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ABSTRACT

Poole Revisited*

We study the properties of alternative central bank targeting procedures in a general equilibrium monetary model of the US economy with labour contracts, endogenous velocity and three shocks: money demand, supply and fiscal. Money demand -velocity- shocks emerge as the main sources of macroeconomic volatility. Consequently, nominal interest rate targeting results in greater stability than money targeting. Interestingly this holds independently of the type of the shock (unlike Poole). Interest rate targeting also generates a higher level of welfare.

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Keywords: central bank operating procedures, interest targeting, macroeconomic stability, monetary policy, welfare and money targeting

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NON-TECHNICAL SUMMARY

In the years following the influential article of Poole (1970), many central banks reoriented their operating procedures to focus more on interest rates and less on monetary aggregates. The fast pace of innovation in financial markets was widely perceived to have reduced the stability of money demand equations. Poole's insight suggested that a central bank would have better control of output and prices if it targeted the nominal interest rate instead of a monetary aggregate. With a few exceptions (such as the German and the Swiss central banks), monetary aggregates have been playing a minor role in the design of monetary policy.

The optimal selection of an operating procedure is nowadays drawing renewed attention as a result of several developments. First, a new central bank – the European Central Bank – has been formed and endowed with a targeting procedure. There existed significant differences of opinion among the participating countries as to which procedure ought to be adopted. Second, McCallum's proposals on nominal income targeting have attracted a great deal of attention. McCallum has demonstrated that, not only does nominal income targeting have nice properties, but it is also feasible from an operational point of view. And, third, direct inflation targeting has been suggested – and implemented by several central banks (England, Sweden) – as a superior alternative to standard intermediate targeting procedures.

The original analysis of Poole was conducted within the standard textbook, static, fixed price IS-LM framework. It also evaluated alternative procedures exclusively on the basis of output volatility. It is natural to ask whether Poole's insights survive the use of more up-to-date models where prices are not perfectly, permanently rigid. And also whether his rankings are affected by the adoption of more general welfare criteria.

In this Paper we undertake a faithful, general equilibrium rendition of Poole. We modify the standard, stochastic growth model to incorporate labour market frictions (nominal wage rigidity) and to include three types of shocks: supply, government expenditure and velocity (money demand). The model is then calibrated and used in simulations aiming at drawing its implications for a large number of macroeconomic variables of interest. Our simulations rely on the historical properties (volatility and auto-correlation) of these three shocks in the post-World War II US economy. Three results stand out.

First, interest rate pegging produces significantly lower volatility in almost all quantities and prices considered (real balances are the only exception) when all three shocks operate. Remarkably, the same holds true for individual shocks, whether demand or supply (with the exception of inflation). Unlike Poole, interest rate targeting leads to greater macroeconomic stability even when fiscal shocks are the only source of variation in the economy. Unlike previous, related work by Canzoneri and Dellas, this ranking is independent of the degree of intertemporal substitution. This result also contrasts with other findings in the literature.

Second, the volatility rankings induce analogous welfare rankings (that is, the covariance terms between leisure and consumption that are present under a non-separable utility function do not undermine this pattern). Nominal interest rate targeting fares always better and naturally, its advantage is increasing in the degree of risk aversion. The superiority comes mainly from reacting to velocity shocks as the other two sources of macroeconomic volatility do not create pronounced differences.

And third, the main source of macroeconomic variability differs significantly across regimes. Most of the volatility in output, inflation and interest rates comes not from supply shocks under nominal interest rate targeting, but from money demand shocks under monetary targeting. This suggests that the relative contribution of supply shocks typically claimed in the literature as valid only if monetary policy was mostly aimed – and has been successful – at nominal interest rate smoothing.

INTRODUCTION

The optimal selection of central bank operating procedures has been debated extensively in monetary theory. It is nowdays drawing renewed attention as a result of several developments. First, many claims hav been advanced that Taylor type of rules describe well actual central bank practices. Second, McCallum's proposals on nominal income targeting (McCallum 1988) have attracted a great deal of attention. And, third, direct inflation targeting has been suggested — and implemented by several central banks — as a superior alternative to standard intermediate targeting procedures.

In the three decades since its publication, the seminal work of Poole 1970 has defined the framework of the theoretical debate in the area of central bank targeting procedures. It has also exerted a significant influence on actual monetary policy practices. While there exists significant cross country and time series variation in the operating procedures adopted by central banks in the industrial world, the particular choices are usually justified by referring to the basic insights of Poole. For instance, as implied by Poole's analysis, the pace of financial innovation and the resulting instability in velocity during the 70s and 80s created a presumption in favor of interest rate targeting as a means of smoothing fluctuations in aggregate economic activity and inflation. Similarly, the Bundesbank often defended its decision to target monetary aggregates by pointing out that velocity in Germany had been remarkably stable.

The original analysis of Poole used output volatility as the sole evaluation criterion and was conducted within the standard textbook IS–LM framework. The shortcomings of this model are well known. Canzoneri et al. 1983 "redid" Poole within the imperfect information, rational expectations model. They found that Poole's basic insights remain valid. It was also found that within this class of models the optimal choice of targeting procedure tends to be ambiguous when supply shocks are the dominant source of macroeconomic volatility (the ranking depends on the slope of the IS curve; see Blanchard and Fisher, 1986).

A natural question is whether similar results would obtain if one repeated Poole's analysis within the modern, standard monetary general equilibrium models. And also whether the rankings would change if a more general welfare criterion were adopted. Some recent work has touched on these issues but without providing a concrete answer to this question. For instance, Canzoneri and Dellas, 1996, 1998, study the implications of alternative targeting procedures but for the level of *long term real interest rates* rather than for macroeconomic volatility and welfare. Carlstrom and Fuerst, 1996, argue that interest rate pegging produces superior outcomes compared to money targeting but their analysis is not related to Poole's work at all[1].

The papers mentioned above possess several attractive features for studying the issues raised by Poole. For instance they rely on dynamic, general equilibrium models and also posit utility maximization on the part of all economic agents. This permits the execution of consistent and meaningful welfare comparisons. Nevertheless, the Canzoneri and Dellas papers are not perfectly suited to "redo" Poole. First, they employ a cash in advance constraint specification which results in zero interest elasticity of demand for money, an element that plays an important role in Poole's analysis (the "slope" of the LM curve). Second, they abstract from governemnt expenditure shocks. Consequently, both the results and the rankings obtained are conditional not only on the model used but also on the absence of particular shocks and may not carry over to the general case. And third, the model economies considered are not constructed with the intention to match particular actual economies. As a result, it is difficult to assess the empirical plausibility of their findings.

