Interest Rates, Inflation, and Federal Reserve Policy Since 1980

Peter N. Ireland*
Boston College

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Abstract: This paper characterizes Federal Reserve policy since 1980 as one that actively manages short-term nominal interest rates in order to control inflation and evaluates this policy using a dynamic, stochastic, sticky-price model of the United States economy. The results show that the Fed's policy insulates aggregate output from the effects of exogenous demand-side disturbances and, by calling for a modest but persistent reduction in short-term interest rates following a positive technology shock, helps the economy to respond to supply-side disturbances as it would in the absence of nominal rigidities.

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*Please address correspondence to: Peter N. Ireland, Boston College, Department of Economics, Carney Hall, 140 Commonwealth Avenue, Chestnut Hill, MA 02467-3806. Tel: (617) 552-3687. Fax: (617) 552-2308. E-mail: peter.ireland@bc.edu. I would like to thank Paul Evans and two anonymous referees, along with seminar participants at Boston College, the Federal Reserve Bank of Dallas, Rutgers University, and the University of Pittsburgh, for helpful comments and suggestions.

1. Introduction

Inflation in the United States, after rising throughout the 1960s and 1970s, fell sharply from its peak in the early 1980s and has remained low and stable since then. Figure 1 shows that this great decline in inflation was accompanied, at first, by very high short-term nominal interest rates, as measured either by the federal funds rate or by the three-month Treasury bill rate. In 1982, short-term interest rates began to follow inflation down. Several episodes of rising short-term rates have interrupted this longer-run trend, however. Most notably, short-term interest rates moved back towards 10 percent as inflation crept higher during 1988 and 1989. Short-term rates also rose during 1994 and 1995 as inflation bottomed out after an extended period of low interest rates following the 1990-91 recession. Finally, short-term rates jumped higher during 1983 and 1984; while this move was not accompanied by an increase in actual inflation, Goodfriend (1993) characterizes the period as one in which doubts concerning the Federal Reserve's commitment to its new, low inflation policy contributed to a rise in expected inflation.

In principle, the movements in short-term interest rates displayed in figure 1 could simply reflect market reactions to changes in actual and expected inflation, with higher inflation generating higher nominal interest rates as predicted by standard, Fisherian theory. Most observers, however, including Cook (1989), Goodfriend (1993), and Taylor (1993), view these interest rate movements as deliberate monetary policy actions taken by the Federal Reserve; this view receives support from formal econometric studies by Bernanke and Blinder (1992) and Sims (1992), which identify monetary policy shocks as disturbances to short-term nominal interest rates. Together with figure 1, these studies suggest that since 1980, the Federal Reserve has followed a policy of manipulating short-term interest rates in order to control inflation.

How has the Federal Reserve's interest rate policy affected the cyclical behavior of aggregate prices and quantities? And, more important, how has this policy affected welfare? This paper addresses these questions by evaluating actual Fed policy since 1980 using a dynamic, stochastic, general equilibrium model of the United States economy. In doing so, the paper follows previous work by Hairault and Portier (1993), Kim (1995), King and Watson (1996), Ireland (1997), Rotemberg and Woodford (1997), and Clarida, Gali, and Gertler (1998) by specifying the model at the level of tastes and technologies. This detailed modeling approach offers two key advantages. First, since the model is specified at the level of tastes and technologies, it identifies parameters that should remain invariant to changes in policy regime: the model is structural. Thus, the model can be used to compare the Fed's activist interest rate policy to alternatives that, for example, make no attempt to respond to the state of the economy and instead keep the money supply growing at a constant rate. Second, since the model provides an explicit characterization of a representative agent's utility function, it allows alternative monetary policies to be evaluated in terms of their effects on welfare: there is no need to rely on an arbitrarily-specified loss function that simply penalizes variation in aggregate output and inflation without considering the source of this variation.

In the model, temporary rigidity in nominal goods prices gives the monetary authority considerable leverage over the behavior of real variables in the short run. This nominal price rigidity also turns exogenous shocks to the demand for money into a potentially significant source of aggregate fluctuations. Must theoretical work, beginning with Poole (1970), indicates that money demand shocks provide the monetary authority with a reason to prefer policies that manage nominal interest rates to those that focus on the behavior of the monetary aggregates;

much empirical work, including some performed here, suggests that such shocks are large and highly persistent. Thus, money demand shocks, coupled with sticky goods prices, play a key role in the analysis. Following in the real business cycle tradition of Kydland and Prescott (1982), technology shocks are introduced as an additional source of aggregate fluctuations in the model developed here. Thus, the model is one in which the monetary authority faces the challenge of responding appropriately to exogenous shocks on both the demand and supply sides.

The results show that the Federal Reserve’s interest rate policy successfully insulates aggregate output from the effects of money demand shocks; this finding is as expected, given Poole’s (1970) analysis. More surprising, however, is that the Fed’s interest rate policy also helps the economy adjust to technology shocks, despite the fact that this policy appears to focus exclusively on the behavior of inflation and not on independent developments in the real economy. Overall, therefore, the results give actual Fed policy, which actively manages short-term interest rates to control inflation, higher marks than a constant money growth rate policy that makes no attempt to respond to the shocks that hit the economy.

2. The Model

2.1. The Economic Environment

The model resembles those used by Hairault and Portier (1993), Kim (1995), and Ireland (1997), which draw many of their features from earlier work by Rotemberg (1982) and Blanchard and Kiyotaki (1987). It describes the behavior of a representative household, a representative finished goods-producing firm, a continuum of intermediate goods-producing firms indexed by $i \in [0,1]$, and a monetary authority in an economy where time periods are indexed by $t = 0,1,2,\ldots$.

The representative household has preferences defined over consumption of the finished good, leisure, and real cash balances; the form of these preferences permits the demand for money to be written as a function of a scale variable, aggregate consumption, and an opportunity cost variable, the nominal interest rate. During each period, the household purchases output from the representative finished goods-producing firm and supplies capital and labor to the intermediate goods-producing firms in competitive markets.

Each intermediate goods-producing firm uses capital and labor to produce a distinct, perishable intermediate good; hence, intermediate goods may also be indexed by $i \in [0,1]$. The intermediate goods-producing firms have identical objectives and constraints, however, allowing the analysis to focus on the activities of a representative intermediate goods-producing firm that produces the generic good i. Since the various intermediate goods substitute imperfectly for one another in the representative finished goods-producing firm's technology, the representative intermediate goods-producing firm sells its output in a monopolistically competitive market; as in Blanchard and Kiyotaki (1987), the firm acts as a price-setter in the market for good i. In addition, the representative intermediate goods-producing firm faces a cost of adjusting its nominal price; as in Rotemberg (1982), this cost of price adjustment permits the monetary authority to influence the behavior of real variables in the short run.

