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Deconstructing the Art of Central Banking

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Deconstructing the Art of Central Banking

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Abstract

This paper proposes a markedly different transmission mechanism from monetary policy to the macroeconomy, focusing on how policy changes nominal inertia in the Phillips curve. Using recent theoretical developments, we examine the properties of a small, estimated U.S. monetary model distinguishing four monetary regimes employed since the late 1950s. We find that changes in monetary policy are linked to shifts in nominal inertia, and that these improvements in supply-side flexibility are indeed the main channel through which monetary policy lowers the volatility of inflation and, even more importantly, output.

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[1] The idea for this paper dates back to the time when the authors were working on the IMF's *World Economic Outlook*. We would like to thank Marco Terrones and David Robinson for useful suggestions.

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I. INTRODUCTION

The great inflation of the 1970s and its aftermath are one of the major events in monetary history. Indeed, the failure of monetary authorities across the major industrial countries to provide a stable nominal anchor during that decade has been a main motivation for subsequent developments of monetary policies and institutions. These include the widespread analysis of monetary rules, the most famous of which was suggested by John Taylor, and the generalized adoption of independent central banks. There has also been a focus on explaining the mechanisms by which monetary policy subsequently tamed inflation using both descriptive approaches and quantitative analysis.[2] This discussion has recently widened to the role of monetary policy in the reduction in output volatility, particularly in the United States.[3]

This paper reexamines the consequences of the loss of monetary credibility in the 1970s and the subsequent regaining of stability. The focus is on the interaction between shifts in the behavior of policymakers and the private sector. In particular, using recent theoretical developments as a guide, we argue that monetary stability allows pricing decisions by the private sector to become more focused on expectations of future inflation. This reduction in inflation inertia improves supply responses, making it easier for policymakers to stabilize output volatility while keeping inflationary forces in check. Indeed, in contrast to the prevailing literature, we argue that the benefits coming from these shifts in the Phillips curve overwhelm those coming from the changes in the monetary policy rule itself.

One way of looking at the contribution of this paper is that it explores the linkage between the science and the art of monetary policy. Recent academic work on monetary policy has focused on describing conduct in terms of rules, and consequences in small models embedding these rules (see, for example, Taylor, 1999). Practitioners, on the other hand, insist that there is also an artistic element to the process (Blinder, 1997) using words such as "credibility" that seem more akin to a paper on psychology than the scientific approach to monetary policy in much academic work. We argue that this "artistic" quality can be captured by the impact of monetary policy on private sector perceptions and behavior. Convincing the public they are in good hands actually makes it easier for policymakers to achieve both inflation and output stabilization. This paper uses analytical methods of the scientific approach to explore this artistic element.

Our hypothesis is that the main impact of changes in monetary stance comes through its bearing on inflation inertia. This directly questions what we dub the "central dogma" of the scientific approach of monetary economics, namely that the impact of alternative monetary

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[2] See, for example, Clarida and others (1998 and 2000), Viñals (2001), and Orphanides (1998 and 2000).

[3] See, among others, Taylor (1999), Blanchard and Simon (2001), Boivin and Giannoni (2002), Cecchetti, Flores-Lagunes, and Krause (2001), and Stock and Watson (2003).

policy rules can be measured while ignoring effects on the rest of the economy. [4] We approach our hypothesis by estimating how monetary policy *and* responses in the rest of the economy have shifted over time, and then examining the consequences of these changes through simulations of a small rational expectation monetary model. In a companion paper (Bayoumi and Sgherri, 2004), we examine in more detail the crucial theoretical link between changes in monetary policy uncertainty and inflation inertia, using estimation techniques better designed for approaching this particular issue. Together, these two papers make the case for a strong link between monetary stability and inflation inertia, using theoretical insights, historical data analysis, empirical estimates, and model simulations.

The next section of the paper examines some key stylized facts about the rise and fall of inflation since the late 1960s. Sections III and IV discuss the empirical model and reports estimation results based on rolling regressions. Section V explores the consequences of these shifts in behavior across equations using model simulations. Section VI concludes.

II. Stylized Facts

One of the most remarkable economic developments of recent decades has been the success in restoring low inflation in the United States and elsewhere in the industrial world. Figure 1 graphs U.S. CPI inflation since 1965. The pattern of inflation is hump shaped, increasing to 1973 and, after a brief lull following the first oil price hike, rising further through the 1979 oil shock. The subsequent deflationary period is characterized by a rapid fall in inflation in the early 1980s followed by a more gradual trend to the lower inflation achieved more recently.

There is a broad consensus that changes in the conduct of monetary policy by the Federal Reserve Board played the central role in taming inflation, albeit aided by other factors such as structural reforms, declining oil and commodity prices, and, in the 1990s, more prudent fiscal policies.[5] The pivotal event was the appointment of Paul Volcker as Chairman of the Federal Reserve in 1979, which led to a tougher monetary response to increases in inflation. Influential studies of estimated policy reaction functions, such as Taylor (1999) and Clarida, Galí, and Gertler (1998), find that during the great inflation period the U.S. Federal Reserve pursued a policy that accommodated inflation and induced instability in the economy, by lowering real interest rates when expected inflation increased and vice versa. They suggest that this perverse practice ended with Paul Volcker's appointment, when the policy response to expected inflation became "sufficiently" aggressive to restore monetary stability.[6] This

[4] To be fair, the central role of public responses has been emphasized in extreme situations such as the end of hyper-inflations (Sargent, 1993) and the Great Depression in the United States (Friedman and Schwartz, 1963). However, this lesson does not seem to have been more generally absorbed.

[5] On these aspects, see also IMF (1999, 2001).

[6] Christiano and Gust (2000) emphasize such an inflation expectations trap.

view, however, is not unchallenged. An alternative interpretation ascribes the loss of monetary control in the 1970s to an overemphasis by policymakers on flawed measures of the output gap that overestimated the slack in the economy. By estimating monetary reaction functions using measures of the output gap and future inflation available to policymakers in "real time," Orphanides (1998 and 2000) and McCallum (2001) suggest that it was flaws in the data rather than inattention to inflation that led the Federal Reserve to stimulate demand excessively.

Disinflation was accompanied by other changes in inflation and macroeconomic volatility (see also Figure 1). First, inflation has become less volatile and more predictable.[7] Secondly, inflation has become less persistent, as has been documented using several different econometric approaches and for a number of countries.[8] Finally, there has also been a marked fall in U.S. output volatility in the 1990s. Explanations for this fall in output volatility have been much debated. Some recent research indicates that the reduction in business cycle fluctuations largely reflects a more benign underlying environment, and is hence just a case of serendipity.[9] Others, however, have argued that the fall in output volatility owes much to the fall in inflation volatility associated with more stable monetary policies.[10] This follows from the more general argument that lower and less volatile inflation and a more stable nominal environment improves economic performance.[11]

These stylized facts create a conundrum when considering common theoretical explanations for the existence of nominal rigidities. In particular, it is difficult to see why a reduction in inflation and inflation uncertainty would be accompanied by lower persistence in a model relying on staggered contracts (see Taylor, 1981, and Calvo, 1983) or menu costs

[7] The existence of a positive association between the average level of inflation and its volatility has long been recognized (Friedman, 1977, and Taylor, 1981). This trend can be observed from measures of inflation uncertainty derived from surveys of consumers or professional forecasters (Diebold and others, 1999; IMF, 2002).

[8] See Taylor (2000), Cogley and Sargent (2001), Isard and others, (2001), and Erceg and Levin, (2003).

[9] For example, Ahmed, Levin, and Wilson (2002) and Stock and Watson (2003) suggest that over half of the decline in output volatility is the result of smaller common international shocks. Other possible causes include better inventory management (McConnell and Pérez-Quirós, 2000) and shifts in output composition (Alcalá and Sancho, 2004).

[10] Rudebusch and Svensson (1999) estimate that 7 percent of the reduction in output variance since 1984 reflects improved monetary policy. Blanchard and Simon (2001) find a strong correlation between output volatility and the level and volatility of inflation across G-7 countries. Cecchetti, Flores-Lagunes, and Krause (2001) document this effect across a wider range of countries.

[11] For empirical work see, for instance, Fischer (1996), Judson and Orphanides (1996), and Khan and Senhadji (2001).

(Rotemberg, 1996). Lower and less volatile inflation would appear likely to provide an incentive to lengthen wage contracts—indeed, there is evidence that this has indeed occurred (Taylor, 2000). Similarly, lower and less volatile inflation would seem to make it less attractive to change prices in the face of menu costs.

Recent theoretical work on models in which agents are unsure as to whether changes in individual prices reflect relative price shifts or inflationary trends provides a model of nominal rigidities more consistent with these observations. In this framework, greater uncertainty about the future path of nominal aggregate demand generates greater nominal rigidities.[12] The intuition behind these results is that as information about the future becomes more accurate, people make more use of it in making decisions. Given that monetary policy is a major contributor to volatility in aggregate demand, such models imply that greater monetary stability (and the associated fall in inflation) will tend to reduce inflation inertia, thereby improving supply-side responses and lowering the volatility of inflation and output. This key theoretical link between monetary stability and inflation inertia in the Phillips curve is extensively analyzed in a companion paper (Bayoumi and Sgherri, 2004). Here, we want to stress the importance of such a drop in inflation inertia for the stabilization of inflation and output volatility.

It should finally be noted that the stylized facts we have highlighted here reflect general trends across the industrial countries, rather than developments particular to the United States. Indeed, in many cases the institutional changes made elsewhere have been much more dramatic than those seen in the United States, such as the widespread adoption of independent central banks and new operating procedures, such as inflation targeting.[13] Hence, even though the analysis in this paper focuses on U.S. data, its implications are deemed to be much more general.