The objective of this paper is to examine[2] the properties of alternative targeting procedures in an economy in which not only are all three shocks present but they also all matter for economic activity and prices. In a sense, this paper represents a faithful, general equilibrium rendition of Poole. The model is the standard two factor, stochastic growth model, augmented with a cash in advance specification that allows for interest rate effects

[1]They use a limited participation model with perfectly flexible prices and wages and velocity shocks (which play a critical role in Poole) are absence. Moreover, their analysis mixes first and second moment effects. Interest rate targeting fares better in their model because it generates -needed- greater output (consumption) volatility.

[2]Following the literature it is also assumed that all operating procedures are equally feasible from a technical point of view.

in the demand for money (this specification has been developed by Canzoneri et al., 1996, and removes a key weakness of this class of models). Consequently, the model can be calibrated and evaluated according to standard practices and it also produces implications for a large number of variables.

Our simulations rely on the historical properties (volatility and autocorrelation) of these three shocks in the post world war II US economy. Three results stand out.

First, interest rate pegging produces significantly lower volatility in almost all quantities and prices considered (real balances are the only exception) when all three shocks operate. Remarkably, the same holds true for individual shocks, whether demand or supply (with the exception of inflation). Unlike Poole, 1970, interest rate targeting leads to greater macroeconomic stability even when fiscal shocks are the only source of variation in the economy. Unlike Canzoneri and Dellas, 1998, this ranking is independent of the degree of intertemporal substitution. This also contrasts with Carlstrom and Fuerst who find that that interest rate targeting gives rise to greater overall output volatility. Moreover, unlike Carlstrom and Fuerst, we find that the differences in volatility across regimes are quite substantial.

Second, the volatility rankings induce analogous welfare rankings (that is, the covariance terms between leisure and consumption that are present under a non–separable utility function do not undermine this pattern). Nominal interest rate targeting fares always better and naturally, its advantage is increasing in the degree of risk aversion. The superiority comes mainly from reacting to velocity shocks as the other two sources of macroeconomic volatility do not create pronounced differences.

And third, the main source of macroeconomic variability differs significantly across regimes. Most of the volatility in output, inflation and interest rates comes from supply shocks under nominal interest rate targeting but from money demand shocks under monetary targeting. This suggests that the relative contribution of supply shocks typically claimed in the literature is valid only if monetary policy has mostly aimed – and been successful - at nominal interest rate smoothing.

THE MODEL

This section describes the arrangement of the markets as well as the behavior of the households, the firms, the government and the monetary authorities.

The Representative Household

The economy is populated by many identical, infinitely lived agents. There are two markets, the asset market and the goods market. The asset market is visited first. Once an agent has completed his financial transactions and departed for the goods market he cannot return to it for at least one period. The values of all the random shocks to the economy become known during the visit to the asset market.

In the goods market, all purchases require the use of money. There are three ways of acquiring cash: by accumulating it in the asset market before leaving for the goods market; by receiving it at home at the end of period — and after the goods market has closed — as remuneration for labor and capital services supplied during that period; and by visiting the firm while the goods market is open and claiming part of the current proceeds in the form of a zero interest loan. The first two ways do not carry any direct cost, while the last one requires resources. Nevertheless, the agent may have an incentive to make costly trips to the firm for cash withdrawal purposes in order to reduce his exposure to the inflation tax. That is, in order to minimize the amount of cash received at home from the firm at the end of the period, as that cash cannot be used contemporaneously and its value may be eroded by inflation. We will assume that the cost of each trip is fixed and independent of the amount withdrawn. There is a maximum amount that can be claimed in one trip, though. The frequency of the visits is chosen optimally by the household in a manner reminiscent of the Baumol–Tobin theory of the demand for money.

While in the asset market, the agent receives his labor and capital income accrued during the previous period minus the interest free loans he received by visiting the firms during that period. He sells and buys bonds, receives transfers from the government and pays taxes, and finally sets aside cash that may be used to purchase goods when he visits the goods market. At the same time, the agent decides on the number of trips to the firm.

In the goods market, the household purchases goods for consumption and investment purposes. The budget constraint faced in the asset and goods market in period t is given respectively by

$$W_{t-1}h_{t-1} + Z_{t-1}K_{t-1} - (N_{t-1} - 1)\zeta_{t-1}M_{t-1} + \Psi_t + (1 + i_{t-1})B_{t-1} \geq M_t + B_t + T_t \quad (1)$$

and

$$M_t[1 + \zeta_t(N_t - 1)] \geq P_t(C_t + X_t) \quad (2)$$

where W is the nominal wage and Z the nominal rental rate on capital; h and K are hours worked and units of capital rented out to the firm respectively; M_t is the amount of cash acquired in this period to be used during the visit to the goods market; M_{t-1} is the amount of money withdrawn from the firm in each trip to the goods market during the previous period[3] and $N - 1$ is the number of withdrawals from the firm. Ψ is a monetary transfer from the government, B is the quantity of nominal bonds purchased, and i is the corresponding interest rate; T is lump sum taxes paid to the government and C and X are goods purchased for consumption and investment purposes respectively. Finally, ζ_t is a velocity shock[4] which is assumed to follow the following stochastic process

$$\log(\zeta_t) = \rho_\zeta \log(\zeta_{t-1}) + (1 - \rho_\zeta)\log(\overline{\zeta}) + \varepsilon_{\zeta,t} \quad (3)$$

with $-1 < \rho_\zeta < 1$, and $E(\varepsilon_{\zeta,t}) = 0$ and $E(\varepsilon^2_{\zeta,t}) = \sigma^2_\zeta$. $\log(\overline{\zeta})$ denotes the unconditional mean of the process.

Note, that when the agents first visit the goods market, they can use the cash acquired during asset market transactions, M_t. Once these balances have been exhausted the agent

[3] Note that the way the budget constraint is written implies that the money withdrawn from the firm is to be interpreted as a loan that the firm makes to the agents which is to be repaid within the same period at zero interest rate.

[4] We interpret the velocity shock as a random fluctuation in the upper limit of the amount withdrawn from the firm during an individual trip (that is, the fraction of the sales that can be handed out to the agent). There is no theoretical requirement for that fraction to be strictly bounded between zero and one. The firm may be able to pay an amount exceeding the value of its sales by issuing the appropriate asset.

needs to take a trip to the firm. In each trip, a quantity of $\zeta_t M_t$ is withdrawn. Hence, after the last trip, the firm is left with an amount of money equal to $P_{t-1}Y_{t-1} - (N_{t-1} - 1)\zeta_{t-1}M_{t-1} = W_{t-1}h_{t-1} + Z_{t-1}K_{t-1} - (N_{t-1} - 1)\zeta_{t-1}M_{t-1}$ which is sent to the home of the workers/capitalists and is available for spending during the next period[5] (Y_t is real output).