2.2. The Representative Household

The representative household carries M_{t-1} units of money, B_{t-1} bonds, and K_t units of capital into period t. At the beginning of the period, the household receives a lump-sum nominal transfer T_t from the monetary authority. Next, the household's bonds mature, providing it with

B_{t-1} additional units of money. The household uses some of this money to purchase B_t new bonds at the nominal cost B_t/R_t; hence, R_t denotes the gross nominal interest rate between t and $t+1$.

During period t, the household supplies $H_t(i)$ units of labor and $K_t(i)$ units of capital to each intermediate goods-producing firm $i \in [0,1]$; its choices of $H_t(i)$ and $K_t(i)$ must satisfy

$$H_t = \int_0^1 H_t(i)di$$

and

$$K_t = \int_0^1 K_t(i)di$$

for all $t = 0,1,2,...$, where H_t denotes total hours worked. Labor is paid the nominal wage W_t and capital is paid the nominal rental rate Q_t; the household receives total nominal factor payments $W_tH_t+Q_tK_t$ during period t. In addition, the household receives nominal profits $D_t(i)$ from each intermediate goods-producing firm $i \in [0,1]$, for a total of

$$D_t = \int_0^1 D_t(i)di$$

in nominal profits during each period $t = 0,1,2,...$.

The household uses its funds to purchase output from the representative finished goods-producing at the nominal price P_t, which it divides between consumption C_t and investment I_t. By investing I_t, the household increases its capital stock according to

$$K_{t+1} = (1-\delta)K_t + I_t, \qquad \textbf{(1)}$$

where the depreciation rate satisfies 1> δ > 0, but must pay an associated cost of adjustment, measured in terms of the finished good and given by

$$\frac{\phi_K}{2}\left(\frac{K_{t+1}}{gK_t} - 1\right)^2 K_t,$$

where $\phi_K > 0$ governs the magnitude of the adjustment cost and $g > 1$ measures the gross steady-state growth rate of the capital stock. The household then carries M_t units of money, B_t bonds, and K_{t+1} units of capital into period t+1, subject to the budget constraint

$$\frac{M_{t-1} + B_{t-1} + T_t + W_t H_t + Q_t K_t + D_t}{P_t} \geq C_t + I_t + \frac{\phi_K}{2}\left(\frac{K_{t+1}}{gK_t} - 1\right)^2 K_t + \frac{B_t/R_t + M_t}{P_t} \qquad \textbf{(2)}$$

for all t = 0,1,2,....

The household's preferences are described by the utility function

$$E\sum_{t=0}^{\infty} \beta^t \left(\left(\frac{\gamma}{\gamma-1}\right) \ln[C_t^{\frac{\gamma-1}{\gamma}} + b_t(M_t/P_t)^{\frac{\gamma-1}{\gamma}}] + \eta \ln(1-H_t) \right), \qquad \textbf{(3)}$$

where 1 > β > 0, γ > 0, and η > 0. The preference shock b_t follows the autoregressive process

$$\ln(b_t) = (1-\rho_b)\ln(b) + \rho_b \ln(b_{t-1}) + \epsilon_{bt}, \qquad \textbf{(4)}$$

where b >0, 1 > ρ_b > -1, and ϵ_{bt} is serially uncorrelated with mean zero and standard deviation σ_b.

The household, therefore, chooses C_t, H_t, M_t, B_t, I_t, and K_{t+1} for all t = 0,1,2,... to maximize its utility described by (3) and (4) subject to the constraints imposed by (1) and (2). Kim (1995) shows that the first-order conditions for this problem can be used to derive the model's money demand function, which takes the familiar form

$$\ln(M_t/P_t) = \ln(C_t) - \gamma\ln(r_t) + \gamma\ln(b_t), \qquad \textbf{(5)}$$

where $r_t = R_t$ -1 denotes the net nominal interest rate. Thus, the preference parameter γ determines the interest elasticity of money demand and the preference shock b_t represents a serially correlated shock to money demand.

2.3. The Representative Finished Goods-Producing Firm

The representative finished goods-producing firm uses $Y_t(i)$ units of each intermediate good $i \in [0,1]$ during each period t to produce Y_t units of the finished good according to the constant returns to scale technology described by

$$\left(\int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} di\right)^{\frac{\theta}{\theta-1}} \geq Y_t, \qquad \textbf{(6)}$$

with $\theta > 1$. Intermediate good i sells at the nominal price $P_t(i)$, while the finished good sells at the nominal price P_t; given these prices, the finished goods-producing firm chooses Y_t and $Y_t(i)$ for all $i \in [0,1]$ to maximize its profits, subject to the constraint imposed by (6) for all t = 0,1,2,....

The first-order conditions for this problem are (6) with equality and

$$Y_t(i) = [P_t(i)/P_t]^{-\theta} Y_t \tag{7}$$

for all $i \in [0,1]$ and $t = 0,1,2,....$ Competition in the market for the finished good drives the representative firm's profits down to zero in equilibrium. Along with (7), this zero profit condition determines P_t as

$$P_t = \left(\int_0^1 P_t(i)^{1-\theta} di \right)^{\frac{1}{1-\theta}}$$

for all $t = 0,1,2,....$

2.4. The Representative Intermediate Goods-Producing Firm

The representative intermediate goods-producing firm hires $H_t(i)$ units of labor and $K_t(i)$ units of capital from the representative household during period t to produce $Y_t(i)$ units of intermediate good i according to the constant returns to scale technology described by

$$A_t K_t(i)^{\alpha} [g^t H_t(i)]^{1-\alpha} \geq Y_t(i), \tag{8}$$

with $1 > \alpha > 0$, where $g > 1$ denotes the gross rate of labor-augmenting technological progress. The aggregate technology shock A_t follows the autoregressive process

$$\ln(A_t) = \rho_A \ln(A_{t-1}) + \epsilon_{At}, \tag{9}$$

where $1 > \rho_A > -1$ and ϵ_{At} is serially uncorrelated with mean zero and standard deviation σ_A.

Since the intermediate goods substitute imperfectly for one another in the representative finished goods-producing firm's technology (6), the representative intermediate goods-producing firm sells its output in a monopolistically competitive market. Thus, during each period t, the intermediate goods-producing firm sets its nominal price $P_t(i)$ subject to the requirement that it satisfy the finished goods-producing firm's demand (7), taking the aggregates P_t and Y_t as given. In addition, the intermediate goods-producing firm faces a cost of adjusting its nominal price, measured in terms of the finished good and given by

$$\frac{\phi_P}{2}\left(\frac{P_t(i)}{\pi P_{t-1}(i)}-1\right)^2 Y_t$$

for all $t = 0,1,2,...$, where $\phi_P > 0$ governs the magnitude of the adjustment cost and $\pi > 1$ denotes the gross steady-state inflation rate. Rotemberg (1982) interprets this quadratic adjustment cost specification as capturing the negative effects of price changes on customer-firm relationships, which increase in magnitude with the size of the price change and with the overall scale of economic activity, as summarized by total output of the finished good Y_t.