III. THE THEORETICAL MODEL

This section describes the small monetary model we estimate. It comprises three equations: a monetary policy reaction function, a Phillips curve, and an aggregate demand relationship. Small macroeconomic models of this type involving a few key relationships and rational expectations have been extensively used to analyze monetary issues, as they highlight two main monetary transmission channels: the real interest rate channel, through which central banks affect the spending decisions of the private sector; and an expectation channel, where

[12] See, for example, Woodford (2001) and Amato and Shin (2003) based on the original insights of Lucas (1972) and Phelps (1983). Mankiw and Reis (2001) develop a slightly different imperfect information pricing model.

[13] For an overview across industrial countries, see IMF (2002). In a cross-country analysis, Corbo and others (2001) point out the role of inflation targeting in weakening the weight of past inflation inertia.

the monetary authority influences private sector's expectations, by conveying information about the future course of monetary policy.[14]

The following relatively typical small monetary model was estimated:

$$i_t = \alpha_0 + (1-\rho_1-\rho_2)(\alpha_1\pi^e_{4,t+4} + \alpha_2 y_t) + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \varepsilon^i_t \tag{1}$$

$$\pi_t = \beta\pi^e_{4,t+4} + (1-\beta)\pi_{4,t-1} + \gamma y_t + \varepsilon^\pi_t \tag{2}$$

$$y_t = \delta_0 + \delta_1\left(i_t - \pi^e_{t+1}\right) + \delta_2 y^e{}_{t+1} + (1-\delta_2)\, y_{t-1} + \varepsilon^y_t\,. \tag{3}$$

where i_t is the Federal Funds interest rate, π_{4t} is the annual rate of inflation over the last year (measured as the fourth difference in the logarithm of prices), y_t is the output gap (i.e. the logarithm of the ratio of actual output to potential), π_t is the annualized rate of inflation over the last quarter (i.e. four times the change in the logarithm of the price level), and the ε_t's are error terms.

The monetary reaction function equation (1), follows the approach of Clarida, Galí, and Gertler (1999). It comprises a Taylor rule in which the nominal interest rate responds to expected future inflation and the current output gap (with coefficients α_1 and α_2) augmented by lagged dependent variables to reflect interest rate smoothing (coefficients ρ_1 and ρ_2), while the unobserved inflation target and natural rate of interest are subsumed in the constant term. The innovation in this specification is the inclusion of a second autoregressive parameter in the smoothing terms. As discussed below, this more flexible dynamic structure provides a better description of some of the changes in monetary responses over time.[15]

The expectations-augmented Phillips curve given in equation (2) describes the model's supply side. It relates current inflation to a weighted average of future and past inflation, with the weights adding up to one.[16] This type of specification is typical in empirical work (for

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[14] Applications of such models include Taylor (1979), Clarida, Galí, and Gertler (1998), Rudebusch and Svensson (1999), Svensson (2000), King (2000), and McCallum and Nelson (1999).

[15] Sack and Wieland (1999) provide an in depth discussion of interest rate smoothing. On the issue of gradualism as optimal response to uncertainty, see Brainard (1967) as canonical reference on the theory side, Woodford (1999) and Levin, Wieland, and Williams (1999) for recent applications, and Walsh (2004) for an exhaustive review.

[16] Most models suggest these coefficients should sum to the discount factor. This is so close to unity in quarterly data that we chose to let the coefficients add to one.

example, Clarida, Galí, and Gertler, 1999; King and Wolman, 1999; Levin, Wieland and Williams, 1999), although its theoretical justification has been a source of contention.[17]

The key theoretical insight we exploit is that modern versions of the Lucas "islands" model of nominal rigidities imply that they depend on uncertainty about aggregate demand. As discussed in detail in the companion paper, this implies that nominal inertia should depend upon the conditional volatility of the signal (i.e., the forecast of the interest rate) relative to that of the noise (the uncertainty generated by monetary policy plus unpredictable uncertainty about aggregate demand). More specifically, we estimate the following linear relationship:

$$(1-\beta) = \chi_1 + \chi_2 \left(\frac{\delta_1^2 \sigma^2_{\varepsilon,t|t-1}(r)}{\delta_1^2 \sigma^2_{\varepsilon,t|t-1}(r) + \sigma^2_{\varepsilon,t}(y)} \right) \tag{4}$$

where δ_1 is the interest rate semi-elasticity in the aggregate demand equation (3), $\sigma^2_{\varepsilon,t|t-1}(r)$ is the uncertainty about the real interest rate at time *t*, conditional upon information available at time *t*-1 (this includes the conditional uncertainty about the parameters as well as the idiosyncratic shocks to the equation), $\sigma^2_{\varepsilon,t}(y)$ is the residual variance in aggregate demand, and χ_1 and χ_2 are estimated coefficients. The companion paper finds a strong, statistically significant and correctly signed cointegrating relationship between the signal-to-noise ratio and nominal inertia, with the former Granger causing the latter and no reverse feedback. The results also indicate that the impact on nominal inertia comes through with a significant lag—the half life on the error correction term being around 5 years. In what follows, we use this underlying framework to assess how developments in monetary conduct and associated shifts in the degree of inflation inertia in the Phillips curve have contributed to radically lower not simply inflation, but also disinflation costs and macroeconomic volatility.[18]

[17] Using overlapping *relative* real wage contracts, Buiter and Jewitt (1989), and Fuhrer and Moore (1995) argue that there is a structural interpretation for a backward-looking element involving past inflation. An alternative approach has been to assume that some agents use simple autoregressive rules of thumb to forecast inflation (Roberts, 1998; Galí and Gertler, 1999, Ball, 2000; Ireland, 2000) or respond to non-credible announcements by the monetary authority (Ball, 1995). Departures from an optimizing-agent framework are, however, unpalatable to some involved in the microfoundation approach to macroeconomics (Rotemberg and Woodford, 1997).

[18] IMF (2002) examined the link between monetary policy and inflation interia, while Erceg and Levin (2003) suggest that combining a staggered contracts model with information uncertainty about the implicit target for inflation can generate sluggish expectations adjustment. The link between inflation persistence and learning about regime shifts in a monetary reaction function has been analyzed by Fuhrer and Hooker (1993) using stochastic simulations. Cogley and Sargent (2001) use spectral analysis and estimates from a nonlinear Bayesian VAR to investigate the correlation between the degree of inflation persistence and the strength of the monetary response to inflation.

Finally, aggregate demand is determined in equation (3), which links the output gap (i.e. actual output less potential) to the short-term real interest rate, as well as forward- and backward-looking weights on the output gap itself. This type of equation comes from an Euler equation for consumption augmented to allow for habit persistence.[19]

IV. Estimation Results

Given our focus on changes in behavior over time we start by reporting results from rolling regressions, in which parameter estimates are reported over successive fifty-quarter periods.[20] These results permit to identify four sub-periods over which behavior has been relatively stable, and estimates for these period are subsequently used to analyze the impact of shifts in monetary and inflationary behavior on macroeconomic outcomes.

An important issue is the treatment of expectations of inflation and the output gap. There are two basic approaches to this: one is to use instrumented actual realizations of inflation and filtered estimates of the output gap (which we will label the "classical" approach); the other one is to employ "real time" data representing information available at the time. Each approach has advantages and disadvantages. On the one hand, the classical approach is consistent with the rational expectations hypothesis, but may underplay the role of correlated policy errors, particularly over the 1970s. On the other hand, the reliance on real time data assumes there series accurately reflect beliefs at the time.

Rather than taking a stand on these issues, we examine the results from using both approaches. Hence, we report "classical" results using the Generalized Method of Moments (GMM) in which future inflation and the output gap (derived from a standard Hodrick-Prescott filter over the whole sample with a smoothing parameter of 1600) are instrumented,[21] and "real time" data using Federal Reserve estimates of the output gap and inflation expectations from the Michigan Survey of Consumers (the future output gap was instrumented in the same way as in the classical estimation approach).[22] As the real time data

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[19] See, among others, Kerr and King (1996), McCallum and Nelson (1999), Rotemberg and Woodford (1997), Boldrin, Christiano, and Fisher (2001) and Fuhrer (2000).

[20] We experimented with various windows. Fifty quarters struck the best balance between the desire to lengthen the window to provide more accurate parameter estimates and keep the window short to illustrate movements in coefficients over time.

[21] Our Generalized Method of Moments (GMM) estimates use a Newey-West weighting matrix to allow for up to four-quarter of serial correlation. The set of instruments includes the first four quarters of annual inflation, output gap, and effective federal funds rate. For a discussion of GMM estimator and identifying restrictions in the case of monetary policy rules, see Clarida, Gali, and Gertler (1998).

[22] We would like to thank Athanasios Orphanides for providing us with the "real time" output gap data. He also provided us with a real time series on inflation, but the results from this series were essentially identical to those using inflation expectations in the Michigan survey, and we chose to use the latter.

on the output gap are only available from 1965Q4 through 1995Q4, it was extended backwards and forwards using the output gap measure from the Hodrick-Prescott filter, as the real time and classical data largely converge at the beginning and end of the sample. In the event, the results obtained using the two data sets are strikingly similar and are generally not distinguished in the description below.

The estimated coefficients on the Federal Reserve's reaction function reported in Figure 2 indicate significant changes in behavior over time corresponding to conventional wisdom about the loss of monetary control in the 1970s and its subsequent reemergence (see Taylor, 1999; and Clarida, Gali, and Gertler, 2000). The long-run coefficient on inflation falls gradually as the sample moves through the 1960s and 1970s as the focus on controlling inflation was eroded, although this fall is less evident in the real time data, consistent with the argument of some authors that the errors were more in estimating variables than in the monetary reaction function itself. There is a subsequent rise in this coefficient after the appointment of Paul Volcker as Chairman of the Federal Reserve in 1979, and a marked rise in the standard error on the coefficient, presumably reflecting the mingling of two rather different monetary regimes. The long-term response to inflation peaks over samples involving the 1980s and early 1990s (a period which approximately corresponds to Volcker's Chairmanship), before subsequently falling to values not dissimilar from those at the start of the estimation period. This is accompanied by a reduction in the coefficients' standard error, suggesting that the monetary rule was more stable over this period.