We assume that all capital is owned by the households and is rented out to the firms. The capital stock evolves according to the following equation

$$K_{t+1} = X_t + (1-\delta)K_t \tag{4}$$

where $0 < \delta < 1$ is the rate of capital depreciation.

Finally, the household is assumed to be endowed with one unit of time which is allocated between leisure, ℓ_t, work, h_t, and the time spent withdrawing money from the firm, $\theta\,(N_t - 1)$:

$$\ell_t + h_t + \theta\,(N_t - 1) = 1 \tag{5}$$

where θ is the cost of each trip to the firm in terms of time.

The agents have preferences over consumption and leisure represented by the following utility function:

$$\mathcal{U} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^{*t} U(C_t, \ell_t) \right\} \tag{6}$$

where E_0 denotes the conditional expectation operator at time 0. β is the discount factor and C_t and ℓ_t denote respectively consumption and leisure in period t. $U(.,.)$ is the instantaneous utility function and satisfies the standard Inada conditions.

The household maximizes (6) subject to (1), (2), (4) and (5)[6]. Plugging (5) and (4) into the utility function and cash in advance constraint respectively and carrying out the optimization results in the following set of first–order conditions[7] (Λ_{1t} and Λ_{2t} are the

[5] Without any loss of generality we will assume a constant returns to scale production function.

[6] We replace 5 and 4 in the utility function and cash in advance constraint respectively.

[7] The second equation below corresponds to the supply of labor. It is valid only under flexible wages. Under fixed wages, it drops out and is replaced by the requirement that given the fixed wage, mployment is demand determined.

Lagrange multipliers associated with (1), (2)):

$$U_C(t) = \Lambda_{2t} \tag{7}$$

$$U_\ell(t) = \beta^* E_t \; \frac{\Lambda_{1t+1}}{P_{t+1}} W_t \tag{8}$$

$$\theta U_\ell(t) + \beta^* E_t \frac{\Lambda_{1t+1}}{P_{t+1}} \zeta_t M_t = \zeta_t M_t \frac{\Lambda_{2t}}{P_t} \tag{9}$$

$$\frac{\Lambda_{1t}}{P_t} - \Lambda_{2t} \frac{[1 + (N_t - 1)\zeta_t]}{P_t} + \beta^* E_t \left[\frac{\Lambda_{1t+1}}{P_{t+1}} \zeta_t (N_t - 1) \right] = 0 \tag{10}$$

$$\frac{\Lambda_{1t}}{P_t} = \beta^* E_t \left[\frac{\Lambda_{1t+1}}{P_{t+1}} (1 + i_t) \right] \tag{11}$$

$$\Lambda_{2t} = \beta^* E_t \left[\frac{\Lambda_{1t+1}}{1 + i_{t+1}} \frac{Z_{t+1}}{P_{t+1}} + \; (1 - \delta) \Lambda_{2t+1} \right] \tag{12}$$

Equations (7) and (8) describe the optimal choice of consumption and leisure. Equation 9 reports the costs and benefits of an increase in the frequency of withdrawals. An additional trip to the firm to obtain cash balances ($\zeta_t M_t$) has a cost in terms of leisure ($\theta_t U_\ell(t)$). It also reduces the amount of cash that will be received from the firm at the end of the period and which could be used in next period's transactions (which is valued at $\beta^* E_t \frac{\Lambda_{1t+1}}{P_{t+1}} \zeta_t M_t$). The benefit of the trip is that it relaxes the cash-in-advance constraint ($\zeta_t M_t \frac{\Lambda_{2t}}{P_t}$). (10) gives the optimal choice of money holdings. An additional unit of money during this period means both fewer bond holdings ($\frac{\Lambda_{1t}}{P_t}$) and less cash received at the end of the period ($\beta^* E_t \frac{\Lambda_{1t+1}}{P_{t+1}} \zeta_t (N_t - 1)$). The benefit comes from the additional consumption it affords.

Equation (11) is the standard nominal bond pricing equation and finally equation (12) describes the optimal investment choice. Note that the opportunity cost of funds taken away from current consumption for investment purposes is related to consumption two periods later because of the cash in advance constraint on investment purchases.

The Representative Firm

There is a single, homogeneous good which is produced according to the following production function:

$$Y_t = F(K_t, h_t; A_t, \xi_t) \tag{13}$$

where K_t, h_t denote capital and hours used in the production process. ξ_t denotes exogenous Harrod neutral, technical progress and evolves according to :

$$\xi_{t+1} = \gamma \xi_t, \ \gamma > 1$$

$F(.)$ is increasing, concave with respect to each argument and satisfies the Inada conditions. Finally, A_t is an exogenous, technological shock that affects total factor productivity. $\log(A_t)$ is assumed to follow a first order autoregressive stationary process:

$$\log(A_t) = \rho_a \log(A_{t-1}) + (1-\rho_a)\log(\overline{A}) + \varepsilon_{a,t} \tag{14}$$

with $-1 < \rho_a < 1$, and $E(\varepsilon_{a,t}) = 0$ and $E(\varepsilon_{a,t}^2) = \sigma_a^2$. $\log(\overline{A})$ denotes the unconditional mean of the process.

The firm faces a perfectly static optimization problem. Namely, how to select the labor and capital inputs that maximize instantaneous profits, $\Pi_t = P_t Y_t - W_t h_t - Z_t K_t$. The first order conditions are

$$F_h(t) = \frac{W_t}{P_t} \tag{15}$$

$$F_k(t) = \frac{Z_t}{P_t} \tag{16}$$

Conditions (15–16) give the demand for labor and capital respectively.

The government

We assume that the government collects a lump–sum tax, T_t, which is used to finance public consumption. The amount consumed is stochastic and follows a first–order stationary process:

$$\log(G_t) = \rho_G \log(G_{t-1}) + (1-\rho_G)\log(\bar{G}) + \varepsilon_{G,t} \tag{17}$$

with $-1 < \rho_G < 1$, and $E(\varepsilon_{G,t}) = 0$ and $E(\varepsilon^2_{G,t}) = \sigma^2_G$. $\log(\bar{G})$ denotes the unconditional mean of the process.