The cost of price adjustment makes the representative intermediate goods-producing firm's problem dynamic; it chooses $H_t(i)$, $K_t(i)$, $Y_t(i)$, and $P_t(i)$ for all $t = 0,1,2,...$ to maximize its total market value, equal to

$$E\sum_{t=0}^{\infty}\left(\frac{\beta^t\Lambda_t}{P_t}\right)\left(P_t(i)Y_t(i)-W_tH_t(i)-Q_tK_t(i)-\frac{\phi_P}{2}\left(\frac{P_t(i)}{\pi P_{t-1}(i)}-1\right)^2 P_tY_t\right), \qquad \textbf{(10)}$$

subject to the constraints imposed by (7)-(9). In (10), $\beta^t\Lambda_t/P_t$ measures the marginal utility value to the representative household of an additional dollar in profits during period t; the variable Λ_t is the nonnegative Lagrange multiplier on the budget constraint (2) from the household's problem.

2.5. The Monetary Authority

The monetary authority conducts policy by managing either the short-term nominal interest rate R_t or the nominal money supply M_t. Following Taylor (1993), Fuhrer and Moore (1995), Rotemberg and Woodford (1997), and Clarida, Gali, and Gertler (1998), actual Federal Reserve policy is characterized here as one that gradually adjusts the interest rate in response to deviations of inflation and detrended output from their steady-state levels according to

$$\ln(R_t) = (1-\rho_R)\ln(R) + \rho_R \ln(R_{t-1}) + \rho_\pi \ln(\pi_{t-1}/\pi) + \rho_y \ln(y_{t-1}/y) + \epsilon_{Rt}, \quad \textbf{(11)}$$

where $\pi_t = P_t/P_{t-1}$ denotes the gross rate of inflation, $y_t = Y_t/g^t$ denotes detrended output, R, π, and y are the steady-state values of R_t, π_t, and y_t, ρ_R, ρ_π, and ρ_y are parameters, and the disturbance ϵ_{Rt} is serially uncorrelated with mean zero and standard deviation σ_R. Although the existence of a unique equilibrium cannot always be guaranteed when monetary policy is described by an interest rate rule such as (11), numerical analysis reveals that a unique equilibrium does exist in each of the cases considered below. Under (11), the money supply becomes endogenous, responding systematically to each of the model's state variables.

An interest rate rule such as (11) can be contrasted with an alternative policy that simply keeps the money supply growing at a constant rate according to

$$\mu_t = \mu \quad \textbf{(12)}$$

for all t = 0,1,2,..., where $\mu_t = M_t/M_{t-1}$ denotes the gross rate of money growth during period t.

2.6. Symmetric Equilibrium

In a symmetric equilibrium, all intermediate goods-producing firms make identical decisions, so that $P_t(i) = P_t$, $Y_t(i) = Y_t$, $H_t(i) = H_t$, $K_t(i) = K_t$, and $D_t(i) = D_t$ for all $i \in [0,1]$ and $t = 0,1,2,\ldots$. The market-clearing conditions $M_t = M_{t-1} + T_t$ and $B_t = 0$ must hold, as must the aggregate resource constraint

$$Y_t = C_t + I_t + \frac{\phi_K}{2}\left(\frac{K_{t+1}}{gK_t} - 1\right)^2 K_t + \frac{\phi_P}{2}\left(\frac{P_t}{\pi P_{t-1}} - 1\right)^2 Y_t,$$

which shows how adjustment costs for capital and prices subtract from the amount of output available for consumption and investment.

These equilibrium conditions, together with the first-order conditions describing the optimizing behavior of the representative household and firms, the laws of motion (4) and (9) for the exogenous money demand and technology shocks, and a policy rule in the form of (11) or (12), constitute a system of nonlinear expectational difference equations that characterize the model's symmetric equilibrium. Once values are assigned to each of the model's parameters, this system may be log-linearized and solved using methods outlined by Blanchard and Kahn (1980).

3. Parameterizing the Model

Least-squares regressions, run with quarterly data from 1980:1 through 1997:1 and shown in table 1, are used to assign values to some the model's parameters. A regression of the log of real per-capita GDP, $\ln(Y_t)$, on a constant and a trend provides an estimate of $\ln(g) = 0.00380$, or

g = 1.00381. In the model, this value of g yields steady-state growth in real per-capita output of about 1.5 percent annually. A regression of the growth rate of the GDP implicit price deflator, $\ln(P_t/P_{t-1})$, on a constant provides an estimate of $\ln(\pi) = 0.00967$, or $\pi = 1.00972$. In the model, this value of π implies that the steady-state annual rate of inflation is about 4 percent.

To characterize the Federal Reserve's actual monetary policy since 1980, a reaction function in the form of (11) is estimated using the three-month Treasury bill rate as the measure of R_t. While, in practice, the Fed exercises its tightest control over the federal funds rate, Treasury bills correspond most closely to the riskless, one-period discount bonds in the model; moreover, as shown in figure 1, the federal funds and Treasury bill rates behave quite similarly over the sample period, so that the results depend little on the choice between them. The results, also shown in table 1, are obtained using the residuals from the output and inflation regressions described above to measure the deviations $\ln(y_t/y)$ and $\ln(\pi_t/\pi)$ of output and inflation from their steady-state values.

The small and statistically insignificant coefficient on detrended output in the interest rate regression suggests that since 1980, actual Fed policy has focused exclusively on controlling inflation and ignored independent developments in the real economy; Clarida, Gali, and Gertler (1998) reach a similar conclusion. Thus, actual Fed policy is represented here as one that sets $\rho_R = 0.774$, $\rho_\pi = 0.240$, and $\rho_y = 0$. The constant term in the regression implies that $(1-\rho_R)\ln(R) = 0.00361$, or $R = 1.0161$. In the model, the Fisher equation links the steady-state nominal interest rate R to the steady-state real interest rate g/β and the steady-state inflation rate π via $R = \pi g/\beta$. Hence, the estimates of R, π, and g obtained above can be used to construct an estimate of $\beta = 0.9975$. The interest rate regression also yields an estimate of $\sigma_R = 0.00217$.

Least-squares estimates of the money demand equation (5) are biased if the regressors C_t and r_t are correlated with the disturbance b_t. As shown below, however, the model implies that when the monetary authority adopts an interest rate rule such as (11), it successfully insulates the economy from the effects of shocks to money demand; in particular, C_t and r_t are independent of both current and lagged values of b_t. Thus, under the special assumptions of the model, the Cochrane-Orcutt technique yields consistent estimates of the parameters in (4) and (5).

