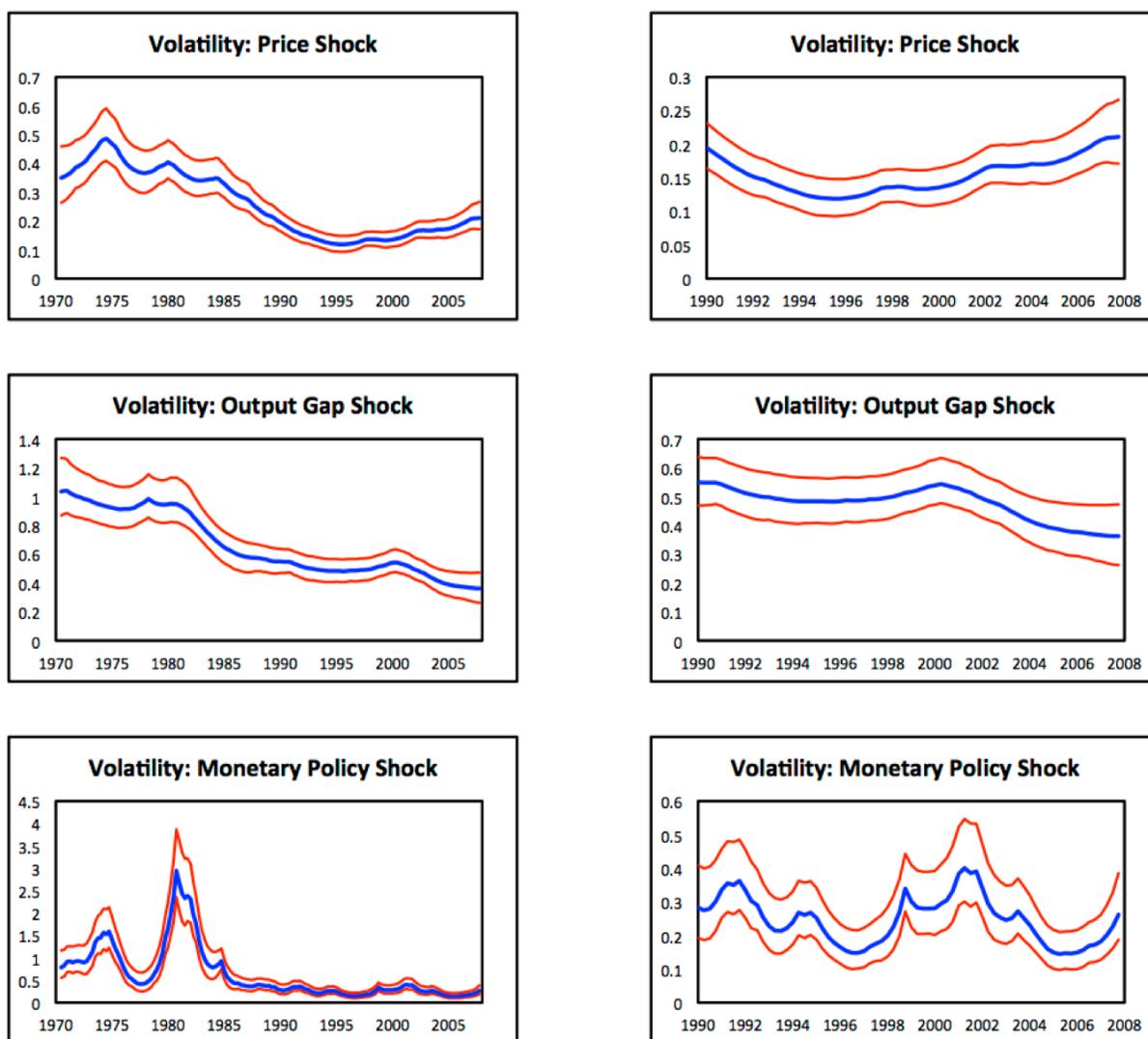


Figure 8. Shock Volatilities. Each graph plots the median (blue line) and the 16th and 84th percentiles (red lines) of the posterior distribution of the indicated parameter.