The government also conducts monetary operations. We will study two monetary regimes. A money supply targeting procedure and a nominal interest rate pegging rule. Under the former, the authorities fix the growth rate of the money supply to some constant value. Under the latter, they manipulate the growth rate of money in order to maintain a fixed nominal interest rate. In either regime, the money created — or withdrawn — in period t is distributed to the households:

$$M_t - M_{t-1} = (\omega_{t-1} - 1)M_t = \Psi_t \tag{18}$$

where ω_t represents — gross — money growth between periods t and $t+1$.

The labor market

In order to make our analysis as comparable to Poole's as possible, we will assume that the labor market is characterized by labor contracts[8]. We adopt — without trying to offer a justification — the specification suggested by Gray, 1976. Namely, we assume that nominal wages are fixed one period in advance at a level that is equal to the expected labor market clearing wage. That is, the contracted wage for period t, W^c_t is simply:

$$W^c_t = E_{t-1}[W_t] \tag{19}$$

Given the wage contract, the level of employment is selected by the firms.

Equilibrium

The resource constraint is

[8] We have also studied the properties of alternative targeting procedures in an economy with perfectly flexible wages. The results are available from the authors upon request. It should be noted that even in such an economy, the choice of monetary procedure makes a difference because money matters for both labor and investment decisions.

$$Y_t = C_t + X_t + G_t$$

Since the economy grows at an exogenous rate γ, we divide each growing variable by ξ_t. Nominal variables are deflated by P_t except for W_t which is deflated by P_{t-1}(recall that the wage is received effectively with a one period lag) and use lowercase letters to denote the new variables[9]. Finally we define $\lambda_t = \Lambda_{1t}\xi_t^{\varphi}$, $\mu_t = \Lambda_{2t}\xi_t^{\varphi}$ and $\beta = \frac{\beta^*}{\gamma^{\varphi}}$ where $\varphi = 1 - \nu(1-\sigma)$.

Let us assume that the utility function takes the form:

$$U(C_t, \ell_t) = \frac{\left(C_t^{\nu}\ell_t^{1-\nu}\right)^{1-\sigma} - 1}{1-\sigma}$$

and that the production function is Cobb-Douglas:

$$Y_t = A_t K_t^{\alpha}(\xi_t h_t)^{1-\alpha}$$

An equilibrium of this economy is a sequence of prices[10] $\{w_t, \pi_t, i_t\}_{t=0}^{\infty}$ and a sequence of quantities $\{c_t, x_t, \ell_t, h_t, N_t, k_t, m_t, b_t\}_{t=0}^{\infty}$ such that:

(i) given a sequence of prices, $\{w_t^c, \pi_t, i_t\}_{t=0}^{\infty}$, $\{c_t, x_t, \ell_t, N_t, k_t, m_t, b_t\}_{t=0}^{\infty}$ is a solution to the representative household's problem;

(ii) given a sequence of prices, $\{w_t^c, \pi_t, i_t\}_{t=0}^{\infty}$, $\{h_t, k_t\}_{t=0}^{\infty}$ is a solution to the representative firm's problem;

(iii) given a sequence of quantities $\{c_t, x_t, \ell_t, h_t, N_t, k_t, m_t, b_t\}_{t=0}^{\infty}$, $\{\pi_t, i_t\}_{t=0}^{\infty}$ clear the bond and the good markets.

(iv) given a sequence of quantities $\{c_t, x_t, \ell_t, h_t, N_t, k_t, m_t, b_t\}_{t=0}^{\infty}$, $\{w_t\}_{t=0}^{\infty}$ is set by contract.

Since the wages are predetermined employment is assumed to be demand determined.

[9] Let D_t be a nominal, growing variable. Then we define $d_t = D_t/(\xi_t P_t)$. For a real, growing variable Q_t, we have $q_t = Q_t/\xi_t$.

[10] where $w_t^c = W_t^c/(\xi_t P_{t-1})$, $m_t = M_t/(\xi_t P_t)$, $\pi_t = P_t/P_{t-1}$ and $x_t = X_t/\xi_t$, $x \in \{c, x, y, n, k, b\}$.

Among the equilibrium conditions we have:

$$\zeta_t m_t = \theta \frac{1-\nu}{\nu} \frac{c_t}{\ell_t} \left(\frac{1+i_t+\zeta_t(N_t-1)}{i_t} \right) \tag{20}$$

where $m_t = M_t/P_t$ and $\pi_t = P_t/P_{t-1}$.

One can view (20) as a representing the demand for money. It relates real balances to the level of economic activity (c) as well as to the exogenous and endogenous components of velocity (ζ and N) and the nominal interest rate. Note, however, that is difficult in general equilibrium to interpret the sign of the derivatives of the "demand for money" (for instance dm/di) because c, ℓ, i and N are simultaneously determined as a function of the exogenous shocks of the economy.

Solution and Calibration

We first log–linearize the system of equations defining the equilibrium of this economy around the deterministic steady state — which is the same for both procedures — and then solve the resulting system of linear equations. We thus obtain a set of linear decisions rules for each operating procedure.

The parameters are selected in order to match the sample averages of the US economy for the period 1964:1–1996:4. The data used are quarterly and were taken from the IFS, except for hours which were taken from the BLS.

The exogenous growth rate γ is set equal to 0.69% per quarter. The share of capital, α is 0.4. The fraction of time devoted to work, h^* is set equal to 0.32 while the steady state number of trips to the firm (the bank), N^*, is given by $N^* = P(C+X)/M = 4.8$. We can then derive θ from the time budget constraint $1 - h^* - \theta(N^* - 1) - \ell^* = 0$, which gives a value of θ =0.00034. That is, the total time devoted to cash withdrawals is 0.0013 per quarter. Using $h^* = 0.32$ we get a value for ν, namely $\nu = 0.3024$.

The growth rate of nominal balances is set to 0.81% per quarter. From Cooley and Prescott, 1995, we borrow the fact that $x/k = 0.076$ in annual data. This implies a quarterly rate of capital depreciation $\delta = 0.012$ ($\delta = x/k+1-\gamma$). Using the Euler equations for capital and bond then gives $\beta = 0.9805$ and the nominal interest rate $i^* = 0.021$.

We set the average values of the technology and velocity shocks, $A^*$and ζ^*, equal to unity. The average value of the government expenditure shock, G^*, was set in accordance to the steady state value $G/Y = 0.1843$ (the sample mean). $AR(1)$ were estimated for A_t, G_t and ζ_t . The ζ_t series was recovered from the equilibrium condition in the market for money.