When per-capita M1 is used to measure M_t, the GDP deflator is used to measure P_t, real per-capita personal consumption expenditures on nondurable goods and services are used to measure C_t, and the three-month Treasury bill rate is used to measure $r_t = R_t - 1$, table 1 shows that $\gamma = 0.0277$. Moreover, since the constant, u_{mt}, and ϵ_{mt} from the regression correspond to $\gamma\ln(b)$, $\gamma[\ln(b_t)-\ln(b)]$, and $\gamma\epsilon_{bt}$ in (4) and (5), the estimates imply that $b = 0.00216$, $\rho_b = 0.981$, and $\sigma_b = 0.487$. Evidently, shocks to money demand tend to be large and highly persistent.

Some of the remaining parameters are set equal to values commonly used in the literature: $\delta = 0.025$, $\alpha = 0.36$, and $\rho_A = 0.95$. The setting $\sigma_A = 0.006$ makes detrended output in the model about as volatile as it is in the data. The setting $\eta = 1.5$ implies that the household spends about one third of its time working in the model's steady state. Equation (7) reveals that θ measures the absolute value of the constant elasticity of demand for each intermediate good i, so that the steady-state markup of price over marginal cost equals $\theta/(\theta-1)$. The setting $\theta = 6$ makes this markup equal to 20 percent, a benchmark value suggested by Rotemberg and Woodford (1992).

When log-linearized, the first-order conditions from representative intermediate goods-producing firm's problem imply that

$$\ln(P_t) - \ln(P_{t-1}) - \ln(\pi) = \left(\frac{\theta - 1}{\phi_P}\right) E_t \sum_{j=0}^{\infty} \beta^j [\ln(P^*_{t+j}) - \ln(P_{t+j})], \qquad \textbf{(13)}$$

where P^*_{t+j} is the nominal price that would prevail in the absence of adjustment costs. The sum on the right-hand side of (13) measures the discounted present value of current and future discrepancies between the target prices P^*_{t+j} and the actual prices P_{t+j}. Hence, $(\theta\text{-}1)/\phi_P$ represents the fraction of these discrepancies that is eliminated during the current period: price adjustment becomes more rapid when θ increases, so that markets become more competitive, and when ϕ_P decreases, so that the cost of price adjustment becomes smaller. Given $\theta = 6$, a setting of $\phi_P = 50$ makes this fraction equal to 10 percent, a value suggested by King and Watson (1996). In addition, Kim (1995) and King and Watson (1996) suggest that large adjustment costs for capital are needed in sticky-price models to generate sensible responses of output to monetary shocks; hence, the setting $\phi_K = 40$ is used here.

Figure 2 displays the impulse responses of detrended output, inflation, money growth, and the nominal interest rate to a one standard deviation policy shock when all parameters are set as described above. A positive value for ϵ_{Rt} in (11) represents a monetary tightening: the short-term nominal interest rate, translated into annualized terms, rises by 87 basis points and remains above its initial steady-state level for more than four periods, or one year, while the money supply declines. Output falls by about three quarters of one percent on impact and does not fully recover for more than one year. The annualized inflation rate declines by more than one percentage point. Thus, the model allows monetary policy to have powerful and persistent effects on the economy.

The results section, below, compares the performance of the economy under the Federal Reserve's actual interest rate policy to its hypothetical performance under an alternative policy that makes no attempt to respond to the state of the economy and instead keeps the money supply growing at a constant rate, as shown in (12). Since, in the model's steady state, money growth and inflation are related via $\mu = \pi g$, a constant money growth rate of $\mu = 1.0136$ guarantees that the steady-state inflation rate π and the steady-state nominal interest rate R are the same under the alternative policy (12) as they are under the Fed's actual policy.

4. Results

As noted above, the constant money growth rule (12) with $\mu = 1.0136$ gives rise to the same steady-state inflation and nominal interest rates as actual Federal Reserve policy, characterized by the interest rate rule (11) with $R = 1.0161$, $\rho_R = 0.774$, $\rho_\pi = 0.240$, and $\rho_y = 0$. Hence, these policies differ only in terms of their effects on the cyclical behavior of the economy.

Figure 3, for example, shows the impulse responses of detrended output, inflation, money growth, and the nominal interest rate to a one standard deviation money demand shock, both when policy is given by the constant money growth rate rule and when policy is determined by the Federal Reserve's interest rate rule. Under the constant money growth rate rule, the money supply does not respond to the shock. Hence, the rigidity in nominal goods prices causes output to fall sharply. The interest rate rule, in contrast, holds R_t constant in the face of the shock by accommodating the increase in money demand. Thus, the figure shows that actual Fed policy insulates the economy from the effects of money demand shocks, as suggested by Poole (1970).

In a version of this model with flexible prices ($\phi_P = 0$) and constant money growth (μ =

1.0136), a one standard deviation technology shock has familiar effects: detrended output jumps immediately by 0.59 percent before slowly returning to its steady-state level. With $\phi_P = 50$, however, prices cannot adjust rapidly enough to bring about the full increase in demand-determined output. Instead, figure 4 shows that under the constant money growth rate rule, detrended output rises only gradually after a technology shock; moreover, at its peak, reached six periods after the shock, output is only 0.44 percent above its steady-state level. Under the Federal Reserve's actual procedures, however, the deflationary pressure brought about by the positive supply-side shock calls forth a modest but sustained easing of monetary policy; the impulse response indicates that the short-term interest rate, converted to annualized terms, is more than 27 basis points below its steady-state level five quarters after the shock. This easing of monetary policy, in turn, helps accelerate and magnify the increase in output, which now peaks just four periods after the shock at a level that is 0.50 percent above steady state. Of course, this mechanism also works in reverse after a negative technology shock, when the Fed's interest rate rule calls for a sustained tightening of monetary policy that accelerates and magnifies the decline in output. In both cases, however, the Fed's policy response helps the economy to adjust to the technology shock as it would in the absence of nominal rigidities.

Taken together, therefore, figures 3 and 4 suggest that by actively managing the short-term nominal interest rate in response to changes in inflation, the Federal Reserve's actual policy allows the economy to respond more efficiently to exogenous shocks, not just to money demand, but to technology shocks as well. Surprisingly, perhaps, this improvement in cyclical performance comes despite the fact that the Fed's policy rule focuses only on controlling inflation and not on independent developments in the real economy.

Table 2 provides a similar message by decomposing the forecast error variance in detrended output into components due to technology, money demand, and policy shocks under the actual and alternative policies. The Federal Reserve's policy removes money demand shocks as a source of output fluctuations while at the same time allowing output to vary more in response to technology shocks. Again, the results suggest that the Federal Reserve's actual interest rate rule improves on the constant money growth rate rule by allowing the economy to respond more efficiently to both demand and supply-side shocks.

