Financial Intermediation, Beliefs, and the Transmission Mechanism

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Introduction

A growing body of literature emphasizes the role of financial intermediaries in the economy. We have chosen to focus on the significance of liquid assets in the behavioural problem of financial intermediaries.[1] To this end, we extend a standard limited-participation model to incorporate: (i) financial intermediaries that optimize profits by allocating funds among longer-term loans and shorter-term liquid assets; and (ii) asymmetric information between private banks and the monetary authority. The interaction of the two factors allows us to capture episodes in which the intent of monetary policy is less than transparent to private agents. In this respect, our work is not a general explanation of the monetary transmission mechanism; instead, it emphasizes the importance of financial intermediaries in the monetary transmission mechanism when the direction of monetary policy or the general state of the economy is unclear.

Our findings show that an expansionary policy may have smaller but more protracted effects on an economy when the public does not clearly understand the intent of a monetary policy action, and when financial intermediaries are in a position to choose between longer-term lending and

1. For Canadian chartered banks, liquid assets comprise, on average, a significant 12 per cent of Canadian dollar assets.

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shorter-term investment in liquid assets. When, in the event of a monetary easing, financial intermediaries invest in liquid assets, there is less positive real impact and less inflationary pressure in the commodity market, because that liquidity is not being lent to firms. Banks release new liquidity into the lending market only when they are certain that the central bank will not withdraw the injected liquidity from the system in the near future. This monetary effect is not caused by an asymmetric information set-up between lenders and borrowers, as described in Bernanke, Gertler, and Gilchrist (1998). Instead, it is driven by the financial intermediaries' misinterpreting monetary policy. Misinterpreting the stance and direction of monetary policy can occur for many reasons, including low policy credibility, infrequent policy shocks, or an environment with other financial market shocks present, which makes it more difficult for financial institutions to understand the stance and direction of monetary policy.

Our findings also suggest that monetary policy actions have variable effects. When the true intent of policy is clear, the transmission lag between the policy action and the economy is relatively short. When the direction of monetary policy is unclear, we find that the effect of monetary policy on output and inflation is more muted, and occurs with a longer lag.

1 The Structure of the Model

The model's basic structure uses the standard limited-participation framework similar to that found in Lucas (1990), Fuerst (1992), and Christiano and Eichenbaum (1992). We modified the model to permit financial intermediaries to maximize profits by allocating resources between short-term liquid assets and longer-term lending when private agents are unclear about the central bank's policy intentions.

One period in the model is assumed to represent a quarter, and is divided into two subperiods. Unlike a standard limited-participation model, there can be two money-growth-rate shocks each quarter, one occurring before lending decisions are made and the other hitting the economy after lending decisions are made. To offset possible costs associated with the second shock, intermediaries hold liquid assets as a buffer stock. Given certain shock processes and information frictions, the amount of liquid assets intermediaries hold can have important effects on the monetary policy transmission mechanism.

All real variables and prices are determined during the first subperiod, when only the first shock is known. Banks are assumed to be able to adjust only their liquid-asset holdings after the second shock occurs. After this, the quarter ends in the usual fashion: loans are repaid, firms and banks pay out dividends, and households select their deposit levels for the next period. This set-up allows liquid assets to be adjusted more often than production decisions.

1.1 The central bank

Monetary policy is conducted in this model through the setting of the money-growth rate. A change in money growth may occur for either policy-related or non-policy-related reasons. Policy-related changes approximate the reaction function, the targeting rule of the central bank, or both. In the model, these changes are considered to be relatively more persistent. Non-policy shocks to the money-growth rate represent such things as neutralized government transactions, random errors, and reactions to transitory-level shocks in the rest of the economy. These changes occur more frequently than the policy-related changes. The distinction between the two types of actions is important; they follow separate processes, causing private agents to respond very differently to each shock. Specifically, let X_t be the total money transfer to banks in period t. According to our assumption, X_t can be decomposed as follows:

$$X_t = X_t^p + X_t^{np}, \tag{1}$$

into a policy component, X_t^p, or a non-policy component, X_t^{np}. We assume that the central bank has full information, but the public observes only X_t. The growth rate of the policy component is assumed to be a positive first-order autoregressive process (AR[1]), so when the central bank conducts a policy action it tends to do so persistently. In contrast, the non-policy component of money growth is given by a negative moving average (MA) process, so any change will be reversed over the next few subperiods. More detail on the parameterization of these processes is provided in the section on calibration.

We assume that the central bank intervenes twice in a given time period to model the characteristic that central banks can generally revise their policy decisions more often than firms can adjust their production plans. Therefore, the policy-shock and non-policy-shock components can be decomposed further into two subperiod values, viz.,

$$X_t^p = X_{1t}^p + X_{2t}^p \tag{2}$$

and

$$X_t^{np} = X_{1t}^{np} + X_{2t}^{np}, \tag{3}$$

where X_{it}^j represents the component $j = \{p, np\}$ money transfer in subperiod $i = \{1, 2\}$ of period t.

1.2 Commercial banks

Financial intermediaries maximize profits by choosing the optimal mix of longer-term lending to firms and shorter-term investment in liquid assets. Lending to firms is considered productive intermediation, because the borrowers of the funds produce real goods. Investment in liquid assets is considered non-productive, because this activity does not produce real goods. Consequently, these liquid assets may be thought of as deposits at the central bank or purchases of government debt. Domestic corporate paper should not be counted as liquid assets, because it represents a method other than direct lending of transferring monetary injections to the firms in the period of the injection.[2]

In our model economy, banks combine deposits from households, N_t, with an initial transfer from the central bank, X_{1t}, make loans to firms, B_t, and invest in net liquid assets of D_{1t}.[3] After observing the first policy shock of period *t*, commercial banks make lending decisions based on their assessment of the breakdown of X_{1t} into X_{1t}^p and X_{1t}^{np}, as well as the forecasts of these components. The second subperiod money transfer, X_{2t}, occurs after lending decisions for period *t* are made. We assume that loans are not callable or that there is some cost making it prohibitively expensive to do so. Consequently, banks can adjust liquid-asset holdings only after seeing X_{2t}, so that monetary transfers received in the second subperiod are used to increase liquid assets or decrease short-term borrowing.

More formally, commercial banks maximize profits, based on the information set $\Omega_{1t} = \{\Omega_{2t-1}, X_{1t}\}$ in the first half of period *t*,[4] by allocating funds between liquid assets and loans to firms; that is:

$$\max_{B_t, D_{1t}} \sum_{t=0}^{\infty} \beta^t \lambda_t \pi_t^b$$

$$= \max_{B_t, D_{1t}} E_0\left[\sum_{t=0}^{\infty} \beta^t \lambda_t \{R_t^l B_t + [R^g(R_t^l, D_{2t}) \cdot D_{2t} | \Omega_{1t}] - R_t^d N_t\}\right] \quad (4)$$

subject to

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2. However, liquid assets could represent purchases of foreign short-term corporate paper, provided there are no significant feedback effects from added production in the foreign economy.

3. D_{1t} is referred to as net liquid assets, because it can be either positive (short-term lending or deposits with the central bank) or negative (short-term borrowing from the central bank).