Table 1. shocks

ρ_a	σ_a	ρ_g	σ_g	ρ_ζ	σ_ζ
0.955	0.0075	0.9787	0.0101	0.9482	0.0567

POLICY

The rules

A Constant Money Supply Growth Rule.—

In this case the monetary authorities simply fix the money growth rate ω independent of the state of the economy.

$$\omega_t = \omega \tag{21}$$

Interest Rate Pegging.—

The gross, nominal interest rate i_t is given by:

$$1 + i_t = \left(E_t \left[\beta \frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_t}{P_{t+1}} \right] \right)^{-1} \tag{22}$$

The monetary authorities must react to the various contemporaneous shocks in such a way that the nominal interest rate remains fixed over time. There are several ways of implementing this targeting procedure. The simplest one has the current money supply respond systematically to current shocks in such a way as to generate expectations of future policy actions which, by influencing expected inflation, stabilize the current rate. Operationally, this can be achieved by having a policy rule that turns the quantity *inside* the expectations operator in (22) into a constant . It may take the form

$$\pi_{t+1} = \Theta \frac{\Lambda_{t+1}}{\Lambda_t} \quad \text{where } \Theta \text{ is an arbitrary constant} \tag{23}$$

In order to implement this rule we must first derive the linear decision rules for π_t and Λ_t when ω_t is allowed to vary freely. Solving the model, we get decision rules for π_t and Λ_t: $\pi_t = \varphi_\pi(m_{t-1}, k_{t-1}, \{a_{t-j}, g_{t-j}, \zeta_{t-j}, j = 0,1\}, \omega_t)$ and $\Lambda_t = \varphi_\lambda(m_{t-1}, k_{t-1}, \{a_{t-j}, g_{t-j}, \zeta_{t-j}, j = 0,1\}, \omega_t)$. We then use these functions in (22) and solve for a function.

$\omega_t = \varphi_\omega(m_{t-1}, k_{t-1}, \{a_{t-j}, g_{t-j}, \zeta_{t-j}, j = 0,1\})$ that will satisfy (23). We will assume that the nominal interest rate is targeted at its steady state[11] value, i^*.

Policy Evaluation

In order to evaluate the implications and "optimality" of alternative operating procedures we use several criteria

- Volatility of quantities -as in Poole- and prices.
- Level of total welfare
$$W = E\sum_{i=0}^{\infty}\beta^{*t}\frac{\left(C_t^{\nu}\ell_t^{1-\nu}\right)^{1-\sigma}-1}{1-\sigma}$$
- Transfer rate as in Lucas, 1987. It is possible to express the cost of utility volatility in terms of consumption. That is, one may ask — following Lucas — how much consumption one would be willing to sacrifice in order to perfectly avoid experiencing any utility fluctuations. The required sacrifice is computed as follows
$$E\sum_{i=0}^{\infty}\beta^{*t}\frac{\left([(1+\tau)C_t]^{\nu}\ell_t^{1-\nu}\right)^{1-\sigma}-1}{1-\sigma} = E\sum_{i=0}^{\infty}\beta^{*t}\frac{\left((\gamma^t C^{\star})^{\nu}\ell^{\star 1-\nu}\right)^{1-\sigma}-1}{1-\sigma}$$
thus τ can be used to attach a consumption value to the welfare level associated with the two operating procedures.

THE RESULTS

Tables (2) and (3) report the moments of the model-generated series under money and nominal interest rate targeting respectively (all data have been detrended using the Hodrick–Prescott filter). Tables (4) and (5) report the solutions (in the form of elasticities)

[11] The well known price indeterminancy problem under nominal interest rate targeting is removed by postulating a path for the money supply (see Canzoneri et al, 1983 or Blanchard and Fischer, 1986).

for the variables of interest as a function of the state variables (from the log–linearized system). The numbers in the Tables are based on $\sigma = 2.5$.

The actual policy regime in the US has involved a combination of these two procedures. Moreover, it is commonly believed that with the possible exception of the 1979-82 period, interest rate smoothing has been given priority over the strict control of the supply of money. It should be kept in mind, though, that in practice interest rate targeting has allowed for some variation in the nominal interest rate (which means that some of the shocks have not been fully accommodated) and monetary targeting for a range of money supply growth rates (rather than a perfectly constant rate). Consequently, the appropriate way of evaluating the model should involve a comparison of a weighted average of the two sets of theoretical moments (with perhaps greater weight given to those associated with interest rate targeting) to the actual moments. Our model would run into trouble in matching the behavior of a particular variable if both sets of moments erred on the same side of the actual ones (and also if different sets of weighs were needed for different variables).

As can be seen from Tables (2) and (3) the model performs satisfactorily[12]. Money targeting generates procyclical nominal interest rates and inflation (and hence a positive correlation between nominal interest rates and inflation). The latter variable's behavior is again accounted for by the presence of significant velocity shocks. If those shocks were either small or non-operative (as it is the case when they are offset by monetary policy) then the movements in the inflation rate would be dominated by supply shocks and would exhibit a countercyclical pattern. This finding points to the importance of including velocity in general equilibrium, monetary models in order to improve their ability to match stylized facts on nominal variables.

The endogenous component of velocity, N, and total velocity are procyclical. The degree

[12]It must be kept in mind that the success of the existing monetary models in matching the stylized facts pertaining to nominal variables is much lower than that of the success of real model in matching real variables. Moreover, the goodness of fit for alternative models tends to be variable specific, so there is no clear winner among competing models.

It is also worth mentioning that because of the lack of staggered contracts, the model's persistence properties are not as good. Nevertheless the comparison of alternative procedures is not affected by this feature of procyclicality is higher under money targeting[13] as this procedure allows velocity to covary with the procyclical nominal interest rates. Moreover, there is a high, positive correlation between velocity and the nominal interest rate. An unsatisfactory aspect of the model is that it cannot capture the negative correlation between interest rates and real balances observed in the data.

Let us now turn to the comparison of the two procedures. A couple of features stand out.

First,volatility is significantly lower under nominal interest rate targeting for all real variables for all types of shocks (the only exception being real balances [14] and consumption under fiscal shocks). The volatilities generated by supply and fiscal shocks also tend to be uniformly lower under interest rate targeting, but for those shocks the differences across regimes are not as pronounced as those for velocity shocks. Consequently, the large differences in volatility arise mostly from the effects of velocity shocks, which are offset under interest but not under money targeting.