The estimated coefficient on the output gap follows a broadly inverse pattern to that on inflation, rising through the '70s, falling over the '80s and then rising again over the '90s, with uncertainty about the parameter again peaking in the middle of the period. The rise and fall in overall monetary instability is graphically illustrated by the hump-shaped movement of standard error on the equation as a whole.

The smoothing parameters provide interesting insights into the conduct of monetary policy over time. The coefficient on the first lag of interest rates follows a U-shape, starting well above unity, falling to below unity in the middle part of the sample, before rising above one again in the 1990s, while that on the second lag follows the opposite pattern, initially significantly negative, rising to close to zero, then falling back to a large negative value. The pronounced second order autoregressive process at the beginning and end of the estimation imply more rapid and predictable movements in interest rates in response to changes in the macroeconomic environment and hence more use of the expectations channel of monetary policy during these periods of monetary stability. This is consistent with our hypothesis that monetary stability encourages more forward-looking behavior in the rest of the economy, as such a shift implies the expectations channels becomes more potent and hence more important to policymakers.

Results for the Phillips curve, reported in Figure 3, indicate significant changes in the degree of inflation inertia over time but much more stability in the impact of the output gap on inflation. The coefficient on forward-looking inflation falls rapidly early in the sample, from under three-quarters to around one-third, before gradually rising back to its initial value. This pattern corresponds to the path of monetary instability over time, and less well with other potential explanations of changes in supply-side flexibility. For example, while deregulation of the U.S. economy over the 1980s and 1990s might help to explain the gradual decrease in nominal inertia, the rapid increase in the early 1970s appears difficult to explain using a slow moving factor such as the macroeconomic impact of structural policies. The coefficient on the output gap, by contrast, is small and hardly significant, but relatively stable over the sample. The standard error on the equation rises and falls over time, but much less dramatically than for the monetary reaction function.

Earlier analysis in Bayoumi and Sgherri (2004) supports the predicted relationship between monetary policy uncertainty. We have two reasons for believing that these results carry over to this paper. First, and most importantly, the path of the coefficient on forward-looking expectations in the Phillips curve is extremely similar, so that we find essentially the same relationship using that papers' measure of monetary stability with this papers' estimates of nominal inertia. Second, a much less accurate measure of the signal-to-noise ratio in monetary policy derived from the standard error of the monetary reaction function in this paper and predictions of the volatility of aggregate demand confirm a correctly signed cointegrating relationship, although the results are not as powerful as those from our earlier work.

Finally, no evidence of a significant break was found in the IS curve (Figure 4), so the full period estimates are used for simulation purposes. The semi-elasticity of the aggregate spending to real interest rate is low and barely significant, whereas the degree of persistence in output fluctuation—which reflects potential adjustment costs in private agents' spending decision—appears to have remained statistically unchanged from about 0.5 over the whole sample. Again, the standard error on the equation rises and falls moderately over the sample.

Overall, these results suggest four distinct periods within the sample with significantly different monetary and inflation responses: the "Bretton Woods" period from the late 1950s through the early 1970s (hereafter the 1960s); the post-Bretton Woods/pre-Volcker period (1972:1 to 1979:3—hereafter the 1970s); Volcker (1979:4 to 1987:3—hereafter the 1980s); and Greenspan (1987:4 through the present day—hereafter the 1990s). Results from regressions over these periods—which broadly correspond to those from the rolling regressions—are reported in Tables 1–3, and form the basis for the simulation analysis of the next section.

V. SIMULATION RESULTS

The small model coefficients estimated using real-time data were employed to explain changes in macroeconomic stability over time.[23] To minimize the degree to which the results

[23] The coefficient estimates obtained using a Hodrick-Prescott filter rather than real time data are relatively close, and generate broadly similar conclusions (results are available upon request). The main reason for using the real time data is that the coefficient on forward-looking inflation in the Phillips in the 1990s seems more sensible.

are affected by noise in the data, only parameters whose values change significantly over the sample are allowed to vary across sub-periods. Hence, the IS-curve is assumed invariant over the sample, as is the response of inflation to real output in the Phillips curve. The monetary response function and the coefficient on forward-looking inflation expectations in the Phillips curve, on the other hand, are allowed to vary across the four sub-periods.[24]

A feature of the model is that the long-run coefficient on inflation in the monetary reaction function is below unity in the 1970s and close to unity in the 1960s. Earlier analysis of monetary rules has generally assumed that such rules are unstable, as they imply a negative response of the real interest rate to a change in inflation. However, in the dynamic model analyzed here, the sluggish responses prevent this perverse effect from prevailing. More specifically, examination of the eigen values indicates that the models are stable for all time periods, although, as might be anticipated, the speed of convergence to equilibrium is at its lowest over the 1970s.[25]

Figure 5 reports impulse responses to a one percentage point one-off shocks to aggregate demand (i.e., the IS curve) and aggregate supply (i.e., the Phillips curve). The two experiments illustrate that, while all of the models are stable, the responses for the 1970s parameterization stand out as larger/more elongated and more cyclical than those from other periods, plausibly reflecting the loss of monetary stability. This striking difference in behavior can also be clearly be observed by comparing implied cross-correlations between output and inflation across the periods for the simulated one-off supply-side shock (Figure 6). Across the other sub-samples, the 1980s responses show generally larger volatility and the 1990s the least.

This pattern holds for the loss in output associated with the losses in output associated with credibly lowering the inflation target by a percentage point on a permanent basis (Figure 7, panel a), implying that the sacrifice ratio was highest in the 1970s, followed by the 1980s, 1960s, and then the 1990s. The responses also underline the importance of the interaction between nominal inertia and the expectations channel of monetary policy. In the case of the disinflation shock, for example, inflation generally falls significantly on announcement of the new inflation target in anticipation of future monetary actions, with the size of the announcement effect being roughly inversely proportional to the degree of nominal inertia in the Phillips curve.

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[24] The coefficient on the output gap in the monetary response function for the 1970s was perverse and, as it was not statistically significant at conventional levels, was set to zero.

[25] As the model is linear (in logs), it can be analyzed using solution methods such as Blanchard and Kahn (1980) or Klein (2000). In all sub-periods (that is, 1960s, 1970s, 1980s, and 1990s), the number of eigen values outside the unit circle (two) is equal to the number of 'non-predetermined' variables of the model, hence the model is saddlepath stable. Our model was solved in Matlab, using McCallum's routines for rational expectation models (http://wpweb2k.gsia.cmu.edu/faculty/mccallum/Software%20for%20RE%20Analysis.pdf).

Panel b of Figure 7 illustrates the role of changes in inflation inertia. It reports the results for the disinflation shock when inflation inertia is held at its 1990s level across all periods—so that while the monetary response function changes over time, the Phillips curve does not. As can be seen, the responses across time periods become extremely similar, illustrating the fact that it is changes in private sector responses that are driving the results across time periods, rather than monetary rules.

Figure 8 reports the impact of a temporary one percentage point reduction in nominal interest rates. When inflation inertia is allowed to vary over time, the 1990s model stands out as generating a larger boost to output and a relatively modest increase in inflation, reflecting the combination of a more pronounced easing of rates after the initial reduction and low levels of inflation inertia. At the other end of the spectrum, the 1970s model shows the largest degree of underlying cycling and instability.

We next examine the relative importance of shifts in monetary rules, changes in private sector inflation dynamics, and differences in underlying shocks in explaining the historical evolution of macroeconomic stability. Table 4 reports the historical estimates of the volatility of output, inflation, and nominal interest rates over time, and those implied by the model with and without changes in inflation inertia. Initially, we focus on the degree to which the estimated model can reproduce the volatility seen in the 1990s. This decade was chosen both because it is recent, and hence more familiar to readers, and because the results in Tables 1-3 suggest this was a period of relative stability, implying that the estimated disturbances are more likely to reflect genuine shocks than instability in the equations. The asymptotic standard deviation of output, inflation, and nominal interest rates derived from the 1990s model, at 1.3, 1.7, and 2.6 percent, respectively, are relatively similar to the historical values of 1.2, 1.5, and 2.1 percent (the slightly higher numbers generated by the model may reflect the fact part of the some of the disturbances actually mirror relationships that altered over time).

To further investigate the role of changes monetary rules over time in explaining macroeconomic volatility, we next calculated the asymptotic standard deviations implied by shifts in the monetary response function while leaving the underlying disturbances and level of inflation inertia fixed at 1990s levels. The results indicate that, on their own, changing monetary rules have a trivial impact on inflation volatility over time. Further more, the results for output and interest rates suggest that both were most stable during the 1970s, even though in the historical data output volatility is at its highest and interest rate volatility is second only to the 1980s. Ignoring the role of changing inflation inertia thus leads to the conclusions that the macroeconomic volatility of the 1970s came entirely from large disturbances, while the monetary rule was a relatively stable one—the opposite of perceived wisdom about this period.

By contrast, if the monetary rule and inflation inertia are both allowed to vary over time but the underlying shocks remain at their 1990s level, the model exhibits its highest macroeconomic volatility in the 1970s and lowest in the 1990s. Indeed, the estimated instability from the model in the 1970s is actually larger than the historical data, possibly reflecting the cycling seen in the impulse response functions. The fit for other periods is generally closer, although interest rate volatility is consistently overestimated, suggesting that the disturbances to the monetary reaction function may be overestimated. The overall impression is that the model including inflation inertia does a fairly good job in tracking the broad patterns of macroeconomic volatility across time—particularly with respect to output—with relatively little need to assume large changes in the size of underlying disturbances. This provides further support for our basic hypothesis that changes in inflation inertia induced by monetary polices are crucial to explain the evolution of macroeconomic stability. Indeed, it suggests that almost all of the observed fall in both inflation and output volatility occurs through this mechanism.

