Identifying Monetary Policy Shocks with Changes in Open Market Operations

Andreas Schabert[1]
University of Cologne

This version: June 6, 2003

Abstract

In this paper we reexamine the effects of monetary policy shocks by exploiting the information contained in open market operations. A sticky price model is developed where money is the counterpart of securities deposited at the central bank. The model's solution reveals that a rise in central bank holdings of open market securities can be interpreted as a monetary expansion. Estimates of vector autoregressions for US data are further provided showing that reactions to an unanticipated rise in open market securities are consistent with common priors about a monetary expansion, i.e., a decline in the federal funds rate, a rise in output, and inertia in price responses. Compared to federal funds rate shocks, prices do not exhibit a puzzling behavior and a larger fraction of the GDP forecast error variance can be attributed to open market shocks. However, the explanatory power of the latter has decreased since federal funds rate targets have been announced.

JEL classification: E52, E32.
Keywords: Monetary transmission, open market operations, vector autoregressions, sticky price model, announcement effects.

[1]University of Cologne, Department of Economics, D-50923 Koeln, Germany, email: schabert@wiso.uni-koeln.de, fax: +49/221/470-5077, tel: +49/221/470-4532.

1 Introduction

Short-run effects of monetary policy have always been of utmost interest for macroeconomists. In the recent past, research in this field has almost reached a consensus with regard to the empirical method by applying vector autoregressions (VARs). Though, different identification schemes have been utilized in the literature (see, e.g., Christiano et al., 1996, Leeper et al., 1996, Sims and Zha, 1998, or Bernanke and Mihov, 1998), the policy measure and some main results for US data are in common in most of these contributions. Monetary policy shocks are usually identified with changes in the operating target, in particular, the federal funds rate,[2] while an unanticipated decline of the latter is found to lead to a strong and persistent rise in real activity and inertia in price reactions. This empirical evidence, which is summarized in Christiano et al. (1999), is – at least broadly – consistent with common priors on the impact of monetary policy. Nevertheless, some questions regarding monetary policy effects are still left open. For example, output and, in particular, aggregate prices often exhibit puzzling responses to changes in the federal funds rate (see Sims, 1992, Uhlig, 2001, and Hanson, 2002), while simultaneity makes it difficult to isolate exogenous policy shocks from endogenous policy responses. Moreover, it is even controversially discussed if these shocks really represent policy actions rather than specification errors (see, e.g., Rudebusch, 1998).

This paper presents an alternative approach to identify exogenous monetary policy actions via changes in open market operations. We reexamine the effects of unsystematic policy actions exploiting the fact that open market operations are the predominant instrument of the Federal Reserve, whereas the federal funds rate actually serves as an (operating) target. In particular, monetary policy actions are identified with changes in central bank holdings of securities which are traded in open market operations. Given that these asset holdings can directly be controlled by the central bank and are less exposed to non-policy disturbances than operating targets, we expect our approach to facilitate a revelation of unsystematic policy effects. On the other hand, we expect this identification scheme to be less appropriate to capture the total leverage of monetary policy on macroeconomic developments when announcements about interest rate targets are already effective with few open market operations, as found by Taylor (2001) and Demiralp and Jordá (2002, 2003) for the US, or even without any immediate use of conventional policy instruments, as shown by Guthrie and Wright (2000) for New Zealand.[3]

Before turning to the empirical analysis, we investigate the flow of funds in open market operations within a general equilibrium framework by introducing repurchase agreements in an otherwise standard sticky price model, i.e., the so-called New Keynesian model (see, e.g.,

[2] Nonborrowed reserves, which served as an operating target of the Federal Reserve in the early 1980's, are also applied for this purpose, as e.g. by Eichenbaum (1992), Strongin (1995), or Hamilton (1997).

[3] These so-called 'open mouth operations' are in fact effective due to a credible threat of future open market operations (see Taylor, 2001).

Clarida et al., 2000, or, Galí, 2002). It is shown that the amount of open market securities held by the central bank declines in equilibrium when the economy is hit by a positive innovation to an interest rate rule. Correspondingly, when the central bank is assumed to control the amount of securities traded in open market operations, it is shown that an unanticipated rise in open market securities can be interpreted as an expansionary monetary policy shock causing a rise in output, prices, and real balances accompanied by a decline in the nominal interest rate. Given the qualitative predictions of the macroeconomic model, we proceed by fitting a VAR for US data where central bank holdings of open market securities, which are either bought outright or held under repurchase agreements, serve as the measure for monetary policy shocks. To facilitate comparisons, we employ a simple recursive identification scheme and additionally provide estimates, where either the federal funds rate or nonborrowed reserves are used as alternative policy measures.

We find that the impulse responses qualitatively accord to the theoretical predictions about the short-run behavior of the flow of funds. Shocks to open market securities do not lead to a puzzling output or price behavior, suggesting that the latter might be a particular feature of identification schemes, where monetary policy shocks are identified with changes in operating targets. At the same time, responses to private sector shocks reveal that the simultaneity problem, which commonly applies for the latter type of identification schemes, seems to be less severe for the novel approach. For the full sample period (1959:1 to 2002:2) we further find that shocks to open market securities account for larger fractions of the GDP forecast error variance than shocks to the alternative measures. However, the role of open market shocks in accounting for movements in GDP has considerably declined in support of the role of federal funds rate movements since 1994, when the Federal Reserve began to publicly announce its federal funds rate target. Hence, our examination of effects brought about by changes in open market operations, on the one hand, confirm common priors about the short-run impact of Federal Reserve policy, and, on the other hand, indicate the diminishing explanatory power of the flow of funds in the recent past.

The paper is organized as follows. A sticky price model with open market operations is developed and solved in section 2. Section 3 presents impulse responses and variance decompositions from corresponding VARs. Section 4 concludes.