4. $\Omega_{2t} = \{\Omega_{1t}, X_{2t}\} = \{..., X_{1t-1}, X_{2t-1}, X_{1t}, X_{2t}\}$ is the information set covering the complete history of money growth until the end of the second subperiod of period *t*.

$$N_t + X_{1t} = B_t + D_{1t}, \tag{5}$$

$$D_{1t} + E_t[X_{2t}|\Omega_{1t}] = E_t[D_{2t}|\Omega_{1t}]. \tag{6}$$

Banks earn an interest rate of R_t^l on lending to firms and a return, R_t^g, on end-of-period holdings of liquid assets, D_{2t}. The holding period of D_{1t} is assumed to be short enough that no return is earned. Equation (5) represents the beginning-of-period cash-in-advance (CIA) constraint for banks, and equation (6) represents the banks' expected CIA constraint for the beginning of the second subperiod. Any monetary injection received at this time cannot be lent out, but can be used to increase the banks' net liquid asset position.

The rate of return on liquid assets is assumed to be greater than R_t^l if financial intermediaries are net borrowers over the period $(D_{2t} < 0)$ and smaller than R_t^l if banks are net lenders $(D_{2t} > 0)$. If intermediaries end the period with deposits at the central bank $(D_{2t} > 0)$, then they earn some return, $R_t^g < R_t^d$, which is less than the loan rate. On the other hand, if intermediaries end period t having borrowed from the central bank $(D_{2t} < 0)$, then they must pay a penalty rate, $R_t^g < R_t^l$, that is above the rate paid on households' deposits. This set-up ensures that banks will hold an optimal level of precautionary liquid assets. Therefore, R^g is a step function, which can be approximated by the continuous function[5]

$$R_t^g = R_t^l - \kappa D_{2t}^{\frac{1}{3}}, \tag{7}$$

where $\kappa > 0$.

The first-order condition associated with the above problem is

$$E_t\left\{\lambda_t(N_t + X_{1t} + X_{2t} - B_t)^{\frac{1}{3}}\middle|\Omega_{1t}\right\} = 0. \tag{8}$$

This implies banks will invest in initial liquid-asset holdings D_{1t} until their expected holdings for the entire period are 0. This is optimal, because, for financial intermediaries, it is more profitable to lend out their funds than to hold them in the form of liquid assets. If banks believe that there will be an expansionary monetary shock in the second subperiod, they will run down their liquid assets, by borrowing from the central bank, in order to lend more

5. The model solution, except for R_t^g, does not depend on the parameters of the R_t^g function in (7). They determine the size of the step in the R_t^g function and do not change the desire of banks to target $D_{2t} = 0$ over the period. The banks wish to avoid all penalties, whether small or large. It would be worthwhile to examine a model with a central bank that conducts policy by temporarily changing the mean of the R_t^g function. This would induce banks to adjust their liquid assets in response to a policy change in their expected returns.

than their initial cash holdings of $N_t + N_{1t}$. If banks, on the other hand, predict a contraction, they will reduce lending to firms and invest instead in liquid assets to offset the expected shock.

1.3 Firms

We assume that firms are perfectly competitive. They borrow funds from commercial banks to finance their wage bill and rent capital from the capital market. These firms, as price takers, maximize profit, π_t, by choosing the optimal amount of capital, k_t, and labour, l_t, based on the same information set as commercial banks. That is,

$$\max_{k_t, l_t} E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \pi_t$$

$$= \max_{k_t, l_t} E_0 \left[\sum_{t=0}^{\infty} \beta^t \lambda_t \{ P_t \cdot F(k_t, l_t) - r_t \cdot P_t \cdot k_t - R_t^l \cdot W_t \cdot l_t | \Omega_{1t} \} \right] \tag{9}$$

where P_t is the output price, r_t is the net capital rental rate, and W_t is the nominal wage rate, and production is given by:

$$F(k_t, l_t) = z_t \cdot k_t^{\alpha} \cdot l_t^{1-\alpha}, \tag{10}$$

where z_t represents the level of production technology. The optimal demand for capital and labour satisfies the following marginal conditions:

$$\frac{\partial F(k_t, l_t)}{\partial k_t} = r_t \tag{11}$$

and

$$\frac{\partial F(k_t, l_t)}{\partial l_t} = R_t^l \cdot \frac{W_t}{P_t}. \tag{12}$$

Equation (11) relates firms' marginal product of capital with their real rental rate of capital. Equation (12) implies that the firms' labour demand is negatively related to the real wage rate and their cost of borrowing funds.

1.4 Households

Households enter period *t* with cash holdings in the goods market of M_t^c and bank deposits of N_t, neither of which can be changed before the end of the period. After observing the initial money transfer in period *t*, but not the second transfer, households receive wage income by supplying labour to firms. Households make purchases of investment, i_t, and consumption, c_t, out of labour income and cash holdings according to the CIA constraint

$$P_t c_t + P_t i_t = M_t^c + W_t l_t. \tag{13}$$

By the end of period t, households, having all the available information regarding the policy shocks, divide their wealth to be carried forward to period $t+1$ between deposits at the financial intermediaries, N_{t+1}, and cash holdings, M_{t+1}^c. Households make this decision using full information for the period $t, \Omega_{2t} = \{\Omega_{2t-1}, x_{1t}, x_{2t}\}$. This process is summarized in the following budget constraint:

$$N_{t+1} + M_{t+1}^c = R_t^d \cdot N_t + r_t P_t \cdot k_t + \pi_t^b + \pi_t. \tag{14}$$

The right-hand side of (14) represents the households' sources of funds: deposits with interest, capital rental income, and dividend payments from banks and firms.

The law of motion for the capital stock is given by

$$k_{t+1} = (1-\delta)k_t + i_t. \tag{15}$$

Households solve a two-step optimization problem to maximize their lifetime expected utility. In the first subperiod, households choose consumption, labour supply, and investment to maximize

$$max_{\{c_t, l_t, k_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t \{U(c_t, 1-l_t)\}, \tag{16}$$

subject to constraints (13) through (15) based on the information set Ω_{1t}. This problem yields the following marginal conditions for l_t, and k_{t+1}, respectively:

$$U_{1t}(c_t, 1-l_t) \cdot \frac{W_t}{P_t} = U_{2t}(c_t, 1-l_t), \tag{17}$$

$$U_{1t}(c_t, 1-l_t) =$$

$$\beta E_t\{(1-\delta) \cdot U_{1t+1}(c_{t+1}, 1-l_{t+1}) + \lambda_{t+1} P_{t+1} r_{t+1} | \Omega_{1t}\}. \tag{18}$$

In the second subperiod, households choose period t+1 deposits and cash holdings to maximize

$$max_{\{M_{t+1}^c, N_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t \{U(c_t, 1-l_t)\}, \tag{19}$$

subject to constraints (13) through (15) based on the information set Ω_{2t}. The marginal conditions for N_{t+1} and M^c_{t+1}, respectively, are given by

$$\lambda_t = \beta E_t\left\{\lambda_{t+1} R^d_{t+1} \middle| \Omega_{2t}\right\}, \tag{20}$$

$$\lambda_t = \beta E_t\left[\frac{U_{1t+1}(c_{t+1}, 1-l_{t+1})}{P_{t+1}} \middle| \Omega_{2t}\right]. \tag{21}$$

The variable, λ_t, is the Lagrangean multiplier associated with the budget constraint (14) and represents the shadow value of adding another dollar to cash holdings in the goods market. Wage and capital rental rates clear the labour and capital markets. The following market-clearing conditions guarantee that commodity and loans markets reach equilibrium:

$$c_t = i_t = F(k_t, l_t), \tag{22}$$

$$N_t + X_{1t} - D_{1t} = W_t l_t. \tag{23}$$

1.5 Information structure and beliefs

As discussed above, changes in the money-growth rate can be separated into policy and non-policy components. Only the monetary authority knows why the money-growth rate has changed. Other agents must form beliefs regarding the proportions of policy and non-policy components in the money-growth rate. We assume that agents extract information from the observable data—the actual money-growth rate—based on a Kalman filter (see Sargent 1987, Hamilton 1994).