In fact, calculations reveal that the Federal Reserve's interest rate rule provides the representative household with a higher level of expected utility than the constant money growth rate rule: expected utility equals 300.877 under the Fed's policy and 300.851 under the constant money growth rate rule. As is typically the case in representative agent models of this type, the differences in welfare brought about by changes in monetary policy are small: here, the household requires a permanent increase in consumption of just 0.0066 percent to be as well off under the constant money growth rate rule as it is under the Federal Reserve's interest rate rule. In fact, other changes in the economic environment also imply small changes in welfare. Under the Federal Reserve's interest rate rule, for example, the complete elimination of nominal price rigidity (a decrease in ϕ_P from 50 to 0) yields an increase in expected utility equivalent to a permanent increase in consumption of only 0.011 percent.

Despite the small welfare effects, however, the superiority of the Federal Reserve's interest rate rule is robust to a variety of changes in the model's parameters. Figure 5 illustrates this by plotting the difference between the level of expected utility achieved under the Fed's actual interest rate rule and the level of utility achieved under the constant money growth rate rule as one of the model's parameters is varied while the others are held constant; in each graph, positive numbers represent cases where the Fed's policy continues to dominate and negative values correspond to cases where the constant money growth rate rule is preferable.

Equation (13) shows that together, θ and ϕ_P govern the speed of price adjustment. As prices become more flexible, either because markets become more competitive due to an increase in θ or because the cost of price adjustment falls due to a decrease in ϕ_P, money demand shocks have smaller effects on output. Thus, figure 5 reveals that the value of the Federal Reserve's policy, which insulates the economy from these shocks, diminishes as either the markup $\theta/(\theta-1)$ or the adjustment cost ϕ_P falls. The Fed's policy improves on the constant money growth rate rule for all values of the markup exceeding 3 percent and for all values of ϕ_P exceeding 8.

In the data, the disturbance ϵ_{Rt} to the interest rate rule (11) picks up movements in short-term nominal interest rates that cannot be attributed to Federal Reserve's efforts to control output or inflation. In the model, however, this disturbance serves no useful purpose; if the monetary authority could choose, it would set $\sigma_R = 0$. Thus, figure 5 also shows that the Federal Reserve's policy outperforms the constant money growth rate rule for values of σ_R less than the benchmark of 0.00217; in fact, as σ_R declines, the Fed's policy yields larger welfare gains.

The results are most sensitive to changes in σ_b, the standard deviation of the money demand shock. When money demand shocks become less important, so does the role of the Federal Reserve's policy in insulating the economy from these shocks. The Federal Reserve's policy continues to improve on the constant money growth rate rules, however, for all values of σ_b exceeding 0.37.

5. Conclusion

Since 1980, the Federal Reserve has followed a policy of actively managing short-term nominal interest rates in order to control inflation. By holding the interest rate constant in the face of exogenous shocks to money demand, this policy insulates the real economy from the effects of such shocks, exactly as suggested by Poole (1970). The results obtained here, however, go beyond Poole's by indicating that the Fed's interest rate policy also helps the economy adjust to technology shocks. Positive supply-side shocks produce temporary deflationary pressures; the Fed reacts to these pressures with a modest but persistent reduction in short-term interest rates. When prices are sticky, this easing of policy accelerates and magnifies the increase in output, allowing output to respond as it would in the absence of price rigidities. Thus, by focusing exclusively on nominal variables, and on the inflation rate in particular, the Fed's policy works to improve the cyclical performance of the economy and to increase overall welfare. In fact, the focus on inflation that characterizes Federal Reserve policy since 1980 appears to be critical to its success. Clarida, Gali and Gertler (1998) compare Fed policy before and after 1980 and find that in the earlier period, the Fed responded only weakly to changes in inflation, leading not only to increased nominal instability but to increased real instability as well.

The results obtained here suggest that the Fed, or any other central bank, can implement a successful activist policy of managing short-term nominal interest rates, provided it recognizes that ultimately, its job is to control inflation. Before this conclusion is accepted unequivocally, however, two extensions to the analysis must be considered. First, while the model developed here includes three sources of randomness--money demand shocks, technology shocks, and monetary policy shocks--it abstracts from other disturbances that may be important. McCallum and Nelson (1997), for example, show how an exogenous shock to the representative household's marginal utility of consumption can act, in equilibrium, like a disturbance that resembles the IS shock in traditional, Keynesian analysis. It remains to be seen whether actual Fed policy, as it is characterized here, continues to perform well in the presence of this additional type of shock. Second, while the results obtained here indicate that the Federal Reserve's actual interest rate rule outperforms one alternative, a constant money growth rate rule, there may be other policies that dominate both of those considered here. How close does the Fed's interest rate rule compare to the model's optimal monetary policy? This question remains for future research.

6. Appendix: Data Description

All data used in this paper are quarterly and are drawn from the Federal Reserve Bank of St. Louis' FRED database. Figure 1 measures inflation as year-over-year percentage changes in the seasonally adjusted GDP implicit price deflator. The federal funds rate and the three-month Treasury bill rate are both expressed in annualized terms.

The regressions use real GDP, in chained 1992 dollars, as the measure of output and the GDP implicit price deflator as the measure of the price level. The money supply is measured by the M1 money stock; consumption is measured by real personal consumption expenditures on nondurable goods and services, in chained 1992 dollars; and the nominal interest rate is measured by the three-month Treasury bill rate. All data, except for the interest rate series, are seasonally adjusted; output, the money stock, and consumption are converted to per-capita terms by dividing by the civilian noninstitutional population, ages 16 and over. The original data express output, consumption, and the interest rate in annualized terms; in the regressions, these figures are converted to quarterly rates so that they correspond to the variables in the model.

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Table 1.--Regression Results

(Standard Errors in Parentheses)

Output Growth

$$\ln(Y_t) = \underset{(0.01)}{8.82} + \underset{(0.00014)}{0.00380}t + \epsilon_{yt}$$

Inflation

$$\ln(P_t/P_{t-1}) = \underset{(0.00063)}{0.00967} + \epsilon_{\pi t}$$

Federal Reserve's Interest Rate Rule

$$\ln(R_t) = \underset{(0.00110)}{0.00361} + \underset{(0.062)}{0.774}\ln(R_{t-1}) + \underset{(0.083)}{0.240}\ln(\pi_{t-1}/\pi) + \underset{(0.011528)}{0.000372}\ln(y_{t-1}/y) + \epsilon_{Rt}$$

$$\sigma_R = 0.00217$$

Money Demand

$$\ln(M_t/P_t) = \underset{(0.114)}{-0.170} + \ln(C_t) - \underset{(0.0157)}{0.0277}\ln(r_t) + u_{mt}$$

$$u_{mt} = \underset{(0.032)}{0.981}u_{mt-1} + \epsilon_{mt}$$

$$\sigma_m = 0.0135$$

Table 2.--Forecast Error Variance in Detrended Output Under Alternative Policy Rules