2 A macroeconomic model with open market operations

In this section we develop a sticky price model where money is supplied via open market operations. The latter are specified in form of repurchase agreements to facilitate an analytical solution of the model. Macroeconomic effects and the flow of funds in open market operations are disclosed for interest rate policy and for the case where the central bank exerts control over the monetary stance by exogenously deciding on the amount of securities purchased in open market operations. Lower (upper) case letters denote real (nominal) variables.

2.1 Households

There is a continuum of identical and infinitely lived households. At the beginning of period t, households' financial wealth comprises of government bonds B_{t-1} carried over from the previous period. Then, the aggregate shock arrives, goods are produced, wages are credited, and transfers are paid. Before households trade with the central bank, they enter the asset market, where beginning-of-period bonds holdings earn $(1+i_{t-1})B_{t-1}$ and bond holdings are adjusted to B_t. Cash can only be acquired in open market operations, i.e., via repurchase agreements, where money is temporarily exchanged against bonds B_t^c. The amount of money M_t supplied by the central bank equals the discounted value of bonds $B_t^c/(1+i_t)$:

$$M_t = B_t^c/R_t, \qquad \text{with } B_t^c \leq B_t \text{ and } R_t \equiv 1+i_t. \tag{1}$$

Hence, money is the counterpart of government securities deposited at the central bank. After goods are traded, bonds B_t^c are repurchased by the households, such that the costs of money are $i_t M_t$. Modelling money supply in this way, which relates to the specification of open market operations in Drèze and Polemarcharkis (2000), has the vantage that both money and open market securities are jump variables. As a consequence, the amount of state variables does not change when switching from an interest rate policy to an open market policy, which allows for a straightforward comparison of both regimes.[4] The households' budget constraint reads

$$B_t + P_t c_t \leq (1+i_{t-1})B_{t-1} - i_t M_t + P_t w_t l_t + P_t \omega_t - P_t \tau_t, \tag{2}$$

where c denotes consumption, P the aggregate price level, w the real wage, l labor supply, τ a lump-sum tax, and ω profits of firms. Further, they have to fulfill the no-Ponzi game condition, $\lim_{i\to\infty} E_t B_{t+i} \prod_{v=1}^{i} R_{t+v}^{-1} \geq 0$. The objective of the representative household is

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ (1-\sigma)^{-1} \left[c_t^{1-\sigma} + \gamma (M_t/P_t)^{1-\sigma} \right] - (1+\vartheta)^{-1} l_t^{1+\vartheta} \right\}, \quad \text{with } \gamma,\ \sigma,\ \vartheta > 0, \tag{3}$$

where $\beta \in (0,1)$ denotes the subjective discount factor and E_0 the expectation operator conditional on the information in period 0. Maximizing (3) subject to (2) and the no-Ponzi game condition for a given initial value B_0 leads to the following first order conditions

$$l_t^{\vartheta} = w_t c_t^{-\sigma}, \qquad m_t = c_t i_t^{-1/\sigma} \gamma^{-1}, \qquad c_t^{-\sigma} = \beta R_t E_t \left[c_{t+1}^{-\sigma} \pi_{t+1}^{-1} \right]. \tag{4}$$

In the optimum the budget constraint (2) must hold with equality and the no-Ponzi game condition turns into the transversality condition, $\lim_{i\to\infty} E_{t+i} c_{t+i}^{-\sigma} \beta^{t+i} B_{t+i}/P_{t+i} = 0$.

[4] Specifying open market operations in form of outright sales and purchases, as for example in Shreft and Smith (1998), would enlarge the state space of the model in the case of open market policy.

2.2 Production sector

The final consumption good is an aggregate of differentiated goods produced by monopolistically competitive firms indexed with $i \in (0,1)$. The CES aggregator of differentiated goods is defined as $y_t^{(\epsilon-1)/\epsilon} = \int_0^1 y_{it}^{(\epsilon-1)/\epsilon} di$, with $\epsilon > 1$, where y is the number of units of the final good, y_i the amount produced by firm i, and ϵ the constant elasticity of substitution between these differentiated goods. Let P_i and P denote the price of good i set by firm i and the price index for the final good. The cost minimizing demand for each differentiated good is then $y_{it} = (P_{it}/P_t)^{-\epsilon} y_t$, with $P_t^{1-\epsilon} = \int_0^1 P_{it}^{1-\epsilon} di$. A firm i produces good y_i employing a technology which is linear in labor: $y_{it} = l_{it}$. Following recent contributions in monetary business cycle theory (see, e.g., Galí, 2002), the evolution of the aggregate price level satisfies

$$\widehat{\pi}_t = \chi \widehat{mc}_t + \beta E_t \widehat{\pi}_{t+1}, \qquad \text{with } \chi = (1-\phi)(1-\beta\phi)\phi^{-1}, \tag{5}$$

where $\widehat{x}$ denotes the percent deviation of a generic variable from its steady state value x : $\widehat{x} = \log(x_t) - \log(x)$, π_t the gross inflation rate ($\pi_t = P_t/P_{t-1}$) and mc_t real marginal costs. Condition (5) can be rationalized by Calvo's (1983) staggered price setting, where firms may reset their prices with the probability $1-\phi$ in each period independent of the time elapsed since the last price setting. When the fraction ϕ of firms adjust their previous period's prices according to $P_{it} = \pi P_{it-1}$, then the linear approximation of the optimal pricing condition at the steady state is shown, e.g., by Galí (2002), to lead to the aggregate supply constraint in (5). In the symmetric equilibrium labor demand is given by

$$w_t = mc_t. \tag{6}$$

2.3 Public sector

The public sector consists of a fiscal and a monetary authority. The monetary authority supplies money via repurchase agreements, which are essentially swaps of the ownership over securities B_t^c at the rate $R_t \equiv 1 + i_t$. Hence, the central bank earns $i_t M_t$ such that its budget constraint reads: $B_t^c - M_t = i_t M_t = P_t \tau_t^c$, where τ_t^c denotes transfers to the fiscal authority. We consider two alternative monetary policy regimes. The first regime is characterized by the central bank setting the nominal interest rate according to a Taylor(1993)-type rule:[5]

$$\widehat{R}_t = \rho_\pi \widehat{\pi}_t + \rho_y \widehat{y}_t + \varepsilon_t^R, \qquad \text{with } \rho_\pi, \rho_y \geq 0, \tag{7}$$

where the innovations ε_t^R have an expected value of zero and are serially uncorrelated. We assume that the steady state condition $R = 1/\beta$ has a solution for R. In accordance with interest rate rule estimations (see, e.g., Clarida et al., 2000), the response of the interest