At a first glance, this result appears quite different from some statistical analysis, including Stock and Watson (2003), suggesting that the fall in output volatility is largely due to good luck. In Stock and Watson's univariate framework, reductions in output volatility can only be explained by changes in output inertia. On further examination, however, the authors identify that in the case of inflation, lower persistence was able to explain lower inflation volatility but do not make the link to output instability. We too find the IS curve to be stable over the period, but link the fall in real volatility to changes in inflation inertia, as do Cogley and Sargent (1993), using a Bayesian VAR framework.

The importance of changes in inflation inertia on macroeconomic stability is illustrated in Figure 9. Panel (a) reports the sensitivity of the asymptotic volatility of inflation, output, and the interest rate to varying the coefficient on forward-looking inflation expectations in the Phillips curve (β) and the strength of the long-run response of monetary policy to a rise in inflation (α_1) (other parameters are set to their estimated values over the 1990s). For all relevant values, reducing inflation inertia reduces all aspects of macroeconomic volatility, and overwhelms the effects from changing the monetary rule. Panel (b) focuses on the trade-offs across different monetary rules, by graphing the impact on macroeconomic volatility of changing the long-term monetary response to inflation (α_1) and to the output gap (α_2). Resulting changes in macroeconomic stability are much smaller than those implied by shifts to the degree of inflation persistence, and often show trade-offs. For example, a larger response to the output gap leads to lower output volatility but higher inflation instability. Beyond a certain point, a similar trade-off is evident from increases in the long-term response to inflation.

VI. Conclusions and Policy Implications

This paper proposes a markedly different transmission mechanism between monetary policy and macroeconomic stability to that generally presented in the literature, namely that the main impact comes through resulting changes in nominal inertia rather than altering the monetary rule itself. Using recent developments in models of nominal rigidities as our guide, we estimate a small theory-consistent, rational-expectations model of the monetary transmission mechanism. The results strongly suggest that changes in monetary policy are connected over time with shifts in the degree of nominal inertia in the economy, and that these improvements in private sector flexibility are indeed the main channel through which monetary policy lowers the volatility of inflation and, even more importantly, output. By contrast, changes in monetary rules alone appear to have only small effects on macroeconomic stability.

This shift in the transmission mechanism has several implications. It suggests that it may take a significant amount of time for the full impact of a change in monetary policy to be seen. Indeed, these lags may well explain why the early stages of a return to monetary stability (such as that achieved in the United States by Chairman Volcker in the 1980s) can involve substantial losses in output. With the public uncertain about whether nominal stability will indeed be restored, inflation inertia and the costs of deflation remain high for some time. In the longer term, however, the resulting fall in nominal inertia lowers the volatility of output as well as inflation. Indeed, our calculations suggest that most of the fall in U.S. output volatility between the early 1980s and now can be ascribed to improved supply-side responses resulting from better monetary policies.

Finally, by emphasizing the link between monetary policy and private sector responses, this paper focuses on the "artistic" side of monetary management. Putting private sector perceptions about the stability of monetary policies at center stage highlights the importance of central bank communication, of convincing the public that interest rate policy is in good hands. It also suggests that such policies may need to take account of collective social memory. This may justify a greater emphasis on controlling output in countries such as the United States, where memories of the Great Depression loom large, and on controlling inflation in countries such as Germany, Japan, and many countries in Latin America, which can recall destructive hyper inflations. Unlike science, art is, in the end, in the eye of the beholder.

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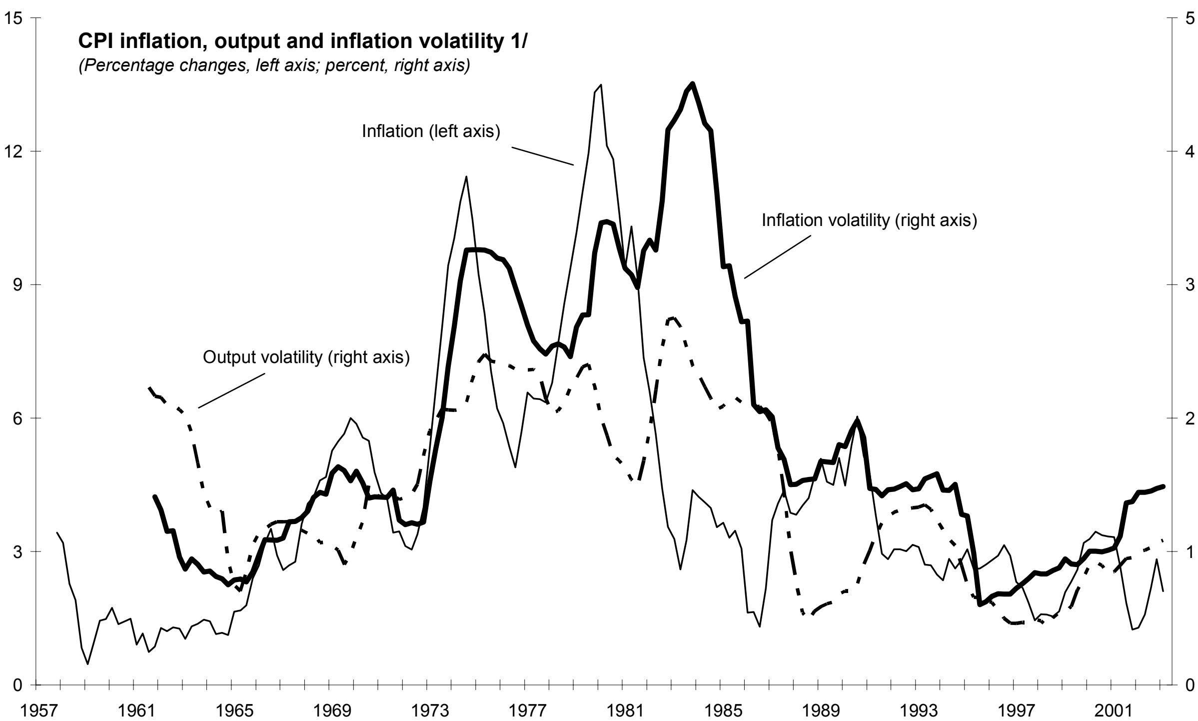
Figure 1. United States: Inflation Dynamics and Macroeconomic Volatility, 1957–2003



1/ Inflation is measured by annual percentage changes in the Consumer Price Index.
Inflation volatility is measured by twenty-quarter rolling standard deviation of annualized the quarterly inflation rate, as measured by CPI.
Output volatility is measured by twenty-quarter rolling standard deviation of the real output gap.
Data source: *International Financial Statistics*.

Figure 2. Rolling GMM Estimates of the U.S. Monetary Policy Rule (using real-time data)

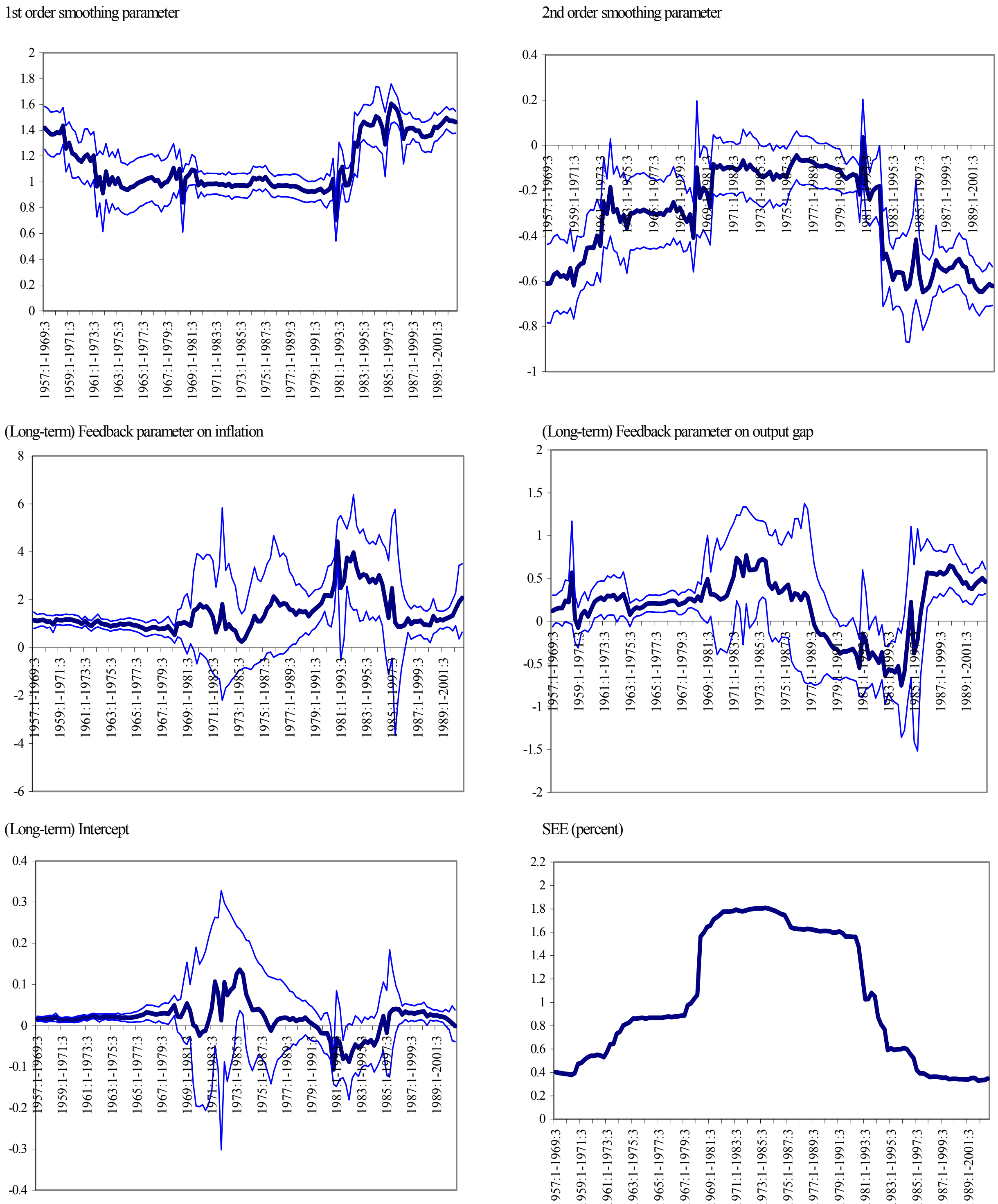


Figure 3. Rolling GMM Estimates of the U.S. Phillips Curve (using real-time data)