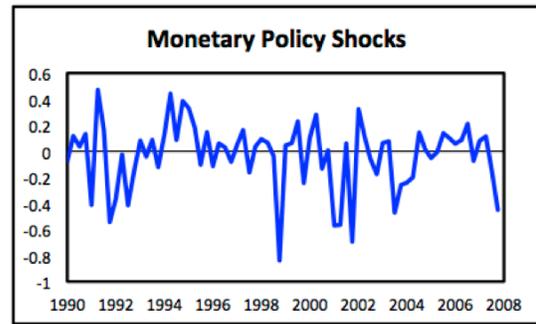
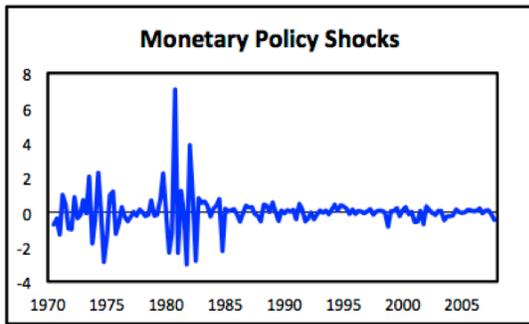
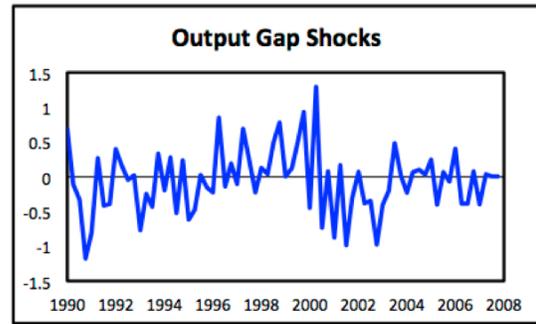
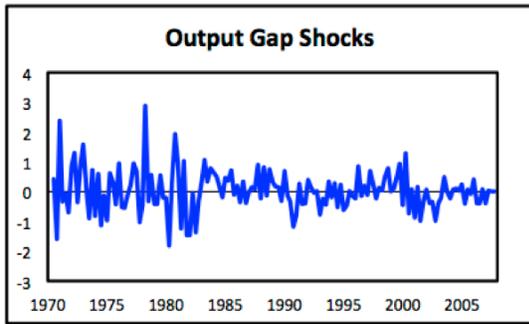
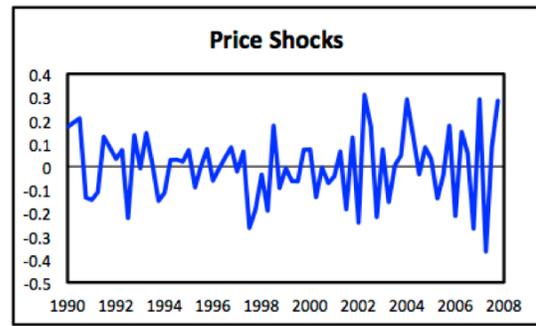
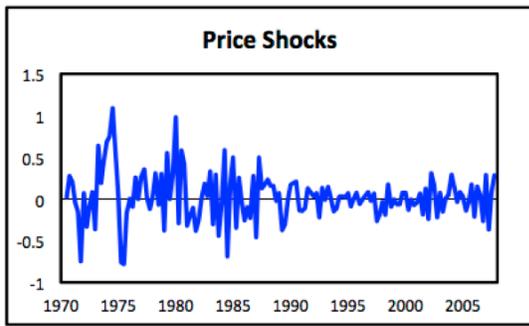


Figure 9. Shock Realizations. Each graph plots the median of the posterior distribution of the indicated disturbance.