Federal Reserve's Interest Rate Rule

Quarters Ahead	Total Variance (Percent)	Percentage Due To Technology	Money Demand	Policy
1	0.006706	13.5	0.0	86.5
4	0.015116	51.6	0.0	48.4
8	0.024090	69.5	0.0	30.5
12	0.030710	76.1	0.0	23.9
∞	0.050862	85.6	0.0	14.4

Constant Money Growth Rate Rule

Quarters Ahead	Total Variance (Percent)	Percentage Due To Technology	Money Demand	Policy
1	0.007156	5.6	94.4	0.0
4	0.015867	30.2	69.8	0.0
8	0.023888	51.9	48.1	0.0
12	0.030161	61.7	38.3	0.0
∞	0.049999	76.5	23.5	0.0

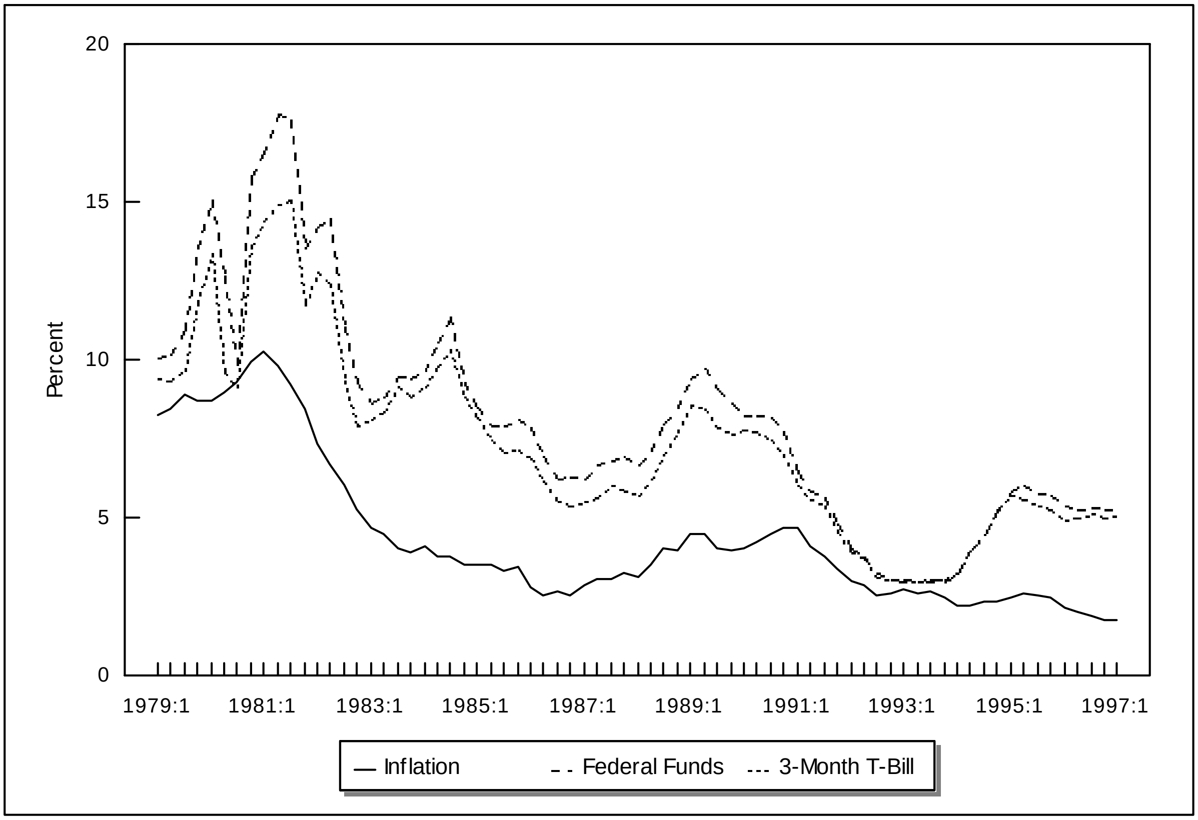

Figure 1. Inflation and Interest Rates, United States