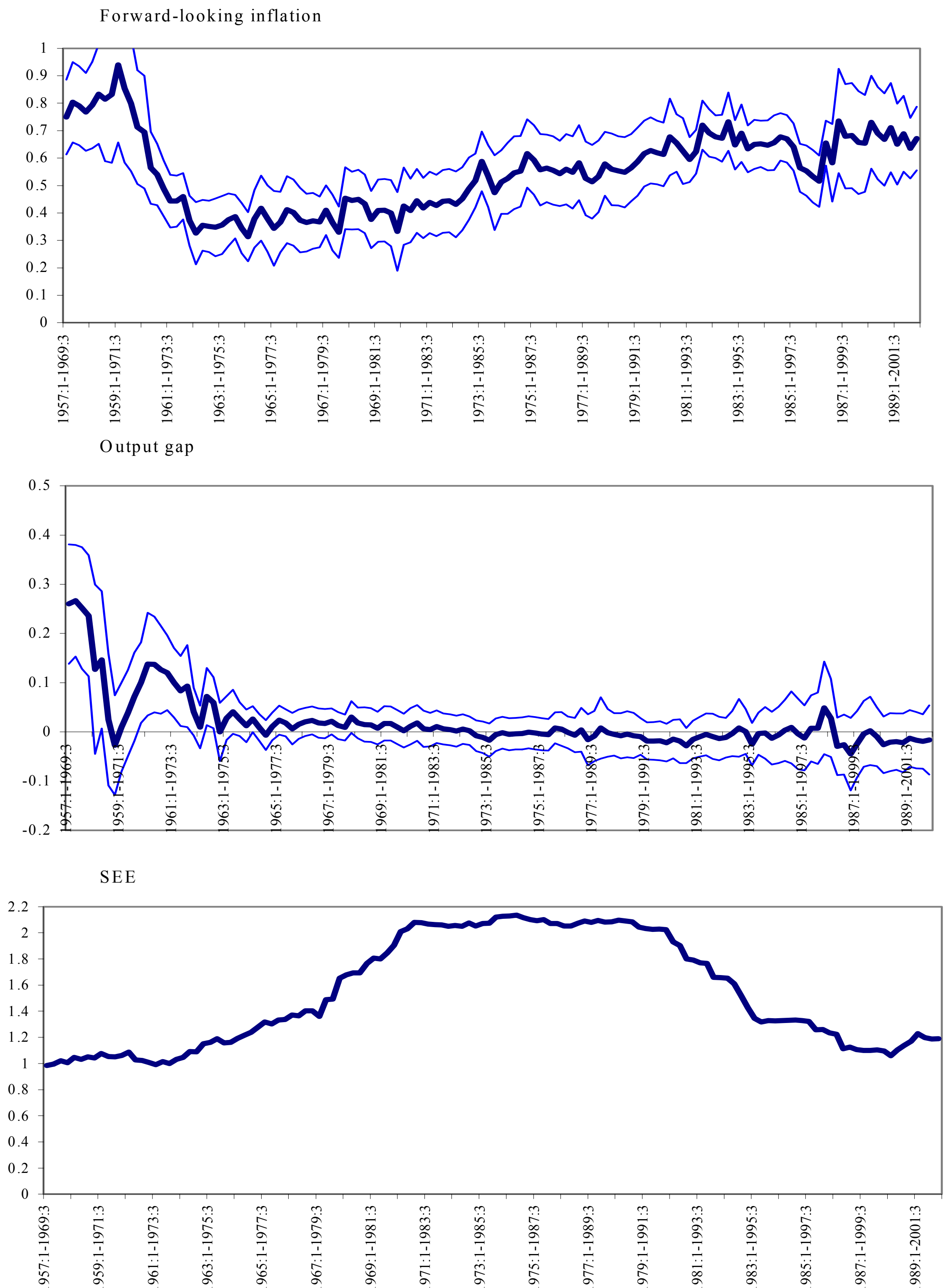


Figure 4. Rolling GMM Estimates of the U.S. Aggregate Demand (using real-time data)

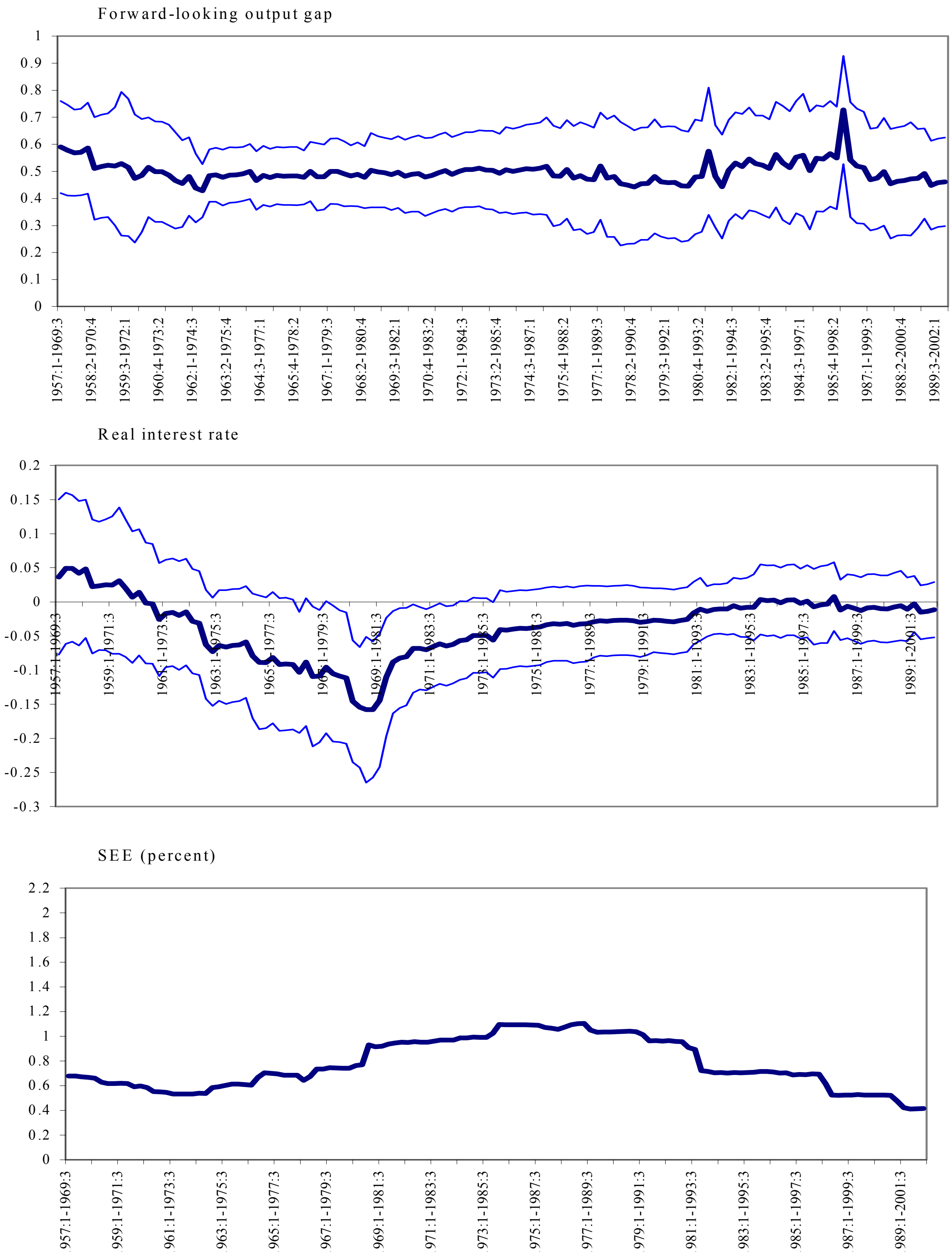


Figure 5 (panel a). Impulse Responses to a Negative One-Percent One-Off Demand Shock

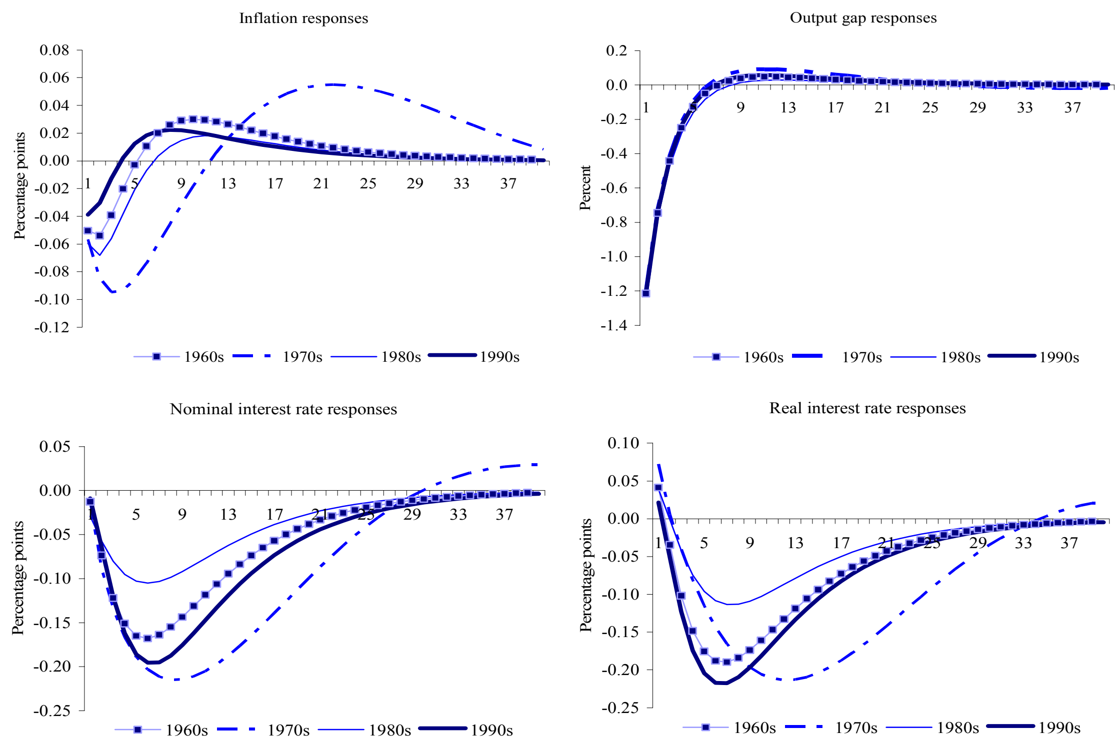


Figure 5 (panel b): Impulse Responses to a Negative One-Percent One-Off Supply Shock