By scaling by the money supply at the beginning of the period, M_t, we can convert the monetary transfers into growth rates. Full information is available to private agents about the parameters and the AR and MA order of the policy and non-policy components of the money-growth rate. However, only the central bank has full information about the realizations of the shocks to these processes. Let the policy component of the growth rate in the first and second subperiods of period t be given by:

$$x^p_{1t} = (1-\rho)x + \rho x^p_{2t-1} + \varepsilon^p_{1t}, \tag{24}$$

$$x^p_{2t} = (1-\rho)x + \rho x^p_{1t-1} + \varepsilon^p_{2t}. \tag{25}$$

The *MA*(*N*) non-policy component of the growth rate is given by:

$$x_{1t}^{np} = \varepsilon_{1t}^{np} + b_1 \cdot \varepsilon_{2t-1}^{np} + \ldots + b_N \cdot \varepsilon_{jt-k}^{np} \tag{26}$$

$$x_{2t}^{np} = \varepsilon_{2t}^{np} + b_1 \cdot \varepsilon_{1t}^{np} + \ldots + b_N \cdot \varepsilon_{lt-m}^{np}, \tag{27}$$

where[6]

$$\sum_{i=1}^{N} b_i = -1 . \tag{28}$$

This last assumption implies that agents believe any non-policy action will be reversed completely in the subsequent periods. While the parameters of these driving processes are known by all agents, the shock values, ε_{1t}^{p}, ε_{2t}^{p}, ε_{1t}^{np}, and ε_{2t}^{np}, cannot be observed by private agents. In future work, we will examine the implications of uncertainty about the parameters as well.

Following Hamilton (1994), we define the state-space representation of the system as the following two equations:

$$\xi_{t+1} = F_{(N+2)\times(N+2)} \cdot \xi_t + v_{t+1} \tag{29}$$

$$x_{1t} = H' \cdot \xi_t, \tag{30}$$

where, in this case

$$\xi_t = [x_{1t}^{p}, \varepsilon_{1t}^{np}, \varepsilon_{2t-1}^{np}, \ldots, \varepsilon_{jt-k}^{np}]' \tag{31}$$

$$F = \begin{bmatrix} \rho & 0 & 0 & \ldots & 0 & 0 \\ 0 & 0 & 0 & \ldots & 0 & 0 \\ 0 & 1 & 0 & \ldots & 0 & 0 \\ 0 & 0 & 1 & \ldots & 0 & 0 \\ \ldots & \ldots & \ldots & \ldots & \ldots & 0 \\ 0 & 0 & 0 & \ldots & 1 & 0 \end{bmatrix} \tag{32}$$

$$v_{t+1} = [\varepsilon_{1t+1}^{p}, \varepsilon_{1t+1}^{np}, 0, \ldots, 0]' \tag{33}$$

$$H' = [1, 1, b_1, b_2, \ldots, b_N] . \tag{34}$$

A similar set of equations defines the representation for the money-growth rate in the second subperiod of period *t*, x_{1t}.

6. For $N \geq 2$, if N is even, then $j = 1 = 1$ and $k = m = N/2$. If N is odd, then $j = 1 = 2$, $k = (N+1)/2$ and $m = (N-1)/2$.

The projection of the unobservable vector, $\xi_{t+1|t}$, can be written in the following recursive form:

$$\hat{\xi}_{t+1|_t} = F \cdot \hat{\xi}_{t|_{t-1}} + K_t[x_{1t} - H' \cdot \hat{\xi}_{t|_{t-1}}], \tag{35}$$

where

$$K_t = F \cdot P_{t|_{t-1}} \cdot H(H'P_{t|_{t-1}}H)^{-1}, \tag{36}$$

and the mean-squared-error matrix is defined by:

$$P_{t+1|_t} = E[(\xi_{t+1} - \hat{\xi}_{t+1|_t})(\xi_{t+1} - \hat{\xi}_{t+1|_t})']. \tag{37}$$

2 Calibration

The competitive equilibrium consists of equations (5), (6), (8), (11) through (15), (17), (18), and (20) through (23). We solved for the stationary representation of the equilibrium by dividing all the nominal variables by the nominal balance, M_t, and then we calibrated the steady state of the stationary equilibrium to quarterly Canadian data from 1956 to 1998.

Since this paper is about the propagation of monetary shocks, we assumed that there is no technological innovation. The discount factor, β, is set to 0.993, so the annualized quarterly real interest rate is 2.8 per cent, which is approximately the average value observed in the data. Capital is assumed to depreciate at a quarterly rate of 2.5 per cent. Following the standard procedure, the capital share parameter is set to be 0.36. The utility function is assumed to have the following functional form:

$$U(c_t, 1 - l_t) = \frac{[(c_t)^{1-\gamma}(1 - l_t)^{\gamma}]^{\psi}}{\psi}. \tag{38}$$

The parameter γ is set to 0.81, so that the representative household spends roughly 0.17 of available time working (total hours worked in Canada divided by the population-hours available based on a 16-hour day). The risk-aversion parameter, ψ, is chosen to be –0.5, which is within the range of other related studies.

Since the average quarterly growth rate for M1 in Canada is 1.1 per cent, we assumed the steady-state money-growth rate in each subperiod to be 0.55 per cent. In the appendixes, we describe both the calibration of the money-growth process and the solution method. Also, we assume that the policy component of the money-growth rate has an AR(1) parameter of $\rho = 0.5$, and that the non-policy component follows an MA(1) process with coefficient $b_1 = -1.0$. Unless otherwise specified, the policy component accounts for 10 per cent of the variance of the total money-growth rate (i.e., $a = var(x_t^p)/var(x_t) = 0.1$). This implies that agents learn about a policy shock slowly.

A low weight on the policy component has several possible interpretations: the central bank has low credibility; policy shocks occur only infrequently; or policy shocks are generally small. The weight on the non-policy component also can be interpreted as the financial institutions' assessment of the probability of needing the current monetary transfer as a cushion against transitory shocks that could occur before the average bank loan matures or generates revenue. For instance, when financial institutions perceive a relatively high risk of financial shocks, they tend to hold larger stocks of financial assets to buffer against these disturbances; this would also lead to a lower value of a. In other words, financial shocks make it more difficult for financial institutions to understand the environment in which they are operating, including the stance and conduct of monetary policy.

We are not arguing that the current calibration of the policy versus non-policy components is realistic for all circumstances. There have been instances when the central bank has clearly signalled its intent. Conversely, there have also been situations when the central bank's intent has not been especially transparent. Our experiments are an attempt to analyze these latter circumstances.

3 The Findings

Our aim in this paper is to explore how financial intermediation helps to propagate an expansionary monetary policy shock when: (i) financial intermediaries are free to choose between loans to firms and investment in short-term liquid assets; and (ii) financial intermediaries and the rest of the public must gradually learn the true intent of monetary policy. The following experiments are designed to serve this purpose.

First, we demonstrate, in a complete-information framework, how our model behaves compared with a standard limited-participation model. Second, given that financial intermediaries can optimize funds between long-term lending and short-term investment, we examine how they propagate a monetary policy shock in cases with and without full information. Third, we show how adding a more realistic financial intermediation sector can improve the performance of the standard model with information frictions. Before presenting the model results, however, we provide some empirical evidence to further stress the importance of financial intermediation in the monetary policy transmission mechanism.