[5] Given that monetary policy shocks are the only source of uncertainty in this economy, the central bank is assumed to respond to the realized rather than to the expected inflation rate.

rate to changes in inflation and output is assumed to be non-negative indicating that the central bank aims at stabilizing the economy. For the purpose of this paper we abstain from restricting the interest rate rule to satisfy the Taylor-principle ($\rho_\pi + \psi\rho_y > 1$, with $\psi \equiv \frac{1-\beta}{\chi(\sigma+\vartheta)}$), which ensures equilibrium determinacy (see, e.g., Woodford, 2001). Here, equilibrium multiplicity is avoided by applying the solution with the smallest set of state variables, i.e., the minimum-state-variable solution (see McCallum, 1999).[6] The qualitative effects of monetary policy shocks then do not depend on whether the interest rate policy is active ($\rho_\pi + \psi\rho_y > 1$) or passive ($\rho_\pi + \psi\rho_y < 1$). Hence, there is no need to take a stand on the reactiveness of monetary policy, which is for example found by Clarida et al. (2000) to vary between different Federal Reserve eras.

As an alternative monetary policy regime, we assume that the central bank controls the amount of securities traded in open market operations.[7] Given that the amount of securities B_t^c is not a predetermined variable, we specify the policy rule in terms of real bonds, $b_t^c \equiv B_t^c/P_t$, for convenience. In particular, an open market policy is characterized by:

$$\widehat{b^c}_t = \beta_\pi \widehat{\pi}_t + \beta_y \widehat{y}_t + \varepsilon_t^b, \tag{8}$$

where the innovations ε_t^b have an expected value of zero and are serially uncorrelated. It should be noted that open market securities are in general not equal to total government bonds outstanding, such that the rule (8) does not govern the evolution of households' real wealth. The fiscal authority issues risk-free one period bonds, receives lump-sum taxes from households, and transfers from the monetary authority: $R_{t-1}B_{t-1} = B_t + P_t\tau_t^c + P_t\tau_t$. We assume that government bonds are issued to a sufficiently large amount such that $b_t \geq b_t^c$ always holds, while tax policy guarantees government solvency, i.e., ensures $\lim_{i\to\infty} E_t B_{t+i} \prod_{v=1}^{i} R_{t+v}^{-1} = 0$, by satisfying $\partial\tau_t/\partial b_{t-1} > 0$. As a consequence, public finance is irrelevant for the remainder of the economy and Ricardian equivalence applies.

A *rational expectations equilibrium* of the model then is a set of sequences $\{c_t,\ l_t,\ m_t,\ w_t,\ \pi_t,\ mc_t,\ R_t,\ b_t^c\}_{t=0}^{\infty}$ satisfying the household's first order conditions (4), the aggregate supply constraint approximated by (5), the aggregate labor demand (6), the money supply constraint (1), the monetary policy rule (7) or (8), the aggregate resource constraint, $l_t = c_t$, and the household's transversality condition.

2.4 Short-run monetary policy effects

In this subsection, we aim at deriving the short-run effects of monetary policy shocks, which are either identified with innovations to the interest rate rule (7) or to the open market rule

[6] This solution can, for example, be rationalized by agents economizing on the use of information.

[7] Obviously, the open market constraint (1) implies that a policy regime where the central bank controls the ratio of assets traded in open market operations, i.e., the bonds-to-money B_t^c/M_t, which is for example applied in Shreft and Smith (1998) and Battacharya and Kudoh (2002), is equivalent to an interest rate policy.

(8). For this purpose, we apply the model's log-linear approximation at a non-deflationary steady state ($\pi \geq 1$), which is presented in appendix 6.1. For the case where the central bank sets the nominal interest rate, the linearized and reduced version of the model accords to the standard New Keynesian model (see, e.g., Clarida et al., 2000), except for the endogenous consideration of open market securities. Given that the model is purely forward looking, its fundamental solution, or, minimum-state-variable solution (see, McCallum, 1999), exhibits no endogenous state variable for both policy regimes (7) and (8). The solution for consumption, inflation, and real balances therefore reads: $\widehat{c}_t = \delta_c^i \varepsilon_t^i$, $\widehat{\pi}_t = \delta_\pi^i \varepsilon_t^i$, $\widehat{m}_t = \delta_m^i \varepsilon_t^i$, for $i \in (R, b)$. The impact effects of monetary policy shocks can easily be derived by applying the method of undetermined coefficients for the fundamental solution. The following proposition summarizes the qualitative effects of an interest rate shock.

Proposition 1 (Interest rate policy) *Suppose the central bank sets the nominal interest rate according to (7). Then a monetary contraction leads to negative impact responses of inflation, consumption, real balances and open market securities if* $R > (\sigma - 1)(R - 1)$.

Proof. See appendix 6.2.

Hence, a positive interest rate innovation leads to real and nominal contractions. Real balances unambiguously decline as the responses of both arguments in the money demand function (4) tend to lower households' willingness to hold money. However, the response of bonds traded in open market operations can in principle take both signs. On the one hand, the rise in the nominal interest rate raises the costs of money such that more bonds have to be supplied by households per unit of money to satisfy the open market constraint (1). On the other hand, the decline in money demand tends to lower the supply of open market securities. According to proposition 1, the latter effect overturns the cost effect for our conventional money demand specification such that open market securities, in real and nominal terms, decline in response to a positive interest rate shock for any plausible parametrization, implying $R > (\sigma - 1)(R - 1)$.