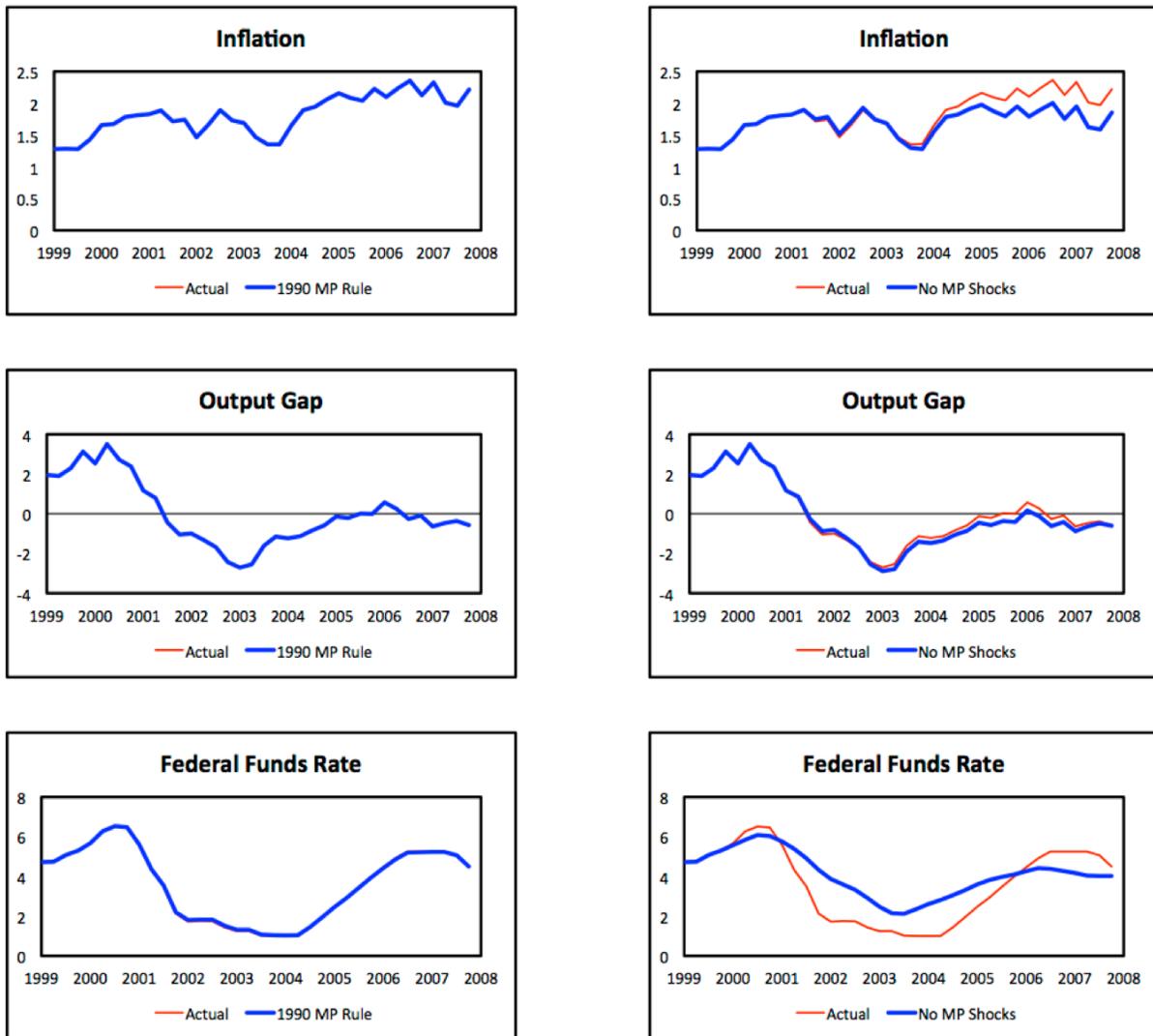


Figure 10. Counterfactual Simulations. Graphs in the left-hand column compare actual values of the indicated series to the median counterfactual paths when the coefficients of the monetary policy rule are drawn from their 1990:1 posterior distribution. Graphs in the right-hand column compare actual values to the median counterfactual paths when there are no monetary policy shocks from 2000:1 through 2007:4.