3.1 Canadian data

In Figure 1, we show the results for a monetary policy shock from a six-variable vector autoregression (VAR) with one-standard-deviation confidence bands using Canadian data from 1956 to 1998. A simple Choleski decomposition is used with a variable ordering of: M1, the overnight interest rate, output, the consumer price index (CPI), the ratio of chartered bank liquid assets to total assets, and the exchange rate. Some variation exists in the results for different samples and orderings, but the general flavour of the impulse responses is robust. An exogenous shock to money causes the interest rate to decline for about three quarters before the anticipated inflation effect takes over and the interest rate rises above its starting point. Output increases with a hump-shaped response, peaking about five quarters after the shock. The increase in inflation is more drawn out; the response peaks about 15 quarters after the shock.

Our main concern in this paper is the buildup of liquid assets by chartered banks immediately after an expansionary monetary policy shock. We believe there are two principal reasons for this result. First, an expected decline in interest rates as the shock unwinds itself creates an expectation of capital gains. Second, the nature of the monetary shock is not always apparent to private agents. Financial intermediaries may interpret the easing as a temporary change that the central bank will soon reverse. In response, banks hold more liquid assets as a buffer stock against growing uncertainty. The variation in liquid-asset holdings changes the composition of a financial intermediary's balance sheet, which, in turn, affects its long-term lending to non-financial firms and other profit-making activities. We argue that theoretical models that omit this (and other) aspects of the financial sector may be deficient, and that this omission can have an important impact on the simulated impulse responses.

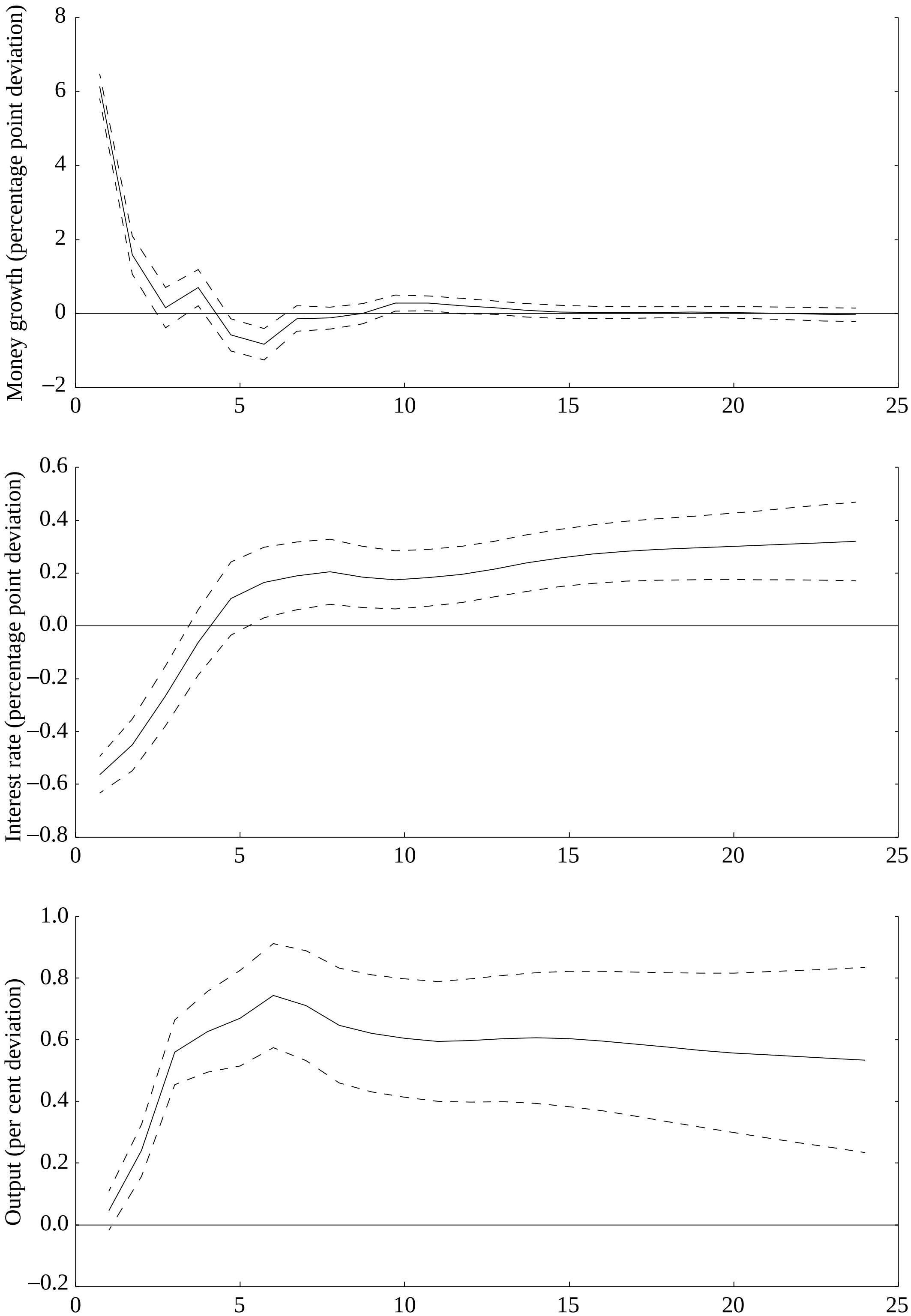
3.2 Some quantitative analysis

3.2.1 Liquid asset-holding decisions matter, even under full information

In the benchmark case, which is essentially a standard limited-participation model, we assume that banks can only take deposits from households and make loans to firms. As an alternative to this case, we examine how banks' lending behaviour changes when they are allowed to choose the optimal amount of liquid-asset holdings. In other words, we explore how introducing more realistic financial intermediaries changes the dynamics of some key macro variables following a monetary policy shock.