In the case of the alternative monetary policy regime, where the central bank controls its holdings of open market securities, monetary policy shocks are identified with innovations to the open market policy rule (8). For the subsequent analysis, it turns out to be convenient to assume that $\Gamma \equiv R - \sigma (R - 1) > 0$ holds, which is clearly satisfied for any reasonable set of parameter values.[8] The following proposition presents an equivalent open market policy rule, i.e., a rule for b_t^c which implements the same fundamental solution as an interest rate policy.

[8] Note that $\Gamma > 0$ is sufficient to ensure $\partial \widehat{b}_t^c / \partial \varepsilon_t^R < 0$ (see proposition 1).

Proposition 2 (Open market policy) *The fundamental equilibrium path for an interest rate policy satisfying (7) can alternatively be implemented by an open market policy (8) if*

$$\beta_\pi = -\widetilde{\beta}\rho_\pi, \;\; \beta_y = -\widetilde{\beta}\rho_y, \;\; \text{and } \varepsilon_t^b = -\left[\widetilde{\beta} + (\sigma + \rho_\pi\omega + \rho_y)^{-1}\right]\varepsilon_t^R, \tag{9}$$

where $\widetilde{\beta} \equiv \Gamma/\sigma(R-1)$.

Proof. The linearized money demand condition, $\widehat{m}_t = \widehat{c}_t - R[\sigma(R-1)]^{-1}\widehat{R}_t$, and the money supply constraint, $\widehat{b^c}_t = \widehat{R}_t + \widehat{m}_t$, imply the nominal interest rate and open market securities to be related by $\widetilde{\beta}\widehat{R}_t = \widehat{c}_t - \widehat{b^c}_t$. Hence, the fundamental solution for (7) also applies for a policy rule satisfying $\widehat{b^c}_t = -\widetilde{\beta}\rho_\pi\widehat{\pi}_t - \widetilde{\beta}\rho_y\widehat{y}_t - \left(\widetilde{\beta} - \delta_c^R\right)\varepsilon_t^R$. Using that $\delta_c^R = -(\sigma + \rho_\pi\omega + \rho_y)^{-1}$ (see proof of proposition 1) establishes the claims made in the proposition. ■

Hence, the central bank can adjust its bonds holdings according to (9) in order to implement an equilibrium sequence for the nominal interest rate which satisfies (7). Proposition 2 further implies that a positive open market shock ($\varepsilon_t^b > 0$) mimics an unanticipated decline in the nominal interest rate and leads – regardless of condition (9) being satisfied – to a rise in output, inflation, and real balances when β_π and β_y are non-positive. When the central bank raises its purchases of securities in open market operations, it increases money holdings of households and, thus, stimulates aggregate demand. The nominal interest rate, which is jointly determined by the stance of open market operations and by the households' demand for money, then declines. We can therefore conclude that a positive innovation to open market securities measures an unanticipated expansionary monetary policy shock.[9]

The qualitative predictions for the short-run monetary policy effects serve, in what follows, as a guideline to assess the empirical performance of monetary policy shocks identified by interest rate or open market shocks. In the latter case, the model predicts that the central bank can alter the short-run nominal interest rate only via changes in its holdings of open market securities. Given the evidence on the reactiveness of the federal funds rate target (see, e.g., Taylor, 1993, or, Clarida et al., 2000), one would thus expect open market securities also to be highly reactive. However, if the central bank is actually able to manipulate the federal funds rate without applying open market transactions, e.g., via open mouth operations (see Guthrie and Wright, 2000, or, Taylor, 2001), a direct relation between interest rates and open market securities, as in proposition 2, does not necessarily exist.

3 Empirical analysis

In this section, we empirically examine the flow of funds in open market operations in a macroeconomic context and assess the ability of changes in open market operations to serve as a measure for exogenous monetary policy actions. In particular, an expansionary monetary

[9] In contrast to a rise in the bonds-to-money ratio, $b_t^c/m_t = R_t$, a positive b_t^c innovation does not reflect a rise in the cost of money.

policy shock is identified with an unanticipated rise in central bank holdings of securities traded in open market operations. The respective time series is constructed by summing up all assets in the central bank's balance sheet which are either bought outright or held under repurchase agreements. These assets, which are labelled Open Market Securities (OMS), consist of treasury securities, federal agency securities, as well as commercial papers and bankers acceptances summarized as 'open market papers' (see Meulendyke, 1998, and the Guide to the Flow of Funds Accounts, 2000).[10] Rather than testing for the structural relations of the illustrative model presented in the previous sections, we compare the model's qualitative predictions about macroeconomic reactions to changes in open market securities with impulse responses computed from estimated VARs. Herein, policy shocks are identified by applying a recursive identification scheme, which corresponds to the one in Christiano et al. (1996, 1999). Though, the identification scheme does not exactly accord to the timing of events in the theoretical model, it is chosen to allow for a direct confrontation of alternative policy measures and to facilitate comparisons with related studies.

In order to isolate monetary policy shocks, we assume that the central bank uses a specific policy rule for the prevailing instrument I_t depending on the current and past state X_t of the economy. Monetary policy shocks are identified with serially uncorrelated innovations ε_t^i to the linear policy rule: $I_t = g(X_t) + \varepsilon_t^i$, where g is a linear function, which allows to measure responses to a monetary policy shock by a regression of endogenous variables on the history of the residuals. Impulse response functions are then computed from fitting a particular vector autoregression applying a recursive identification assumption. The estimation errors are orthogonalized by a Choleski decomposition so that the covariance matrix of the resulting innovations ε_t is diagonal. Policy innovations ε_t^i are obtained using the following Wold ordering of the variables: $(Z_{1t},\ I_t,\ Z_{2t})$, where the vector Z_{1t} consists of j variables entering X_t and ε_t^i is the $(j+1)$-th element of ε_t. The ordering allows the variables in Z_1 to have a contemporaneous impact on monetary policy, whereas the variables in vector Z_2 can only affect the instrument I by lagged realizations. The vector Z_1 contains GDP in prices of 1996 (GDP) and the GDP deflator ($GDPDEF$). For the monetary policy instrument I we alternatively apply central bank holdings of open market securities (OMS), the federal funds rate ($FFRATE$), or nonborrowed reserves ($NBRES$). The vector Z_2 contains the two remaining instruments and $M2$ as a broad monetary aggregate. All variables, except for the federal funds rate, are logged. The VARs are then estimated with quarterly US data for the period 1959:1–2002:2. Guided by the AIC criterion we chose the lags 1, 2, and 4.