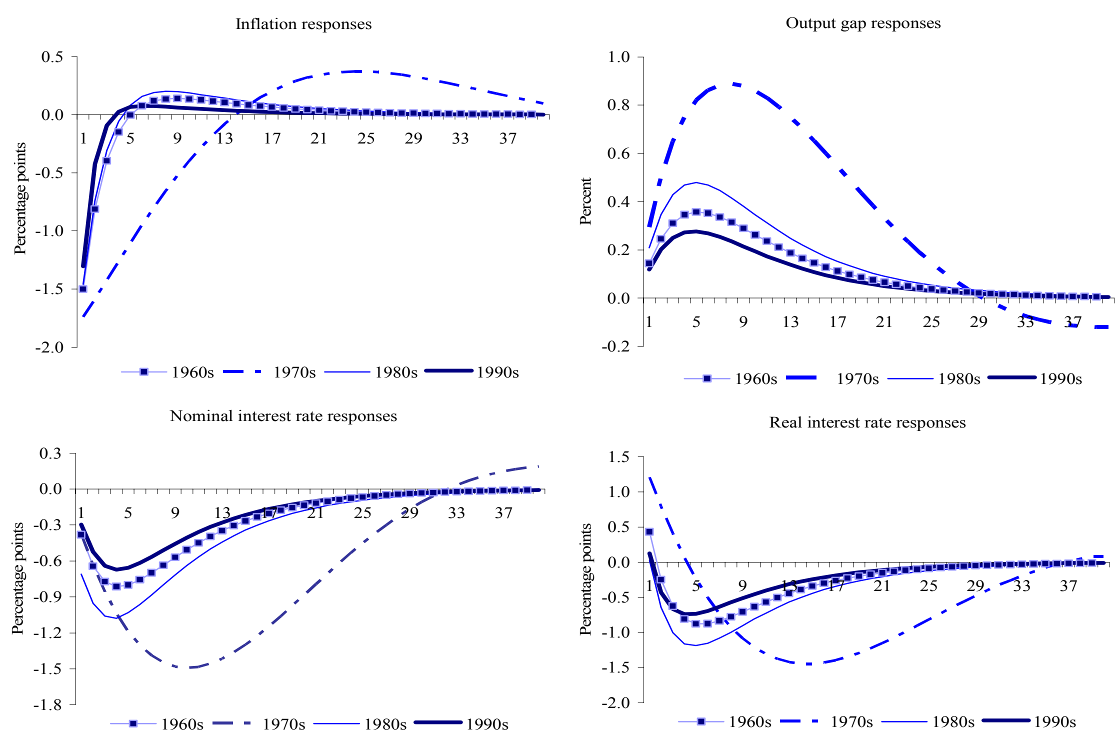


Figure 6. Model-Generated Auto- and Cross-Correlation Functions for a One-Off Supply Shock

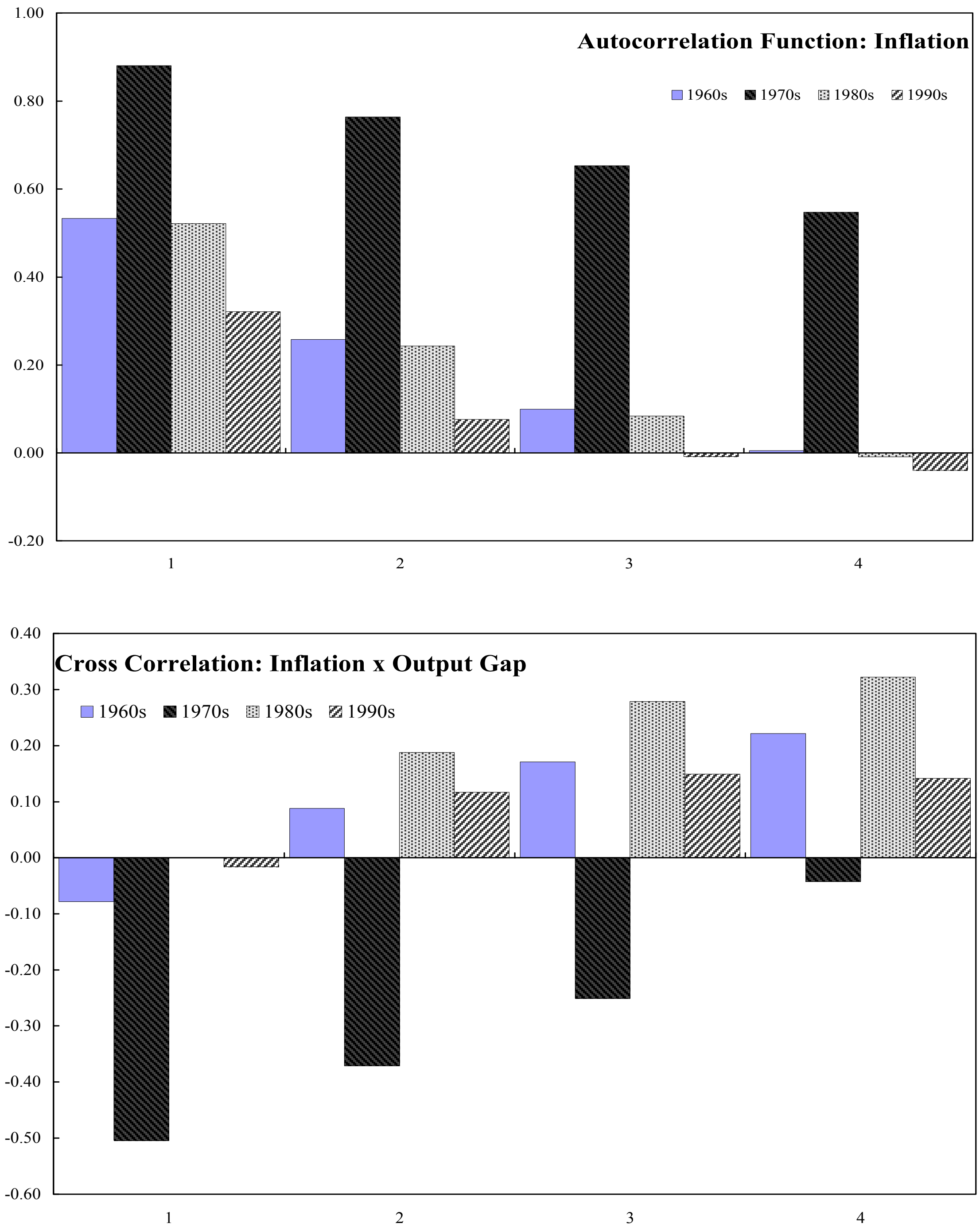


Figure 7 (panel a). Impulse Responses to a Negative One-Percent Permanent Disinflation Shock

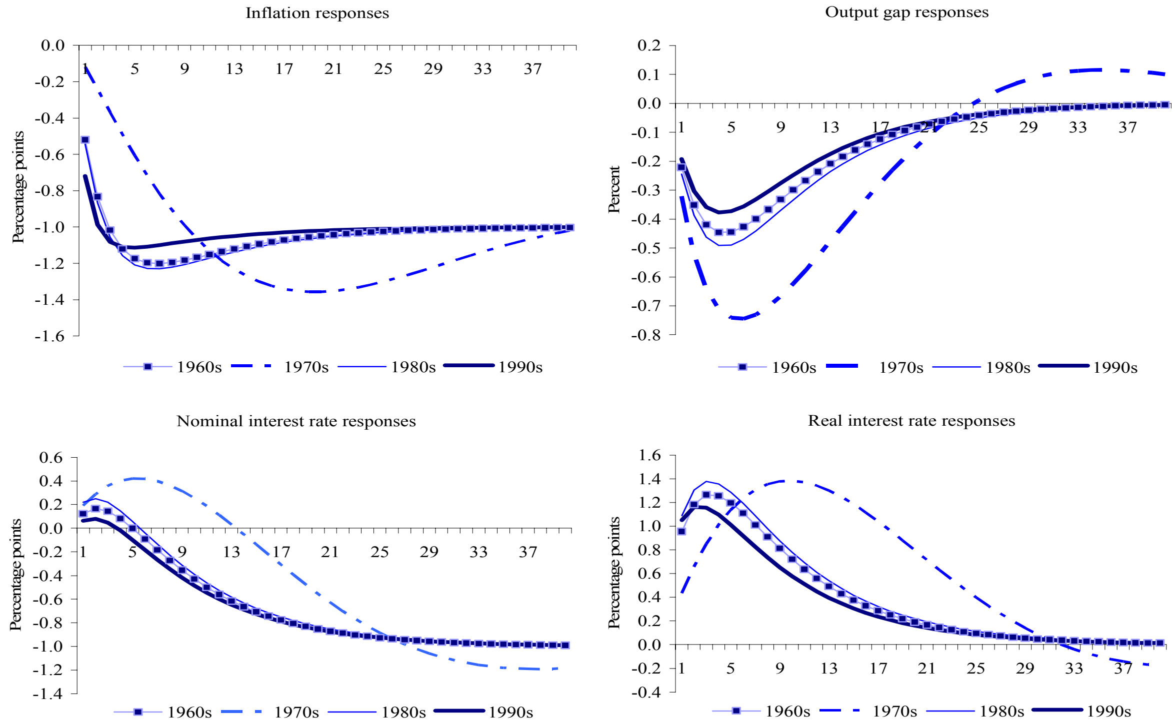


Figure 7 (panel b). Impulse Response Functions to a One-Percent Permanent Disinflation Shock under Constant β's (β=0.726)