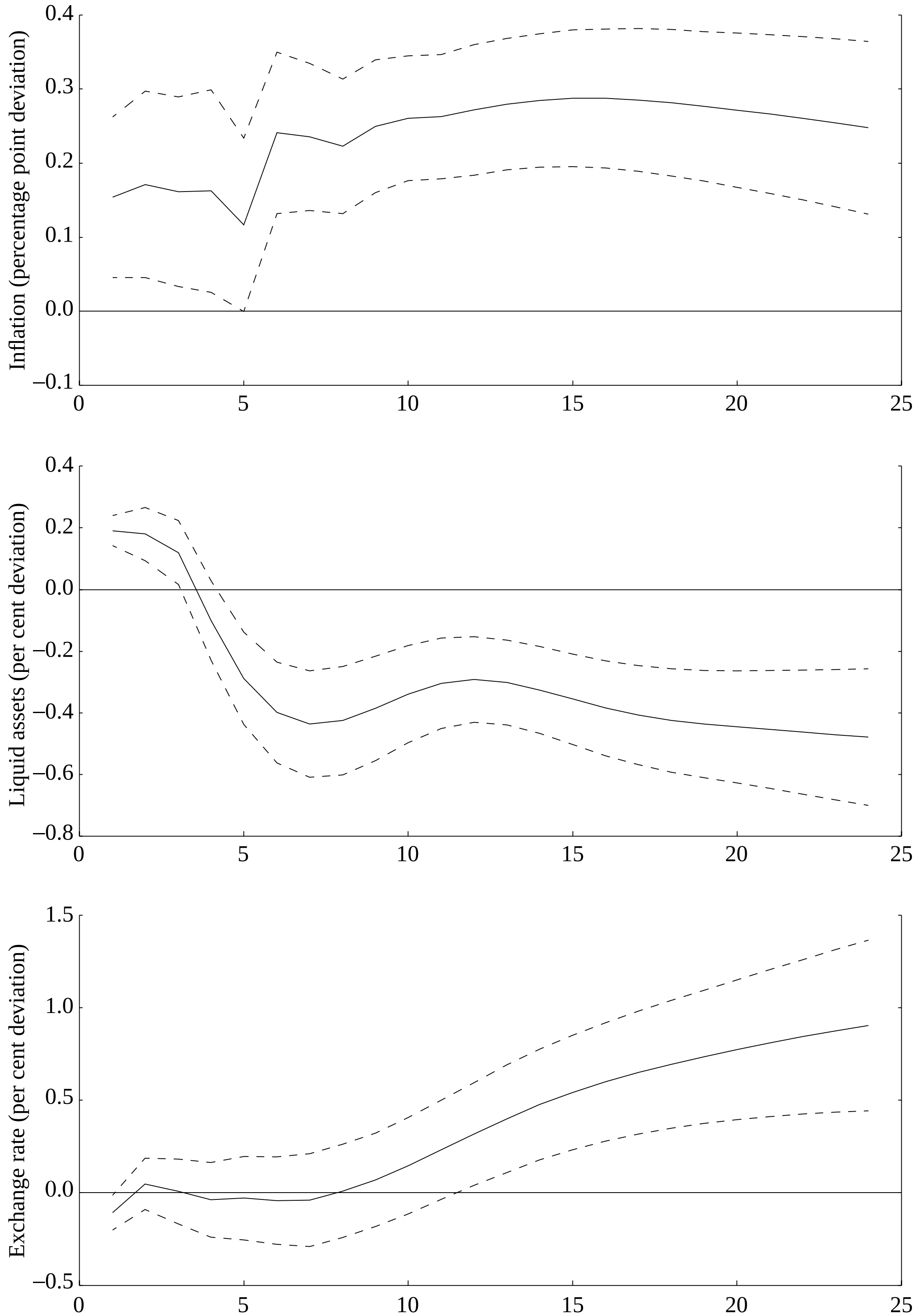
In Figure 2, we show the inflation, output, and interest rate responses following a policy shock to the money-growth rate when there is full

Figure 1
Impulse responses for empirical VAR on Canadian data, 1956 to 1998



(continued)

Figure 1 (continued)
Impulse responses for empirical VAR on Canadian data, 1956 to 1998



information about the nature of the policy shock. The responses tend to be large and short-lived when agents have full information, because only the initial shock is unexpected. Policy shocks are persistent, so the commercial banks correctly anticipate further monetary transfers in the second subperiod and, hence, run down their initial holdings of liquid assets when possible. This puts more money into the economy through increased lending to firms, thereby causing higher inflation and output responses. Because the lending market is flooded with funds, the interest rate liquidity effect is deeper when banks have the option to change liquid assets.

When there is a non-policy shock to the money-growth rate and agents have full information (see Figure 3), the banks can adjust their liquid-asset holdings to completely insulate the economy from the shock. The banks hold back all of the initial monetary injection, knowing that it will be removed by the central bank in the second subperiod. Liquid assets are built up, but lending to firms is unaffected. Inflation and output also remain unchanged at their steady-state values. If banks cannot adjust their liquid-asset position, then the new funds must be lent to firms, which causes the lending rate to fall and output to rise. The inflation rate spikes in the period of the shock, but immediately falls below steady state in the subsequent period as the initial injection is withdrawn from the economy.

3.3 Partial information

The impulse responses in Figure 4 show how beliefs matter to the propagation of monetary shocks when banks can optimize their mix of long-term lending and short-term investments.

In reality, private agents do not have perfect information regarding the central bank's policy changes or about the economic environment generally. For banks, correctly interpreting monetary policy actions is especially important for their decision-making process, because monetary transfers are made directly to them. In this model, agents' beliefs regarding policy can be derived with knowledge of three parameters: the ratio of the variance of x_t^p to the variance of x_t, $a = 0.1$, which controls the speed at which agents learn the true monetary shock; the autocorrelation coefficient of the policy component, $\rho = 0.5$; and the coefficient vector of the non-policy component, $b = -1$.

Figure 4 illustrates how banks misidentify a policy shock as a non-policy shock (the partial information case) and so they believe that, after the expansionary action in the first subperiod, the central bank will unwind the initial shock in the second subperiod. Thus, banks tend to invest more in liquid assets (borrow less from the central bank) and lend less to firms. This leads to a higher lending rate in the loan market, or a smaller liquidity effect,