[10] The data are taken from the Flow of Funds Accounts of the United States provided from the Board of Governors of the Federal Reserve System (see appendix 6.3).

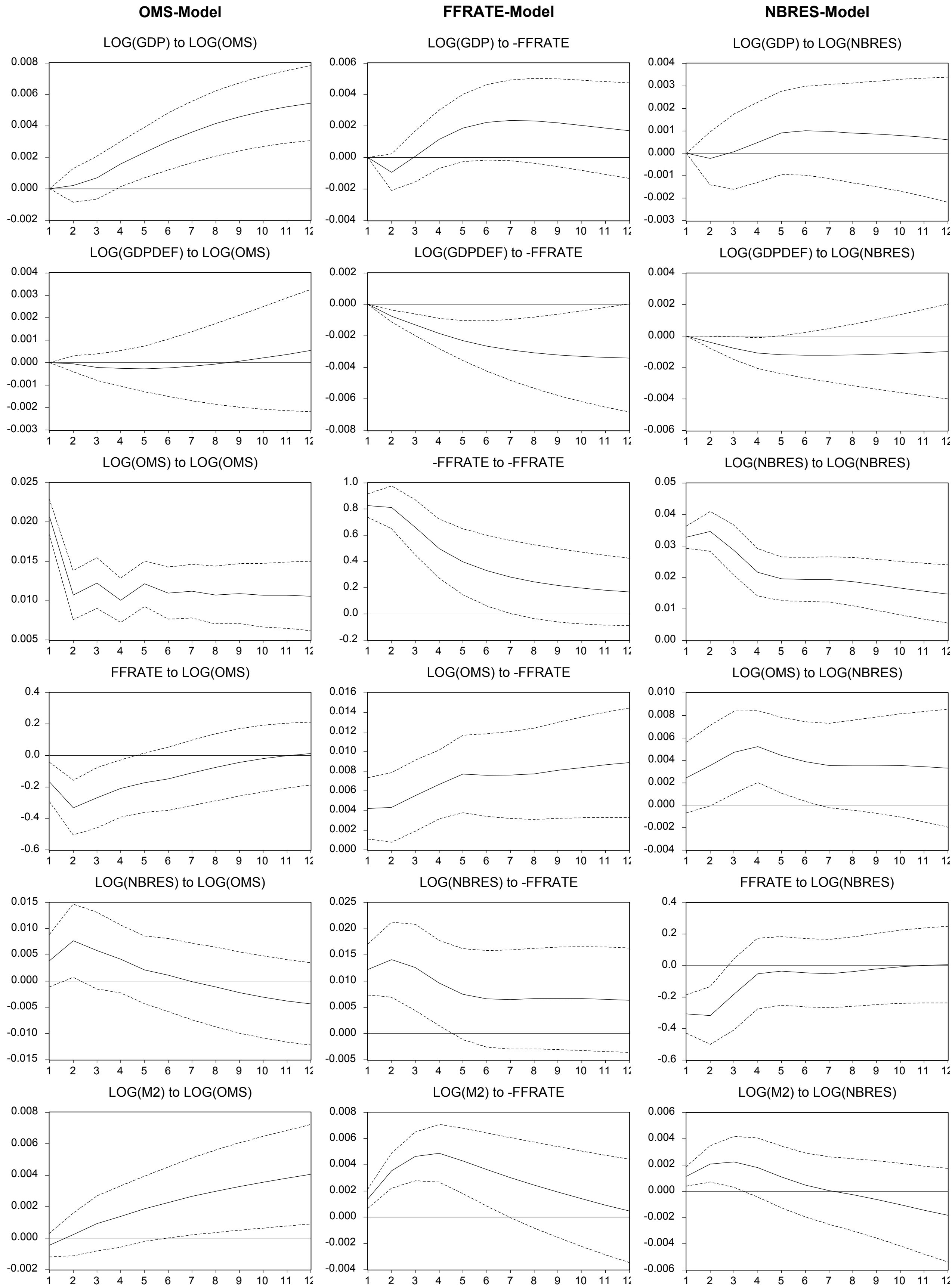

Figure 1: Impulse responses to alternative monetary policy shocks (1959:1–2002:2)

3.1 Alternative policy measures

Figure 1 presents impulse responses to one standard deviation innovation to the prevailing monetary policy instrument for the full sample period (1959:1–2002:2).[11] The variables within one column are arranged according to the Wold causal ordering. The first column in figure 1 presents the impulse responses to an innovation to open market securities held by the central bank (OMS-model). A positive OMS shock leads to a highly persistent rise in open market securities. Real GDP displays a persistent and significant rise, while prices are almost unaffected. In accordance with the theoretical predictions the federal funds rate declines and nonborrowed reserves significantly rise, though, the responses are not very pronounced and only shortly lived. Nevertheless, we can conclude that the responses are not inconsistent with the sign restrictions for open market shock effects implied by proposition 2.