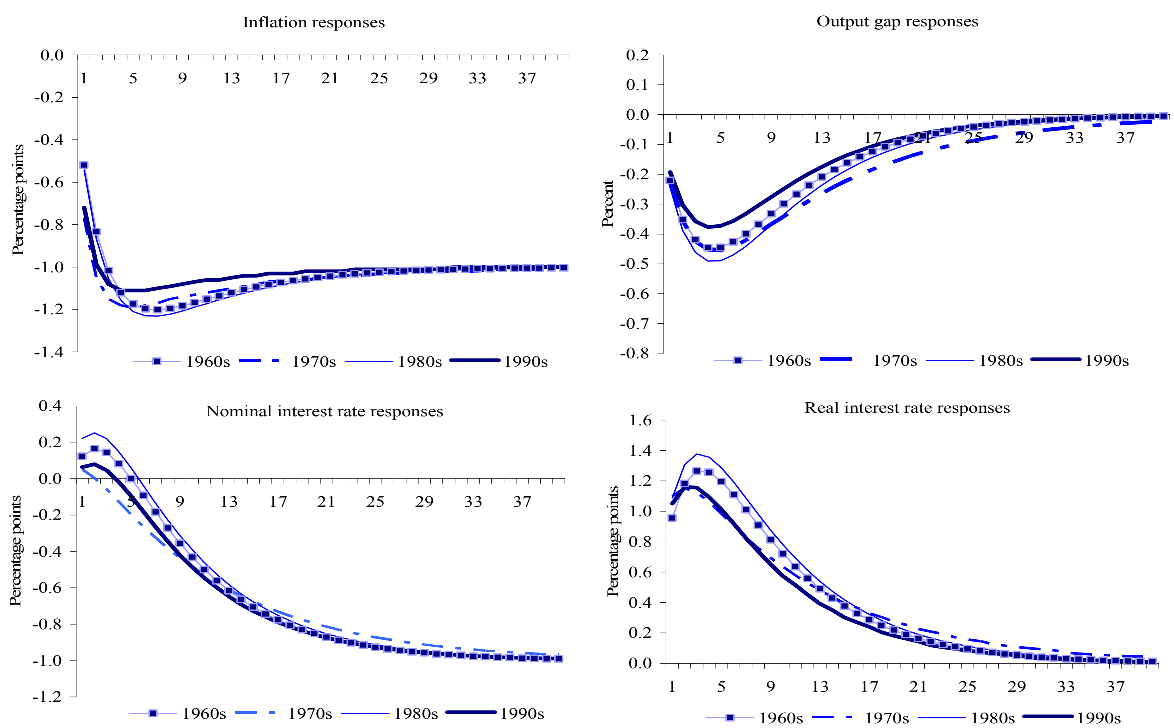


Figure 8. Impulse Response Functions to a One-Percent One-Off Interest-Rate Shock

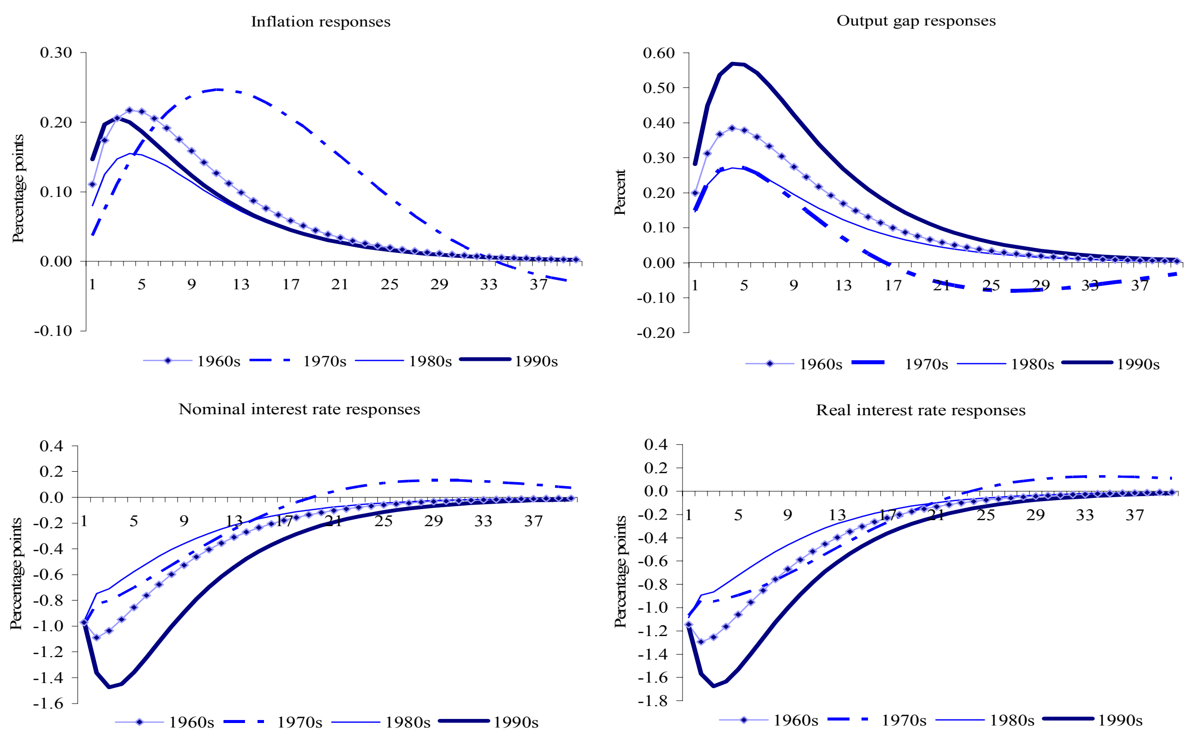


Figure 9 (panel a). Sensitivity of Inflation, Output, and Interest-Rate Volatilities to Alternative Degrees of Forward-Lookingness in Pricing and Conservativeness in Monetary Policy

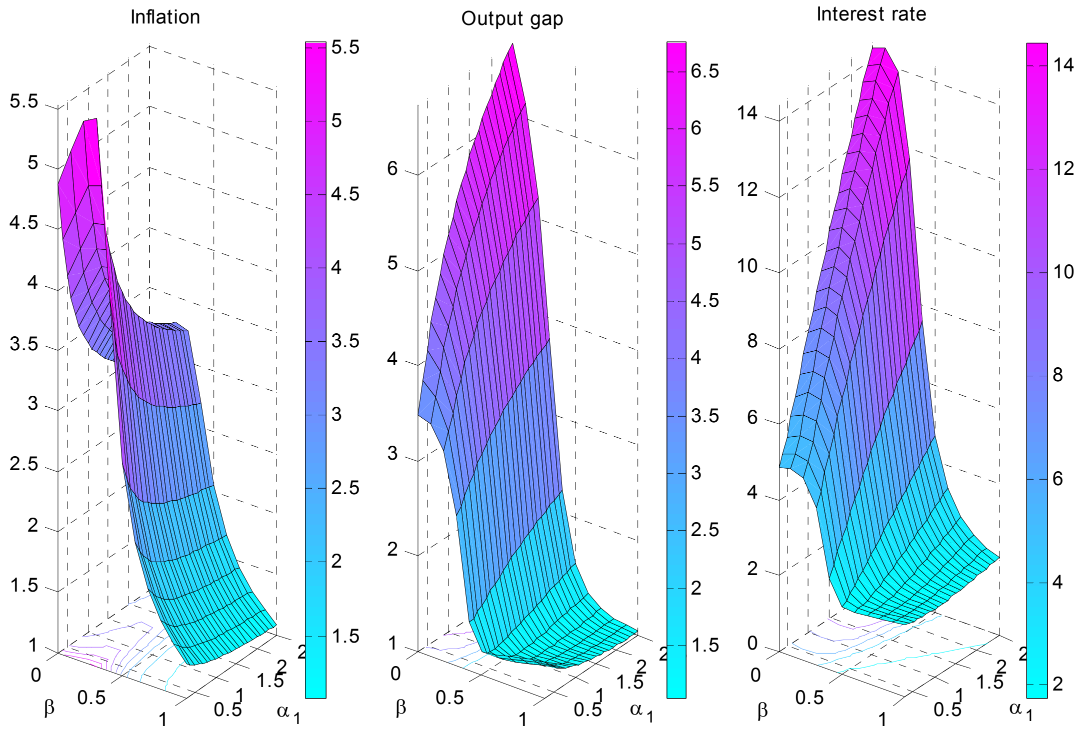


Figure 9 (panel b). Sensitivity of Inflation, Output, and Interest-Rate Volatilities to Alternative Degrees of Conservativeness and Activism in Monetary Policy