Figure 2
Full information, policy shock

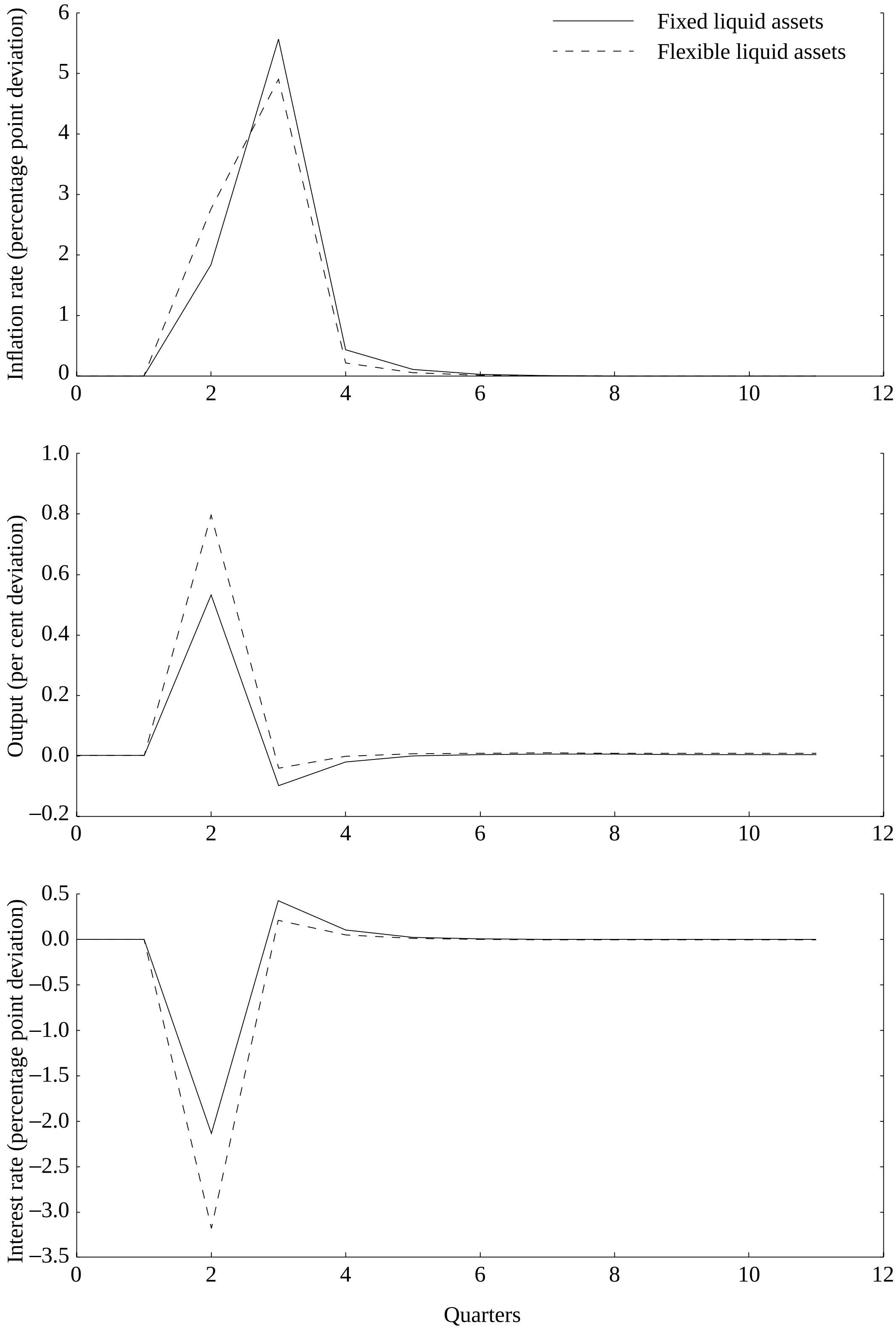


Figure 3
Full information, non-policy shock

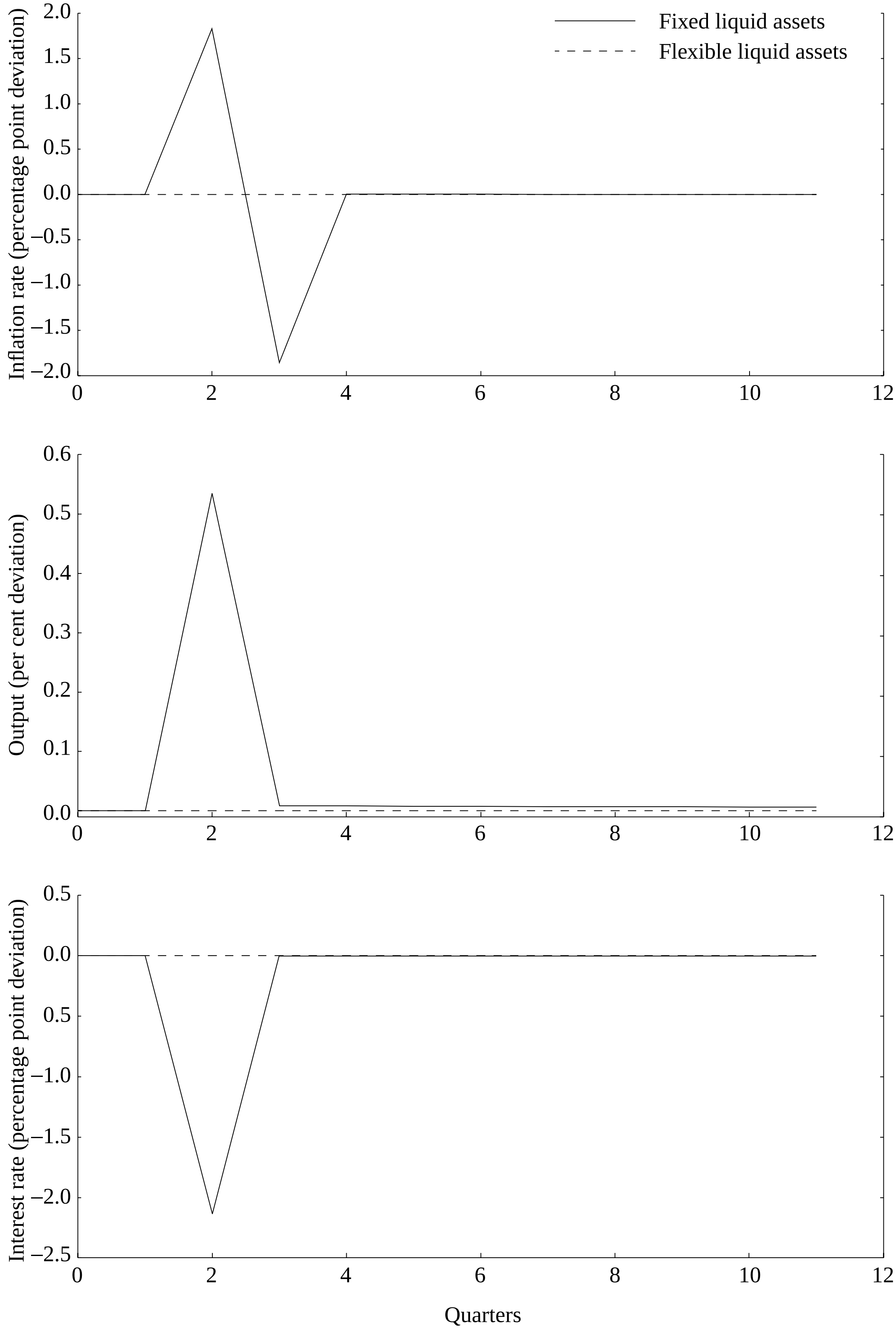
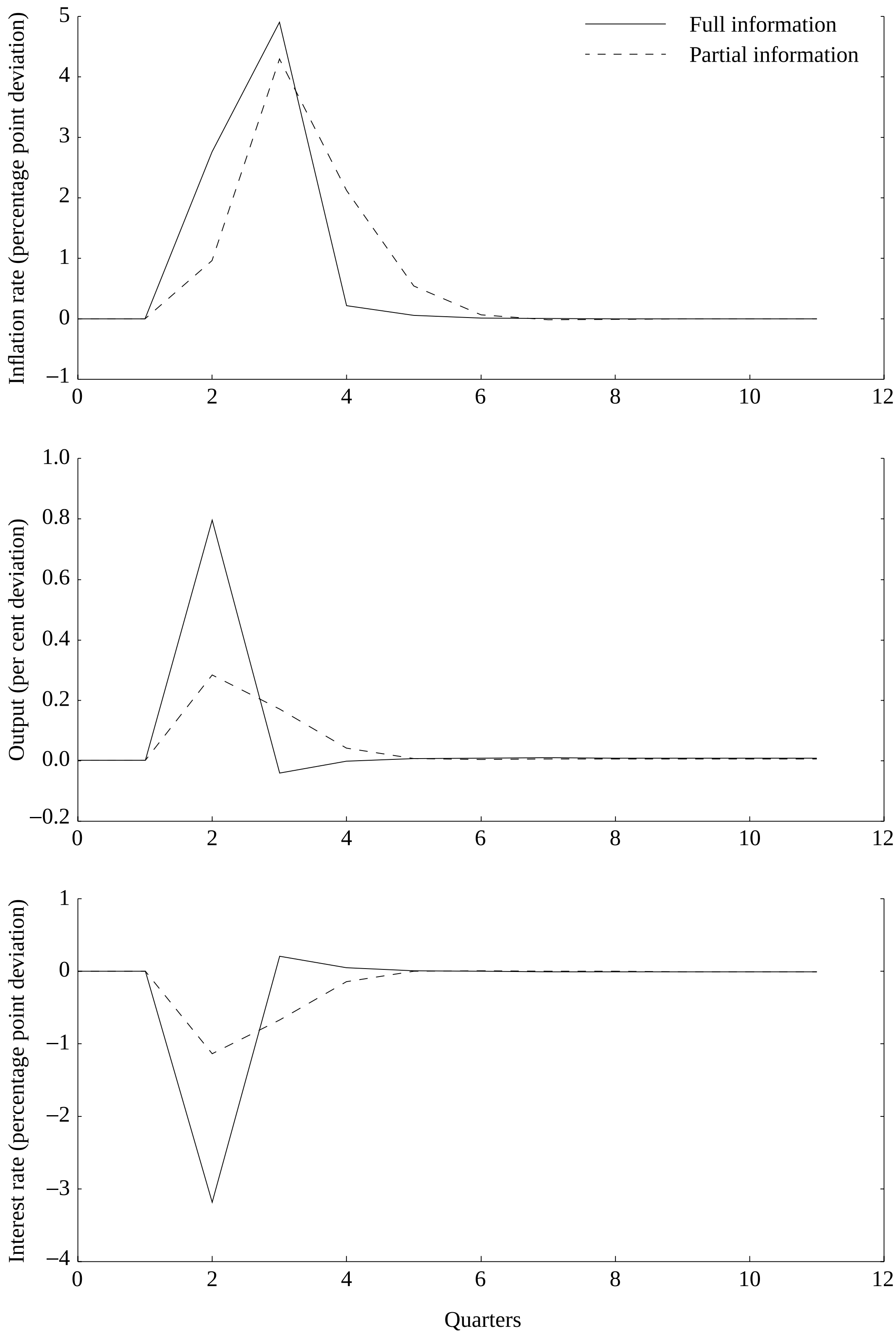