That large and potent velocity shocks can make the operating procedure matter is well known from Poole's analysis. As can be seen from the last column of Table (2), velocity shocks play an important role in this model, hence a policy that minimizes their role — that is, interest rate targeting- is bound to influence significantly macroeconomic performance. This point is also confirmed by looking at Tables (6) and (7) which report the variance decomposition of some key macroeconomic variables at various time horizons. These tables show that most of the short and medium term variability of output, inflation and interest rates can be accounted for by money demand shocks.

Second, as was mentioned above, interest rate targeting provides greater stability even when fiscal shocks are the only source of volatility. This might seem puzzling in the context of an $IS-LM$ model but it has a simple explanation. In Poole, a positive fiscal shock puts upward pressure on the nominal interest rate and requires expansionary monetary policy

[13] Note also that an exogenous velocity shock decreases N under interest rate targeting but leads to a higher frequency of bank trips under monetary targeting. This difference is due to the strong nominal interest rates effect that is present under the latter procedure.

[14] Under interest rate targeting the money supply reacts procyclically to supply and countercyclically to demand shocks in order to stabilize inflation. Such a reaction creates greater fluctuation in nominal balances.

Table 2. Moments: Money targeting

	U.S.	Total	A only	G only	ζ only
σ_c	1.2553	1.5392	0.7447	0.1237	1.3414
σ_h	0.4225	3.8437	0.7249	0.3314	3.7601
σ_y	1.5667	2.9772	1.4189	0.2335	2.6069
σ_x	4.5841	11.2658	5.3766	0.5329	9.8857
σ_π	0.1660	1.2525	0.5014	0.1056	1.1428
σ_i	19.8251	5.8907	1.5409	0.4114	5.6707
σ_N	–	3.6157	1.0990	0.1843	3.4397
σ_ω	2.6570	0.0000	0.0000	0.0000	0.0000
σ_m	3.3259	1.6908	0.6956	0.1427	1.5345
$corr(c, y)$	0.9526	0.9869	0.9860	-0.3145	0.9980
$corr(h, y)$	0.6476	0.9440	0.9008	0.9998	0.9996
$corr(x, y)$	0.9245	0.9972	0.9965	0.6863	0.9995
$corr(\pi, y)$	0.1129	0.6887	-0.6002	0.8617	0.9982
$corr(i, y)$	0.2155	0.8651	0.9497	0.9554	0.8797
$corr(N, y)$	–	0.5719	0.9801	0.8765	0.5120
$corr(\omega, y)$	-0.0562	0.0000	0.0000	0.0000	0.0000
$corr(m, y)$	0.4204	-0.1579	0.9495	-0.7898	-0.4264
$corr(m, i)$	-0.2785	0.1315	0.8061	-0.5750	0.0551
$corr(m, \pi)$	-0.0537	-0.3704	-0.3604	-0.3703	-0.3724
$corr(i, \pi)$	0.4317	0.7173	-0.8055	0.9729	0.9061
$corr(i, n)$	–	0.8689	0.9913	0.9795	0.8589
$corr(\pi, n)$	–	0.4041	-0.7208	0.9993	0.5616

Table 3. Moments: Nominal interest rate pegging

	Actual	Total	A only	G only	ζ only
σ_c	1.2553	0.6836	0.6695	0.1381	0.0043
σ_h	0.4225	0.4607	0.4243	0.1788	0.0177
σ_y	1.5667	1.2763	1.2701	0.1252	0.0124
σ_x	4.5841	4.8151	4.8122	0.1564	0.0557
σ_π	0.1660	0.6237	0.6223	0.0413	0.0045
σ_i	19.8251	0.0000	0.0000	0.0000	0.0000
σ_N	–	1.8003	0.3531	0.0442	1.7648
σ_ω	2.6570	2.2964	0.2863	0.0319	2.2783
σ_m	3.3259	3.2695	1.2054	0.0978	3.0377
$corr(c, y)$	0.9526	0.9386	0.9833	-0.9988	0.9338
$corr(h, y)$	0.6476	0.9371	0.9807	0.9997	0.9958
$corr(x, y)$	0.9245	0.9873	0.9958	-0.9992	0.9950
$corr(\pi, y)$	0.1129	-0.4591	-0.4645	0.3220	0.1500
$corr(i, y)$	0.2155	0.0000	0.0000	0.0000	0.0000
$corr(N, y)$	–	0.1819	0.9931	-1.0000	-0.9989
$corr(\omega, y)$	-0.0562	0.0218	0.2085	-0.4724	-0.3585
$corr(m, y)$	0.4204	0.3547	0.9994	-0.9991	-0.9988
$corr(m, i)$	-0.2785	0.0000	0.0000	0.0000	0.0000
$corr(m, \pi)$	-0.0537	-0.1678	-0.4514	-0.3056	-0.1676
$corr(i, \pi)$	0.4317	0.0000	0.0000	0.0000	0.0000
$corr(i, n)$	–	0.0000	0.0000	0.0000	0.0000
$corr(\pi, n)$	–	-0.1006	-0.5051	-0.3247	-0.1674

Table 4. Elasticities: Money targeting

	k_t	m_{t-1}	a_{t-1}	g_{t-1}	ζ_{t-1}	a_t	g_t	ζ_t
k_{t+1}	0.967	0.000	-0.028	-0.011	-0.040	0.121	0.009	0.041
m_t	0.499	0.000	-0.016	-0.006	-0.023	0.697	-0.108	-0.250
c_t	0.458	0.000	-0.206	-0.081	-0.295	0.886	-0.023	0.306
h_t	-0.203	0.000	-0.560	-0.219	-0.802	1.009	0.360	0.834
y_t	0.158	0.000	-0.392	-0.153	-0.561	1.706	0.252	0.584
x_t	-0.765	0.000	-1.467	-0.575	-2.102	6.431	0.468	2.188
π_t	-0.499	1.000	0.016	0.006	0.023	-0.697	0.108	0.250
i_t	-0.445	0.000	-0.920	-0.361	-1.318	2.063	0.448	0.915
ℓ_t	0.097	0.000	0.265	0.104	0.380	-0.480	-0.170	-0.394
N_t	-0.306	0.000	-0.463	-0.182	-0.664	1.392	0.192	0.173
W_t/P_t	0.361	0.000	0.168	0.066	0.241	0.697	-0.108	-0.250
ω_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 5. Elasticities: Nominal interest rate pegging