The second column shows impulse response functions for a negative federal funds rate shock ($FFRATE$-model), which accord to the estimates in Christiano et al. (1996) for the case where only one price index is included. The amount of open market securities held by the central bank as well as narrow and broad monetary aggregates rise, which qualitatively accords to the prediction of the theoretical model (see proposition 1). Output exhibits a persistent, though, insignificant rise, while the impulse response function of the deflator displays the well-known price puzzle. It should be noted that a sensitive price index, e.g., a commodity price index, which is often included in monetary VARs to reduce the so-called price puzzle, is omitted.[12] Turning to the case of nonborrowed reserves shocks ($NBRES$-model), which is also examined in Eichenbaum (1992), the impulse responses in the third column of figure 1 displays reasonable reactions of the financial variables, while the output response is insignificant and the deflator exhibits an almost significant price puzzle.

Variance decompositions for all three VAR models, which are presented in table 1, further reveal that OMS shocks account for a larger fraction of the GDP forecast error variance than $FFRATE$ or $NBRES$ shocks. This result holds for 4, 8, and 12 quarters and is robust regardless of the Wold ordering between the three alternative policy measures. Within the set of monetary policy measures open market shocks, thus, play the most important role in accounting for movements in GDP. In order to examine how open market operations contribute to endogenous monetary policy actions, we further employ impulse response functions of the OMS-model and explore the reactions of policy measures triggered by non-policy shocks, here, positive innovations to the GDP equation. As displayed in figure 2, where the impulse responses of GDP, OMS and $FFRATE$ are presented, open market securities exhibit no significant reactions to a GDP expansion, whereas the $FFRATE$ strongly rises consistent with Taylor(1993)-type rule predictions about adjustments in the Federal Funds Rate target.

[11] The dotted lines present a two standard error band, computed with the Monte Carlo method, spanning a 95% confidence interval.

[12] Hanson (2002) shows that this strategy can in fact not completely resolve the price puzzle.

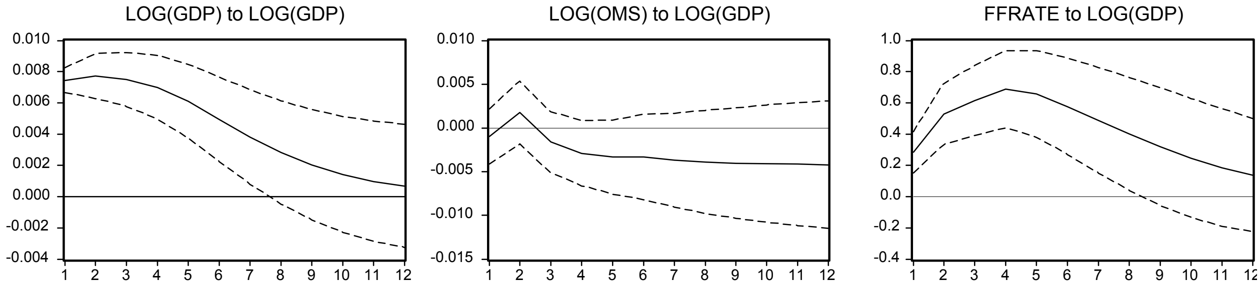

Figure 2: Responses to GDP-shocks in the OMS-model (1959:1–2002:2)

Given that a $GDPDEF$ shock leads to an analogous result (not displayed), we can conclude that the path of OMS is not characterized by a decided structural dependency, which corresponds to a policy regime in the illustrative model, where the open market policy rule (8) features small values for the coefficients β_π and β_y.

In any case, when all possible monetary policy measures jointly enter the VAR, shocks to OMS are the most informative measure for exogenous monetary policy actions. Further, given that only responses to OMS shocks qualitatively accord – except for the insignificant price reaction – to the theoretical predictions, they seem to be more appropriate in this regard than $FFRATE$ and $NBRES$ shocks.

Table 1 Variance decomposition of GDP for 1959:1–2002:2 (in %)

	OMS-Model			FFRATE-Model			NBRES-Model		
Quarters	OMS	FFRATE	NBRES	FFRATE	OMS	NBRES	NBRES	OMS	FFRATE
4	1.2	0.7	0.01	0.88	1.01	0.01	0.12	1.14	0.63
8	10.0	2.4	0.01	4.56	7.83	0.01	0.81	9.46	2.14
12	21.1	2.2	0.03	5.24	17.00	0.03	0.86	20.43	1.98

3.2 Subsample estimates

Having established that OMS innovations can be interpreted as monetary policy shocks, we proceed by investigating variations in the macroeconomic effects over different subsamples. In particular, we divide the full sample period into the three subsamples 1959:2–1979:3, 1979:4–1994:1, and 1994:2–2002:2. The first break date (1979:4) is associated with a policy shift announced by Federal Reserve Chairman Paul Volcker in October 1979, while the second break date (1994:2) is chosen as the Federal Open Market Committee began to announce federal funds rate targets with its 4 February 1994 meeting. The second subsample can often be found in related contributions to be further partitioned in order to isolate the short period between 1979 and 1982 associated with a shift in the operating procedure towards nonborrowed reserves targeting (see, e.g., Christiano et al., 1999, or, Boivin and Gianonni, 2002). Apparently, this shift matters when monetary policy shocks are identified with changes in the operating target. On the contrary, we find that it is irrelevant for our exercise, as we examine effects of shocks to the underlying instrument. The VARs are specified as in the previous section, except for the lag structure, which now only includes the lags 1 and 2. The responses for the OMS-model are presented in figure 3.

The effects of an OMS shock in the first two periods 1959:1–1979:3 and 1979:4–1994:1, which are presented in the first and the second column of figure 3, roughly accord to those for the full sample period. Hence, it seems that the policy regime shift in 1979 does not qualitatively alter the effects of open market shocks. In contrast, however, all responses, except for the response of the policy instrument, are insignificant in the last period 1994:2–2002:2 (see column 3). Herein, a shock to open market securities has essentially no impact on financial variables and on macroeconomic aggregates. In accordance with this observation, OMS shocks account for a much smaller fraction of the GDP forecast error variance in the post-1994 period than shocks to the federal funds rate as can be seen from table 2. In comparison to the pre-1994 period (see table 1) the importance of OMS shocks in accounting for GDP movements thus almost vanished in favor of $FFRATE$ shocks. Furthermore, variance decompositions of $FFRATE$ for the pre-1994 and post-1994 period (given in table 2) reveal that the contribution of open market operations for movements in $FFRATE$ substantially declined in the latter period. Hence, the estimates for the 1994:2–2002:2 period suggest that the central bank operating procedure can be summarized by a highly reactive interest rate policy, as for example by a Taylor (1993) rule.