Figure 4
Flexible liquid-asset holdings, policy shock, partial versus full information



through a decline in the supply of loanable funds. The consequences are less investment, labour supply, and output. Households now receive less labour income and spend less on consumption. By investing more in liquid assets, banks hold money back from entering the goods market, creating less inflationary pressure.

The next policy shock experiment (Figure 5) compares the model with flexible liquid assets and partial information to the model with fixed liquid assets and partial information. Since banks expect the current shock to be reversed, they will tend to hold more funds as short-term investment in liquid assets, when possible, instead of lending to firms. Initially, there is less inflationary pressure in the economy as a significant portion of the liquidity injected into the economy by the central bank is "mistakenly" held back by the financial system and becomes non-productive for at least one period. The initial inflation response is reduced, but later adjustment is higher and somewhat more persistent. The effect on output and interest rates is more significant. That is, the output and interest rate responses are reduced notably, owing to the choices the banks made about their portfolio allocation.

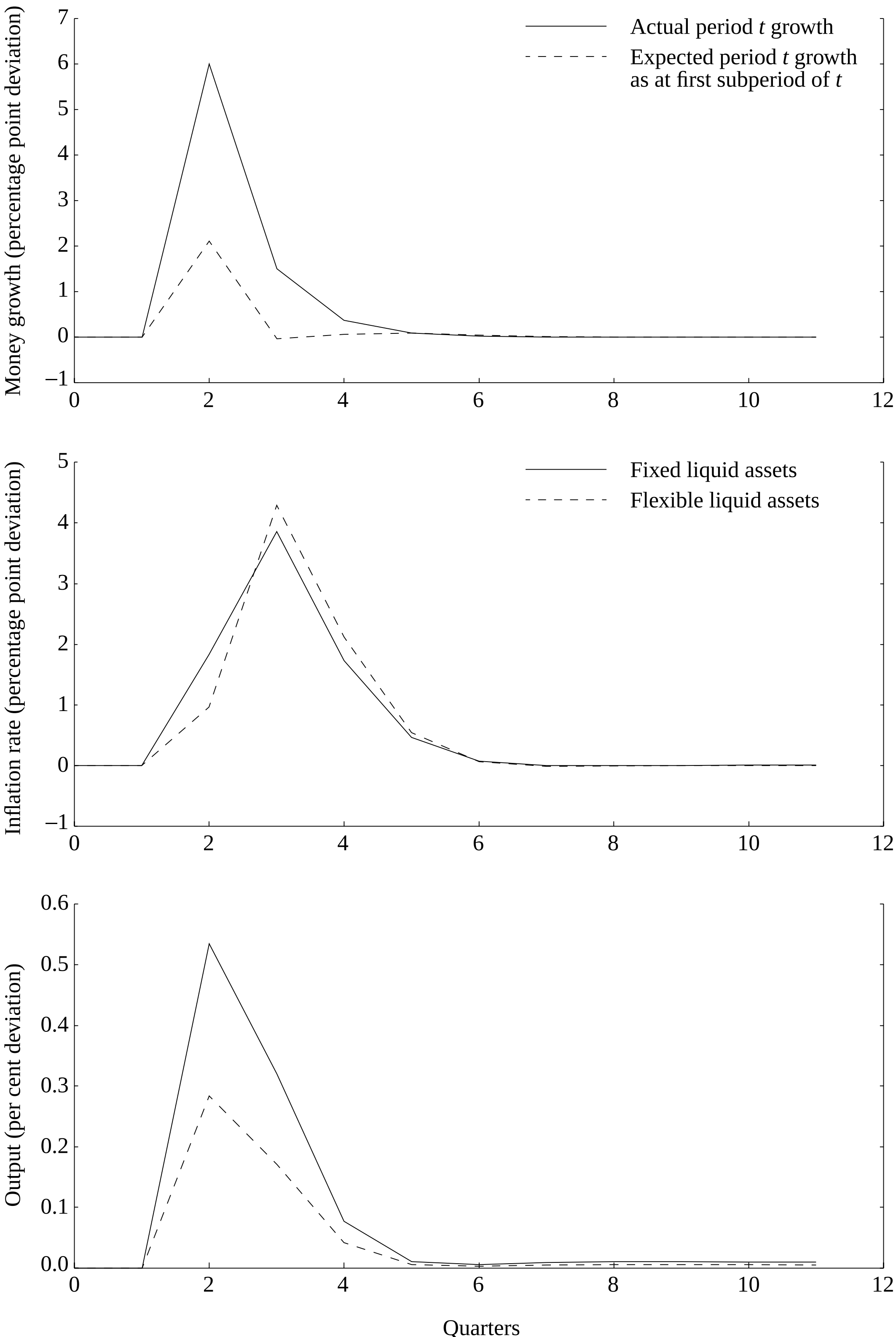
To highlight the points made in the previous impulse responses, in Figure 6 we present impulse responses for a more severe signal-extraction problem—when the weight on the policy component of the money-growth rate is only 0.01 instead of 0.1. The greater the information problem, the larger the impact of liquid-asset flexibility on the economy. The responses of inflation and output are smaller and more drawn out when the banks hold back more funds in the form of liquid assets.

Finally, in Figure 7 we show the impulse responses when there is a non-policy shock to the money-growth rate and partial information about the intent of the monetary policy shock. The responses are more volatile, because this shock is assumed to follow a negative MA(1). The ability of financial institutions to purchase liquid assets helps to insulate the economy from some of this volatility, although not as completely as in the full-information case shown in Figure 3.