	k_t	m_{t-1}	a_{t-1}	g_{t-1}	ζ_{t-1}	a_t	g_t	ζ_t
k_{t+1}	0.967	0.000	0.000	0.000	0.000	0.092	-0.002	0.000
m_t	0.277	0.000	0.000	0.000	0.000	1.231	-0.074	-0.499
c_t	0.458	0.000	0.000	0.000	0.000	0.671	-0.105	0.001
h_t	-0.205	0.000	0.000	0.000	0.000	0.427	0.136	0.003
y_t	0.157	0.000	0.000	0.000	0.000	1.299	0.095	0.002
x_t	-0.769	0.000	0.000	0.000	0.000	4.908	-0.119	0.009
π_t	-0.297	1.130	-0.568	0.041	0.563	-0.872	0.041	0.001
i_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ℓ_t	0.097	0.000	0.000	0.000	0.000	-0.202	-0.064	-0.001
N_t	-0.085	0.000	0.000	0.000	0.000	0.359	-0.034	-0.290
W_t/P_t	0.065	0.000	0.000	0.000	0.000	0.872	-0.041	-0.001
ω_t	-0.020	0.130	-0.568	0.041	0.563	0.359	-0.034	-0.498

Table 6. Variance decomposition: Money targeting

	Output			Inflation rate			Interest rate		
Horizon	A	G	ζ	A	G	ζ	A	G	ζ
1	17.96	0.71	81.33	16.60	0.72	82.68	11.51	0.98	87.51
4	35.47	0.78	63.75	16.58	0.72	82.70	10.96	0.64	88.40
8	47.20	0.83	51.97	16.54	0.72	82.74	9.78	0.50	89.72
20	59.93	0.94	39.13	16.45	0.72	82.83	7.34	0.40	92.26

Table 7. Variance decomposition: Nominal interest rate pegging

	Output			Inflation rate			Interest rate		
Horizon	A	G	ζ	A	G	ζ	A	G	ζ
1	99.03	0.96	0.01	99.60	0.40	0.00	–	–	–
4	99.00	0.99	0.01	99.60	0.40	0.00	–	–	–
8	98.97	1.02	0.01	99.59	0.41	0.00	–	–	–
20	98.88	1.11	0.01	99.57	0.42	0.01	–	–	–

in order to stabilize interest rates. This amplifies output fluctuations in the presence of sticky wages. In our case, a positive fiscal shock also raises the nominal interest rate but triggers *contractionary* monetary policy (see the policy reaction coefficient for a g_t shock in the ω_t row in Table (5) to counter the fiscal shock's positive effect on the current inflation rate. The contraction of money then limits output expansion, stabilizing economic activity. The anti-inflation policy is required in this case in order to generate an expectation that future inflation will be contained by following this particular rule. In general, a nominal interest rate rule dictates that aggregate demand shocks be met by countercyclical and aggregate supply by procyclical monetary policy.

And third, the time path of the variables under consideration as a result of a current perturbation is comparable across procedures. This is due to the fact that it is the length of the labor contracts that determines macroeconomic dynamics. Figures (1)–(2) depict the dynamics of output and inflation for each one of the exogenous shocks.

Finally, it must be noted that the results reported above are robust with regard to variations in the degree of intertemporal substitution. As expected, consumption become less volatile and investment more volatile at a higher degree of substitution and this is true irrespective of the operating procedure in place.

Welfare comparisons

We now turn to the evaluation of the welfare implications of alternative operating procedures. The Welfare row in Tables (8)–(9) reports the level of utility of the representative agent for various values of intertemporal substitution and for different shocks. The $\tau\%$ row gives the percentage of average consumption that the individual requires in order to be indifferent between a volatile and a perfectly stable utility path. The former path is obtained under each one of the targeting procedures while the latter is associated with the deterministic steady state of the model. The differences in the corresponding entries of these two tables give the gain – in terms of consumption — from switching from one procedure to another.

Two features stand out. First, welfare is always higher under nominal interest rate targeting independent of the source of macroeconomic volatility and the degree of risk aversion. The differential is increasing in risk aversion and become substantial for high levels of risk aversion. For instance, for $\sigma = 5$, it is equal to a quarter of one percentage point of growth!. And second, almost all of the superiority of nominal interest rate targeting comes from its handling of the velocity shocks.

CONCLUSIONS

Money demand shocks appear to be an important source of macroeconomic volatility under nominal wage rigidities. Consequently central bank operating procedures that differ in terms of their reaction to velocity shocks will also differ in terms of their output stabilization properties. While there exists no theoretical presumption that a rule that stabilizes one nominal quantity (the nominal interest rate) rather than some other (the nominal stock of money) ought to have better properties either in terms of macroeconomic stability or welfare our results indicate that nominal interest rate targeting does fare better.

There are several important issues that our analysis has abstracted from and which

Table 8. Welfare: Money targeting

	Total	A only	G only	ζ only
		$\sigma = 0.5$		
Welfare	-32.3300	-32.3261	-32.3160	-32.3196
$\tau\%$	0.0750	0.0541	0.0009	0.0199
		$\sigma = 0.8$		
Welfare	-34.5824	-34.5751	-34.5623	-34.5690
$\tau\%$	0.0942	0.0603	0.0014	0.0324
		$\sigma = 1.5$		
Welfare	-40.7219	-40.7020	-40.6802	-40.6987
$\tau\%$	0.1421	0.0752	0.0026	0.0642
		$\sigma = 2.5$		
Welfare	-52.2179	-52.1618	-52.1179	-52.1699
$\tau\%$	0.2155	0.0971	0.0043	0.1140
		$\sigma = 4$		
Welfare	-78.3498	-78.1592	-78.0425	-78.2194
$\tau\%$	0.3323	0.1307	0.0072	0.1944
		$\sigma = 5$		
Welfare	-104.8463	-104.4572	-104.2411	-104.6022
$\tau\%$	0.4131	0.1535	0.0093	0.2503
		$\sigma = 10$		
Welfare	-553.8878	-545.4214	-541.6351	-549.4410
$\tau\%$	0.8346	0.2743	0.0221	0.5410

Table 9. Welfare: Nominal interest rate pegging

	Total	A only	G only	ζ only
		$\sigma = 0.5$		
Welfare	-32.3261	-32.3260	-32.3160	-32.3159
$\tau\%$	0.0544	0.0534	0.0009	0.0000
		$\sigma = 0.8$		
Welfare	-34.5750	-34.5747	-34.5623	-34.5620
$\tau\%$	0.0601	0.0587	0.0014	0.0000
		$\sigma = 1.5$		
Welfare	-40.7016	-40.7008	-40.6802	-40.6795
$\tau\%$	0.0740	0.0715	0.0025	0.0000
		$\sigma = 2.5$		
Welfare	-52.1606	-52.1588	-52.1177	-52.1158
$\tau\%$	0.0945	0.0906	0.0040	0.0000
		$\sigma = 4$		
Welfare	-78.1555	-78.1497	-78.0415	-78.0357
$\tau\%$	0.1268	0.1206	0.0062	0.0000
		$\sigma = 5$		
Welfare	-104.4506	-104.4391	-104.2386	-104.2271
$\tau\%$	0.1491	0.1415	0.0077	0.0000
		$\sigma = 10$		
Welfare	-545.3726	-545.1331	-541.5440	-541.3054
$\tau\%$	0.2711	0.2552	0.0160	0.0000

ought to be the focus of future research in order to produce a more complete ranking of procedures.