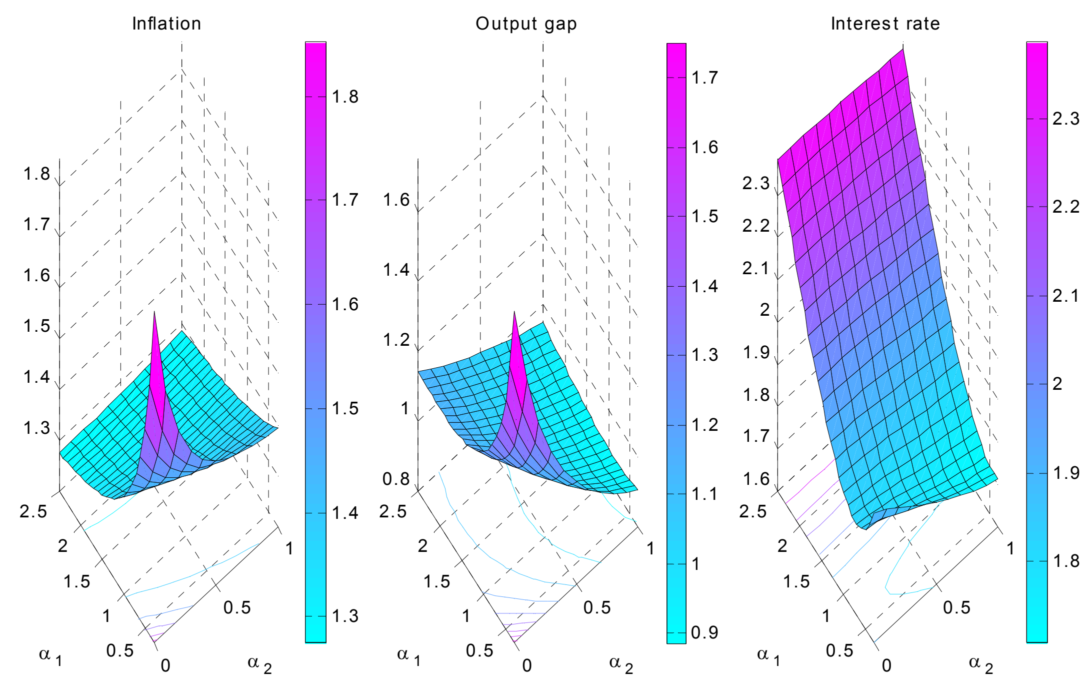


Table 1. Estimated Monetary Policy Rule[1]

Using HP filter[2]							
Sample Period	α_0	α_1	α_2	ρ_1	ρ_2	Overidentifying Restrictions	SEE
Bretton Woods	.018	1.004	.343	1.104	-.385	6.9	.54%
(1957:1-1972:2)	(.004)	(.157)	(.130)	(.139)	(.102)	[.55]	
Post Bretton Woods /	.026	.608	.594	.799	-.138	4.1	1.01%
Pre Volcker (1972:3-1979:4)	(.021)	(.265)	(.330)	(.061)	(.044)	[.85]	
Volcker	.033	1.641	-.101	.828	-.074	5.2	2.00%
(1980:1-1987:3)	(.021)	(.461)	(.238)	(.072)	(.060)	[.74]	
Greenspan	.010	1.563	.333	1.476	-.673	4.6	.37%
(1987:4-2003:2)	(.007)	(.218)	(.196)	(.048)	(.054)	[.80]	
Full sample	.021	1.047	1.064	1.057	-.178	10.3	1.03%
(1957:1-2003:2)	(.010)	(.272)	(.385)	(.057)	(.055)	[.25]	

Using real-time data[2]							
Sample Period	α_0	α_1	α_2	ρ_1	ρ_2	Overidentifying Restrictions	SEE
Bretton Woods	.018	1.062	.253	1.185	-.424	4.9	.52%
(1957:1-1972:2)	(.004)	(.124)	(.112)	(.110)	(.085)	[.77]	
Post Bretton Woods /	.044	.635	.241	.871	-.213	4.9	1.04%
Pre Volcker (1972:3-1979:4)	(.032)	(.264)	(.120)	(.075)	(.069)	[.77]	
Volcker	-.007	1.824	-.467	.840	-.107	4.9	1.99%
(1980:1-1987:3)	(.019)	(.298)	(.258)	(.079)	(.058)	[.77]	
Greenspan	.017	1.405	.375	1.484	-.646	3.1	.36%
(1987:4-2003:2)	(.007)	(.211)	(.102)	(.044)	(.044)	[.93]	
Full sample	.004	1.715	.289	1.054	-.156	7.6	1.04%
(1957:1-2003:2)	(.013)	(.373)	(.163)	(.052)	(.053)	[.47]	

[1] Generalized Method of Moments estimates using the Newey-West weighting matrix and allowing for up to four-quarter serial correlation. Robust standard errors are reported in parentheses. P-values for the Hansen's J-test are reported in square brackets.
[2] The set of instruments includes lags 1-4 of annual inflation, output gap, and effective federal funds rate.

Table 2. Estimated Phillips Curve[1]

Sample Period	Using HP filter[2]			
	β	γ	Overidentifying Restrictions	SEE
Bretton Woods (1957:1-1972:2)	.640 (.092)	.047 (.058)	10.3 [.51]	1.12%
Post Bretton Woods / Pre Volcker (1972:3-1979:4)	.470 (.038)	.005 (.060)	5.7 [.90]	1.64%
Volcker (1980:1-1987:3)	.551 (.055)	.018 (.080)	5.5 [.90]	2.35%
Greenspan (1987:4-2003:2)	.905 (.070)	.260 (.115)	9.9 [.54]	1.26%
Full sample (1957:1-2003:2)	.594 (.059)	.056 (.053)	14.6 [.20]	1.49%

Sample Period	Using real-time data[2]			
	β	γ	Overidentifying Restrictions	SEE
Bretton Woods (1957:1-1972:2)	.620 (.077)	.148 (.047)	10.6 [.48]	1.05%
Post Bretton Woods / Pre Volcker (1972:3-1979:4)	.470 (.040)	.003 (.015)	5.7 [.90]	1.64%
Volcker (1980:1-1987:3)	.623 (.068)	-.030 (.016)	5.3 [.92]	2.36%
Greenspan (1987:4-2003:2)	.726 (.066)	.005 (.038)	7.9 [.72]	1.23%
Full sample (1957:1-2003:2)	0.558 (0.055)	0.014 (0.019)	14.1 [.22]	1.48%

[1] Generalized Method of Moments estimates using the Newey-West weighting matrix and allowing for up to four-quarter serial correlation. Robust standard errors are reported in parentheses. P-values for the Hansen's J-test are reported in square brackets.
[2] The set of instruments includes lags 1-4 of annual inflation, output gap, and federal funds rate.

Table 3. Estimated Aggregate Demand Function[1]

Using HP filter[2]

Sample Period	δ_1	δ_2	Overidentifying Restrictions	SEE
Bretton Woods	.021	.555	8.0	.64%
(1957:1-1972:2)	(.021)	(.035)	[.63]	
Post Bretton Woods /	-.062	.569	4.8	.67%
Pre Volcker (1972:3-1979:4)	(.018)	(.038)	[.91]	
Volcker	-.022	.468	5.4	.57%
(1980:1-1987:3)	(.005)	(.035)	[.86]	
Greenspan	-.000	.481	6.6	.33%
(1987:4-2003:2)	(.006)	(.041)	[.76]	
Full sample	-.013	.499	8.2	.54%
(1957:1-2003:2)	(.006)	(.026)	[.61]	

Using real-time data[2]

Sample Period	δ_1	δ_2	Overidentifying Restrictions	SEE
Bretton Woods	.013	.582	7.4	.63%
(1957:1-1972:2)	(.023)	(.031)	[.69]	
Post Bretton Woods /	-.146	.567	4.8	.94%
Pre Volcker (1972:3-1979:4)	(.021)	(.023)	[.90]	
Volcker	-.029	.458	5.5	1.13%
(1980:1-1987:3)	(.005)	(.025)	[.85]	
Greenspan	-.007	.515	8.1	.49%
(1987:4-2003:2)	(.008)	(.039)	[.62]	
Full sample	-.018	.486	9.4	.74%
(1957:1-2003:2)	(.007)	(.028)	[.49]	

[1] Generalized Method of Moments estimates use the Newey-West weighting matrix and allow for up to four-quarter serial correlation. Robust standard errors are reported in parentheses. P-values for the Hansen's J-test are reported in square brackets.
[2] The set of instruments includes lags 1-4 of annual inflation, output gap, and federal funds rate.

Table 4. Simulated Standard Deviations and Sacrifice Ratios

	Bretton Woods (1960s)	Post Bretton Woods (1970s)	Volcker (1980s)	Greenspan (1990s)
Estimated parameters over the periods (real-time model)				
α_0	0	0	0	0
α_1	1.062	.635	1.824	1.405
α_2	.253	.241	0	.375
ρ_1	1.185	.871	.840	1.484
ρ_2	-.424	-.213	-.107	-.646
β	.620	.470	.623	.726
γ	.014	.014	.014	.014
δ_0	0	0	0	0
δ_1	-.018	-.018	-.018	-.018
δ_2	.486	.486	.486	.486
Historical standard deviations over the periods (percent)				
Inflation	1.79	2.89	3.87	1.49
Output	1.70	2.31	1.83	1.20
Interest rate	1.83	2.58	3.53	2.08
Simulated standard deviations and sacrifice ratios using 1990s-specific shocks and β's estimates				
Asymptotic standard errors (percent)				
Inflation	1.72	1.74	1.70	1.72
Output	1.22	1.05	1.50	1.34
Interest rate	2.00	1.40	2.47	2.61
Sacrifice Ratios	5.84	7.26	6.58	4.96
Simulated standard deviations and sacrifice ratios using estimated parameters but 1990s-specific shocks				
Asymptotic standard errors (percent)				
Inflation	2.23	4.76	2.17	1.72
Output	1.51	3.89	1.88	1.34
Interest rate	2.88	6.74	3.67	2.61
Sacrifice Ratios	6.22	10.20 [1/]	7.28	4.96

[1] Under the 1970s parameterization, the model does not converge to steady state by the end of the simulation horizon. The sacrifice ratio is therefore calculated over the simulation periods during which the output gap remains below baseline, that is over the first 24 quarters.