Table 2 Variance decompositions of GDP and $FFRATE$ for the OMS-model (in %)

	GDP 1994:2-2002:2			FFRATE 1994:2–2002:2			FFRATE 1979:4–1994:1		
Quarters	OMS	FFRATE	NBRES	OMS	FFRATE	NBRES	OMS	FFRATE	NBRES
2	0.26	1.79	1.09	0.03	85.78	1.08	20.25	40.83	0.15
4	1.22	5.01	0.62	1.21	49.75	2.63	19.55	34.66	0.16
8	1.27	13.52	0.62	1.57	53.14	5.02	18.99	34.43	0.26

Our subsample estimates confirm the existence of an 'announcement effect' as reported by Demiralp and Jordá (2003) for the post-1994 period, saying that announcements for the federal funds rate target are relevant in the sense that monetary policy effects do not rely on substantial actions by the Trading Desk. Thus, the analysis presented in this subsection indicates that since 1994 'open mouth operations' (see Guthrie and Wright, 2000, or Taylor, 2001) are effective and OMS shocks are less useful than federal funds rate shocks to measure the total leverage of the Federal Reserve policy on macroeconomic aggregates.

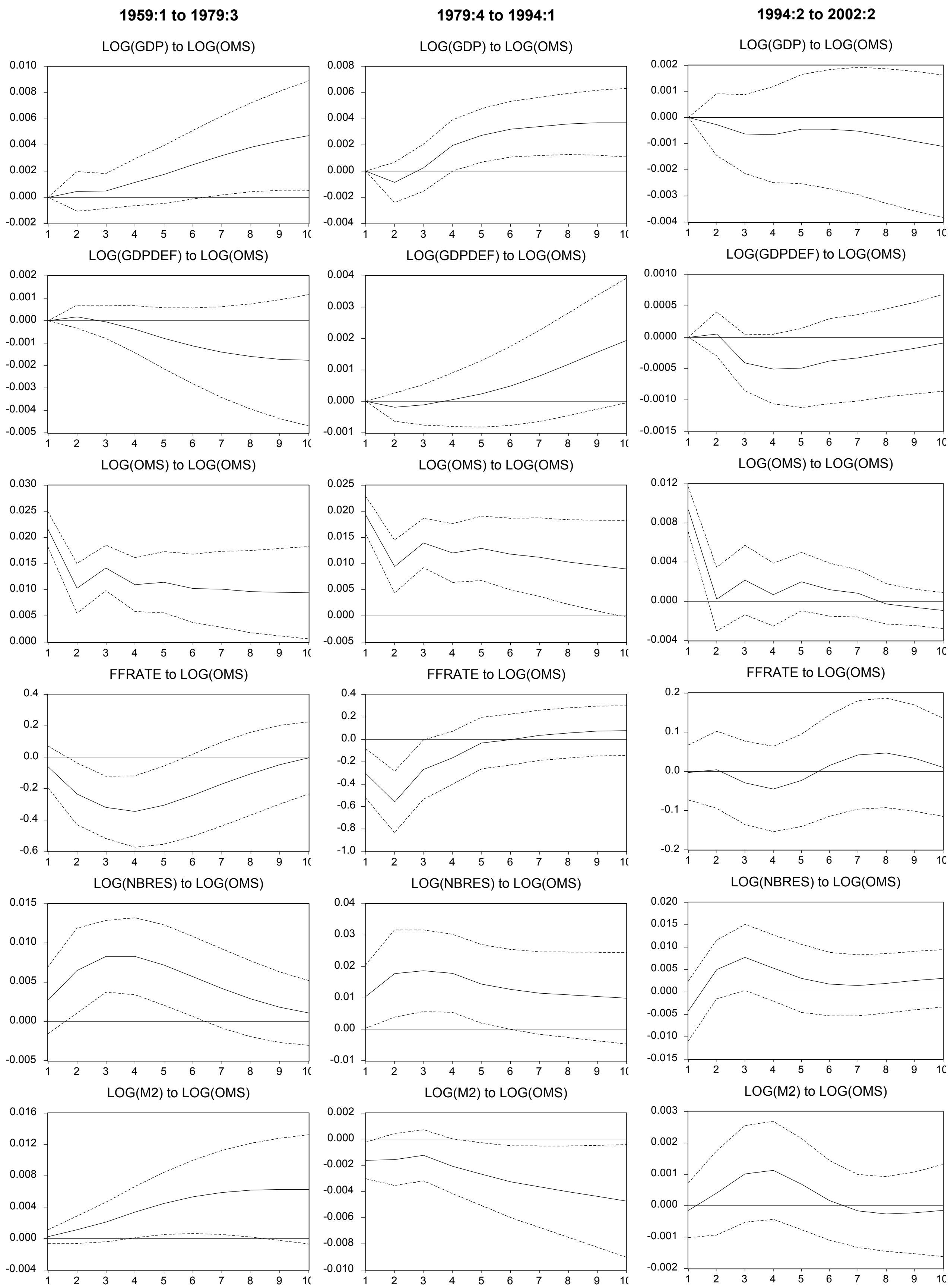

Figure 3: Responses of the OMS-Model for 1959:1–1979:3, 1979:4–1994:1, and 1994:2–2002:2

4 Conclusion

In this paper we exploit the informational content of the flow of funds in open market operations to assess the short-run effects of monetary policy shocks. It is shown in a macroeconomic framework that an unanticipated rise in central bank holdings of open market securities can serve as a measure for an expansionary monetary policy shock. Impulse responses computed from fitting VARs for US data do not exhibit a puzzling output or price behavior. Open market shocks are found to contribute to a larger fraction of the GDP forecast error variance than shocks to the federal funds rate or to nonborrowed reserves for the time interval 1959:1 to 2002:2. Impulse responses to GDP innovations further reveal that the open market measure is less sensitive to macroeconomic developments than the federal funds rate, indicating that the balance sheet composition is (almost) exogenously controlled, whereas the federal funds rate is more susceptible to disturbances caused by non-policy factors.