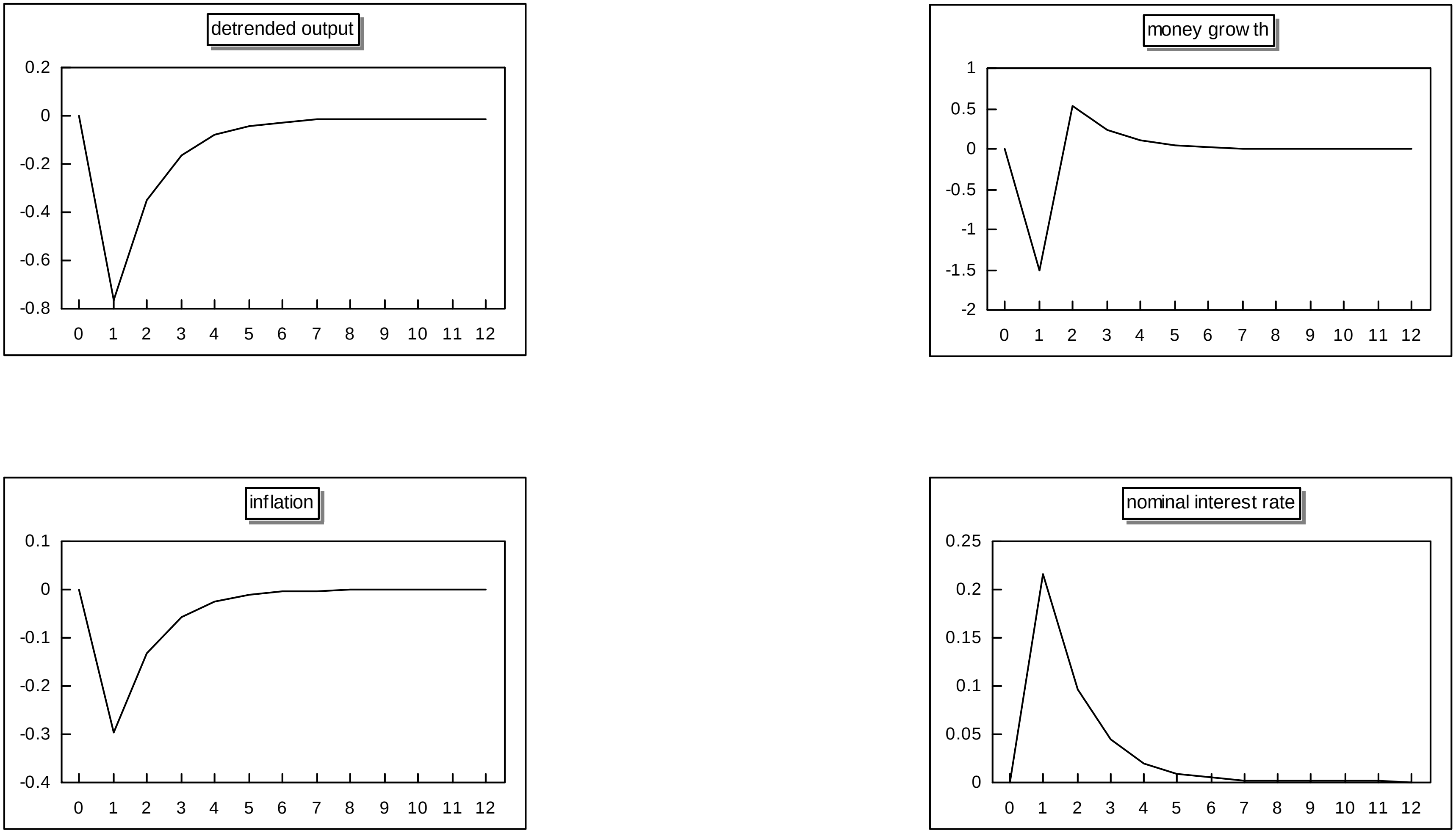

Figure 2. Impulse Responses to a One Standard Deviation Policy Shock Under the Federal Reserve's Interest Rate Rule
Each panel shows percentage deviations of a variable from its steady-state level.

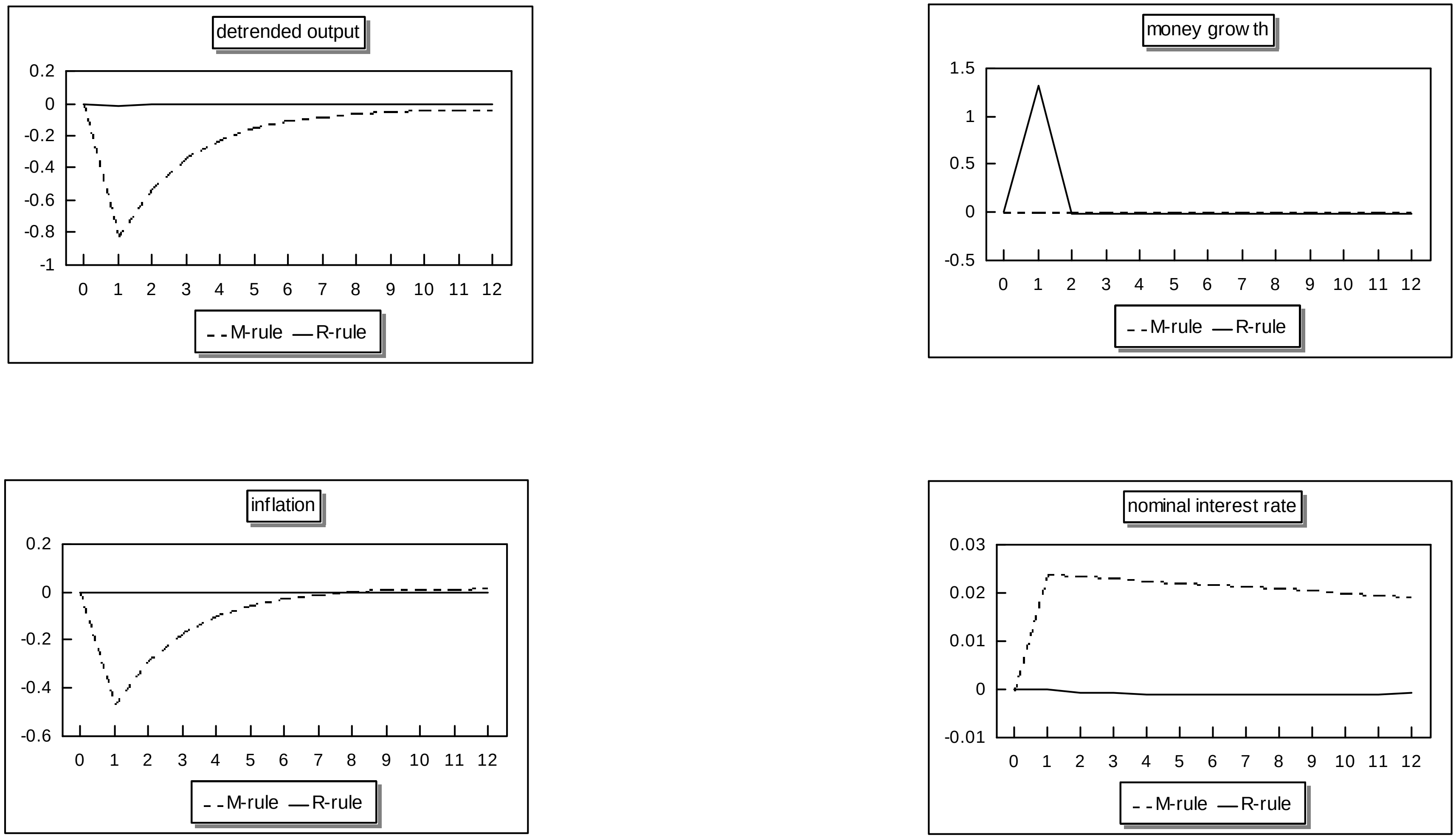

Figure 3. Impulse Responses to a One Standard Deviation Money Demand Shock
Each panel shows percentage deviations of a variable from its steady-state level under the constant money growth rate rule (M-rule) and the Federal Reserve's interest rate rule (R-rule).