First, all procedures studied here are equally feasible from a technical point of view. In practice, controlling a short term nominal interest rate seems far easier than controlling a broad monetary aggregate (at least in the short run). The implications of such differences should be explicitly studied.

Second, economic activity does not relate only to a single term interest rate but rather to the entire term structure. Which maturities matter and for which variables is an interesting question whose answer may matter for the properties of short term interest rate pegging.

And third, the paper has used a solution strategy (linearization around the deterministic steady state) which forces the two operating procedures to operate out of the same steady state. Canzoneri and Dellas, 1998, have demonstrated that these two operating procedures may also induce differences in first moments. A useful extension of this model may be to allow for such a possibility in order to calculate potential trade offs and to make the welfare comparisons complete.

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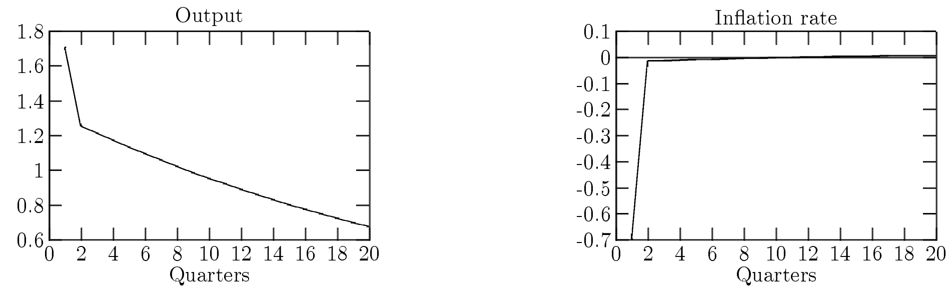
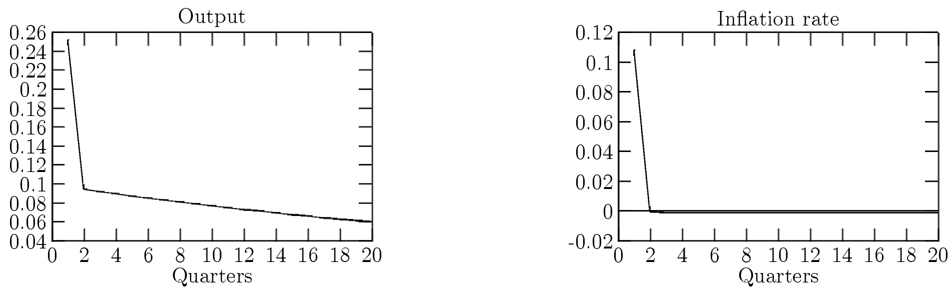
Fig. 1. Impulse response functions: Money targeting

(a) Technology shock



(b) Government expenditures shock



(c) Velocity shock

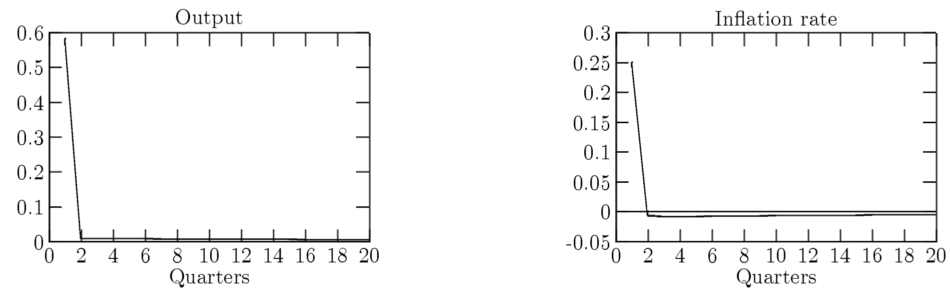
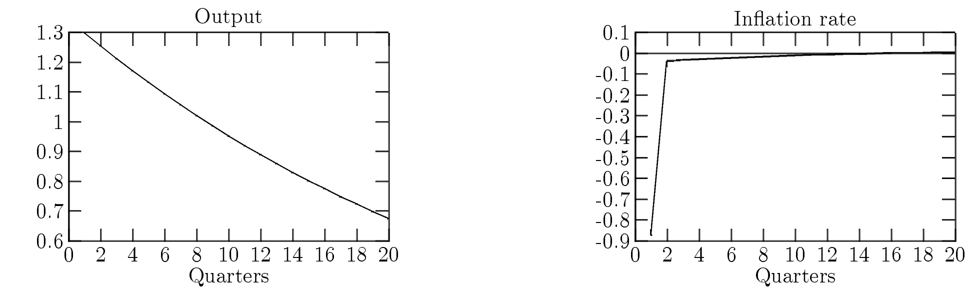
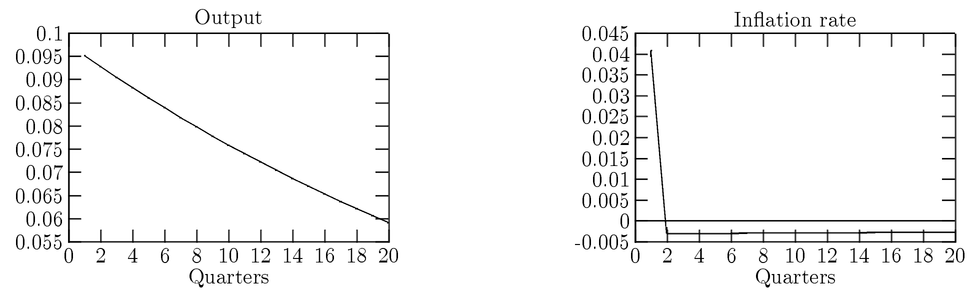


FIG. 2. Impulse response functions: Nominal interest rate pegging

(a) Technology shock



(b) Government expenditures shock



(c) Velocity shock