Our results show that unanticipated changes in central bank purchases of open market securities provide a measure for monetary policy shocks, which seems to be less exposed to simultaneity problems and leads to reactions in macroeconomic aggregates consistent with common priors about monetary policy effects. However, the explanatory power of the information contained in open market operations crucially relies on the necessity of this instrument to implement policy targets. Therefore, the role of open market shocks in accounting for GDP movements can be expected to decrease when the mere announcement of changes in the operating target already affects the federal funds rate and macroeconomic aggregates. Our analysis provides strong evidence for this view, as open market shocks are found to be associated with insignificant macroeconomic reactions and to account for a much smaller fraction of the forecast error variance of real output than shocks to federal fund rate since 1994, when the Federal Reserve began to announce federal funds rate targets.

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6 Appendix

6.1 The log-linearized model

The model is log-linearized at a steady state with $\pi \geq 1$ satisfying $c^{\sigma+\vartheta} = \frac{\epsilon-1}{\epsilon}$, $R = \pi/\beta$, $\gamma m = c(R-1)^{-1/\sigma}$, $b^c = Rm$ and $b > b^c$. A rational expectations equilibrium of the log-linearized model is then a set of sequences $\{\widehat{c}_t, \widehat{\pi}_t, \widehat{m}_t, \widehat{R}_t, \widehat{b^c}_t\}_{t=0}^{\infty}$ satisfying

$$\sigma\widehat{c}_t = \sigma E_t\widehat{c}_{t+1} - \widehat{R}_t + E_t\widehat{\pi}_{t+1}, \tag{10}$$

$$\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} + \omega\widehat{c}_t, \qquad \text{with} \quad \omega \equiv \chi(\sigma+\vartheta) > 0, \tag{11}$$

$$\sigma\widehat{m}_t = \sigma\widehat{c}_t - [R/(R-1)]\,\widehat{R}_t, \tag{12}$$

$$\widehat{b^c}_t = \widehat{R}_t + \widehat{m}_t, \tag{13}$$

and (7) or (8), together with the transversality condition. Note that the equilibrium sequence of open market securities can residually be determined, by (13), for an interest rate policy.

6.2 Proof of Proposition 1

In order to solve the model for an interest rate policy satisfying (7), we replace the nominal interest rate with the policy rule $\widehat{R}_t = \rho_\pi\widehat{\pi}_t + \rho_y\widehat{c}_t + \varepsilon_t^R$ and reduce the model to $\sigma\widehat{c}_{t+1} + \widehat{\pi}_{t+1} = \sigma\widehat{c}_t + \rho_\pi\widehat{\pi}_t + \rho_y\widehat{c}_t + \varepsilon_t^R$ and (11). Applying the fundamental solution, $\widehat{c}_t = \delta_c^R\varepsilon_t^R$, $\widehat{\pi}_t = \delta_\pi^R\varepsilon_t^R$, and $\widehat{m}_t = \delta_m^R\varepsilon_t^R$, we obtain the following conditions for δ_π^R and δ_c^R : $\sigma\delta_c^R + \rho_\pi\delta_\pi^R + \rho_y\delta_c^R + 1 = 0$ and $\delta_\pi^R - \omega\delta_c^R = 0$. Eliminating δ_π^R then reveals that the coefficient δ_c^R and, therefore, δ_π^R is strictly negative: $\delta_c^R = -\left(\sigma + \rho_\pi\omega + \rho_y\right)^{-1} < 0$ and $\delta_\pi^R = \omega\delta_c^R < 0$. Further using the log-linear money demand condition (12) and the interest rate rule (7), gives the following solution for real balances: $\widehat{m}_t = \left[1 + R(R-1)^{-1}\right]\delta_c^R\varepsilon_t^R$, and therefore $\delta_m^R < 0$. To solve for open market securities b_t^c the solutions for real balances and the nominal interest rate, $\widehat{R}_t = \left[(\rho_\pi\omega + \rho_y)\delta_c^R + 1\right]\varepsilon_t^R$, are plugged in into the money supply constraint (13), yielding $\widehat{b^c}_t = \delta_b^R\varepsilon_t^R$, with $\delta_b^R = -\left[1 - \sigma + R(R-1)^{-1}\right]\left(\sigma + \rho_\pi\omega + \rho_y\right)^{-1}$. Hence, the amount of open market securities declines in response to an interest rate shock, $\partial\widehat{b^c}_t/\partial\varepsilon_t^R < 0$, if $R > (\sigma-1)(R-1)$, which completes the proof of the proposition. ■

6.3 Data sources

Board of Governors of the Federal Reserve System, Flow of Funds Accounts
(http://www.federalreserve.gov/releases/)

OMS Tresury Securities (FL713061100.Q)
+ Agency Securities (FL713061703.Q)
+ Open Market Papers (FL713069603.Q), in Bill. of Dollars

Federal Reserve Bank of St.Louis, Federal Reserve Economic Data (FRED II)
(http://research.stlouisfed.org/fred2/)

$GDPDEF$	Gross Domestic Product Deflator, seasonally adjusted
GDP	Deflated Gross Domestic Product, 1996, seasonally adjusted, in Bill. of Dollars
$FFRATE$	Federal Funds Rate, averages of daily figures, in percent
$NBRES$	Nonborrowed Reserves, seasonally adjusted, in Bill. of Dollars
$M2$	M2, seasonally adjusted, in Bill. of Dollars