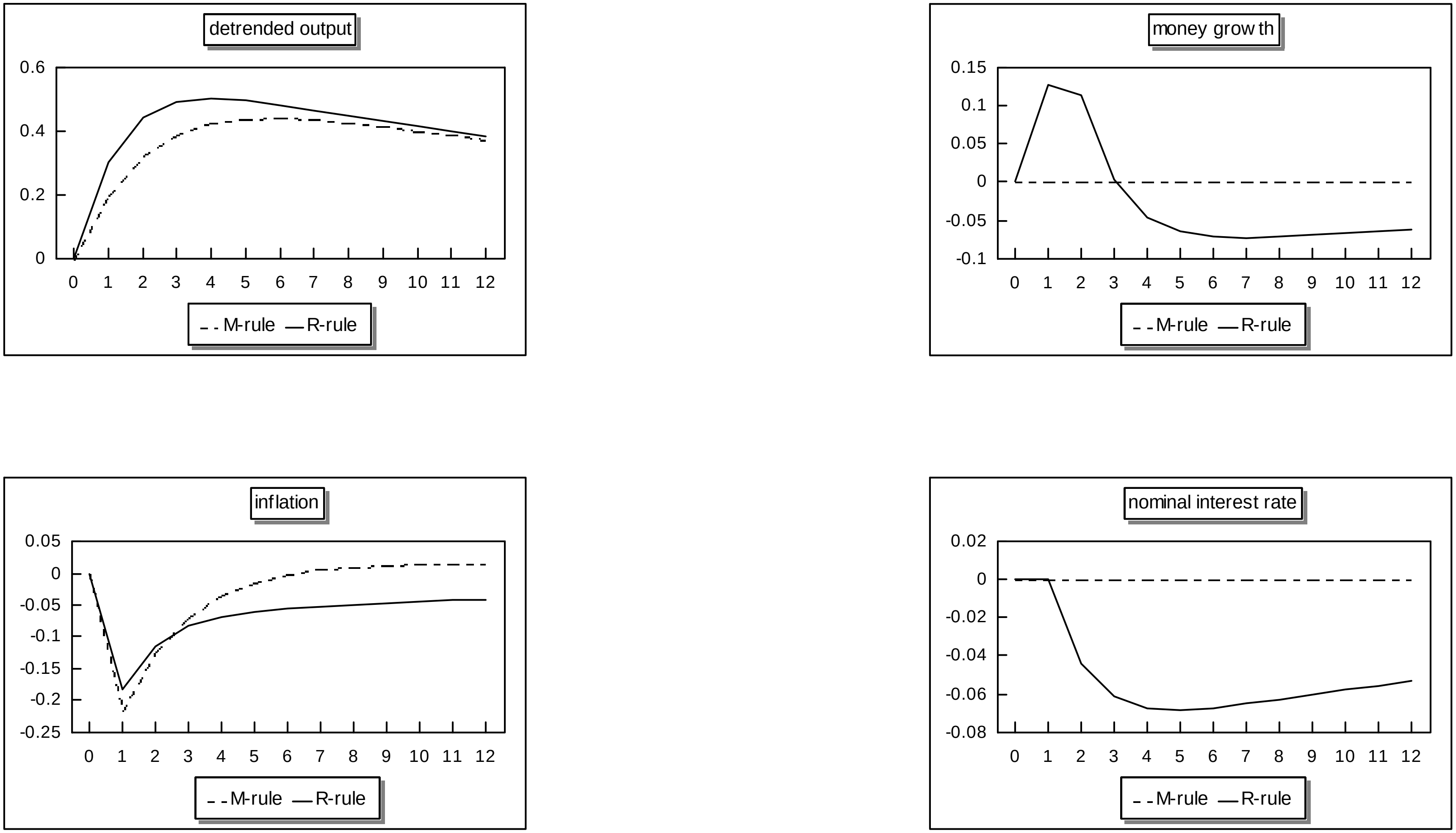

Figure 4. Impulse Responses to a One Standard Deviation Technology Shock
Each panel shows percentage deviations of a variable from its steady-state level under the constant money growth rate rule (M-rule) and the Federal Reserve's interest rate rule (R-rule).

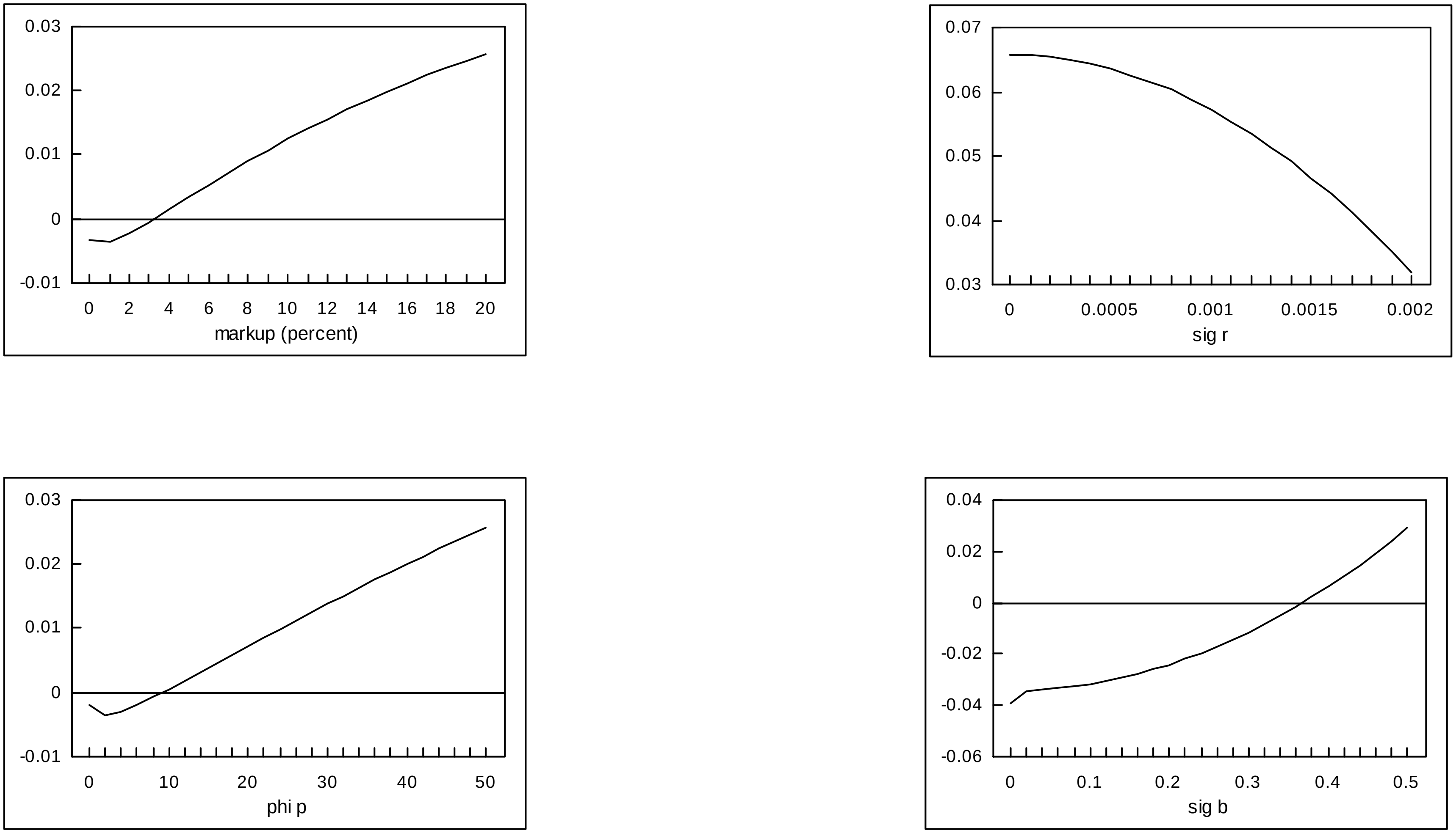

Figure 5. Sensitivity of Welfare Results

Each panel shows the difference between the level of expected utility provided by the Federal Reserve's interest rate rule and the level of expected utility provided by the constant money growth rate rule; positive values indicate cases in which the Fed's rule dominates.