4 Policy Implications and Conclusions

Financial intermediaries behave very differently depending on their information about the future of central bank policy actions. When there is an information friction, financial intermediaries' behaviour can reduce and prolong the effects of monetary policy actions. As well, when financial intermediaries increase their liquid-asset holdings, liquidity is diverted from the main lending channel, and less short-run inflationary pressure builds up

Figure 5
Partial information, policy shock



(continued)

Figure 5 (continued)
Partial information, policy shock

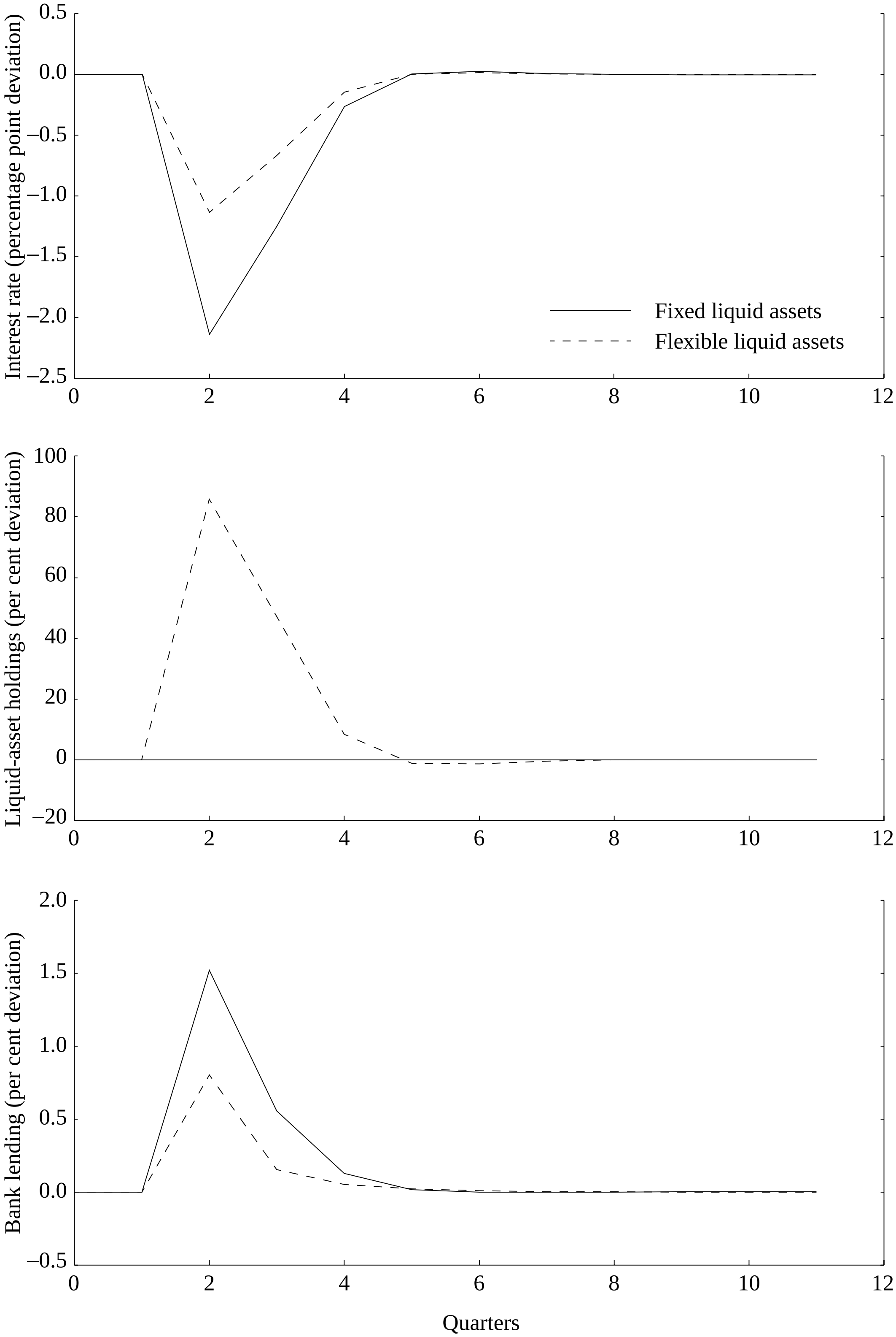


Figure 6
Flexible liquid assets, partial information, low weight on policy shock (*a* = 0.01)

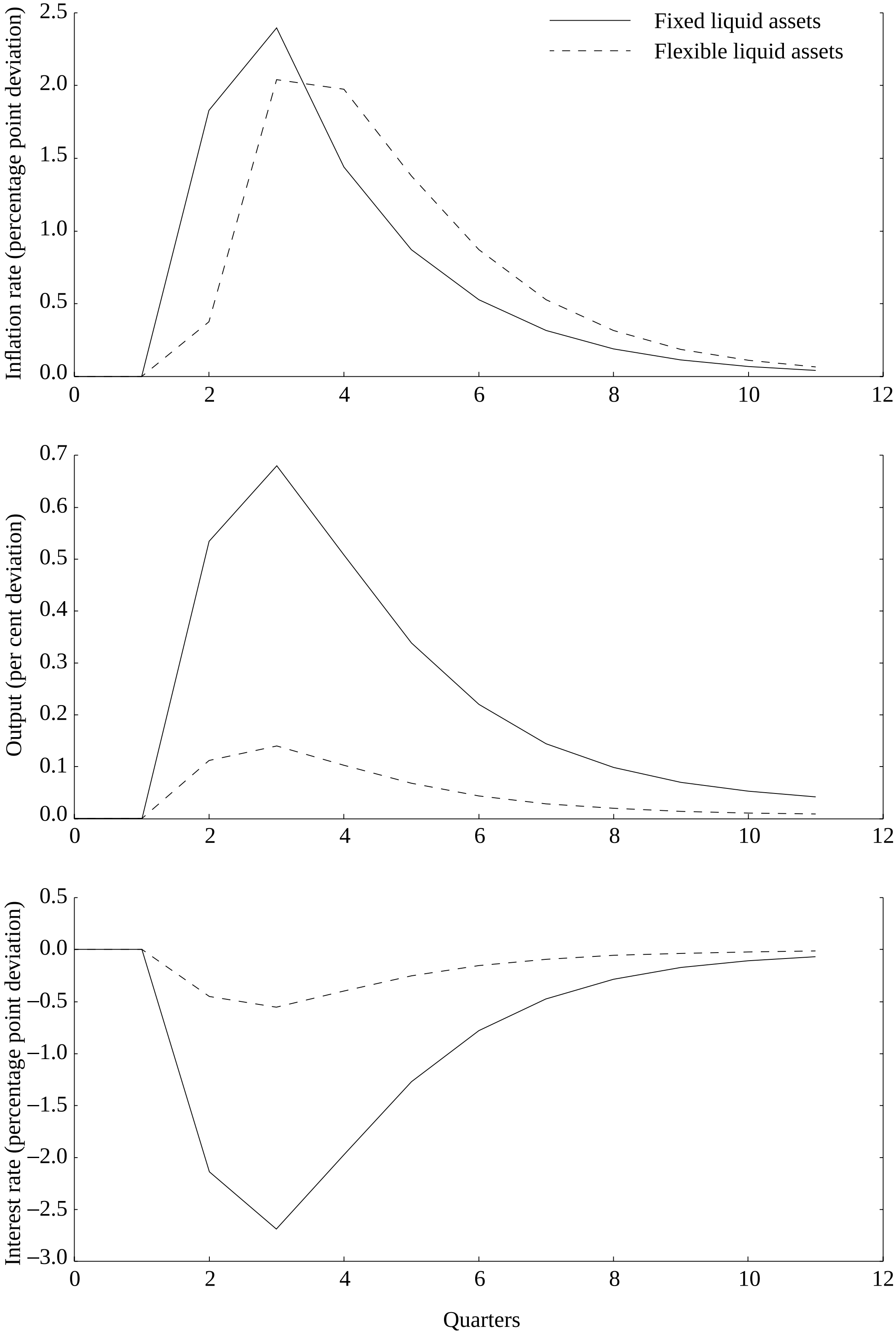
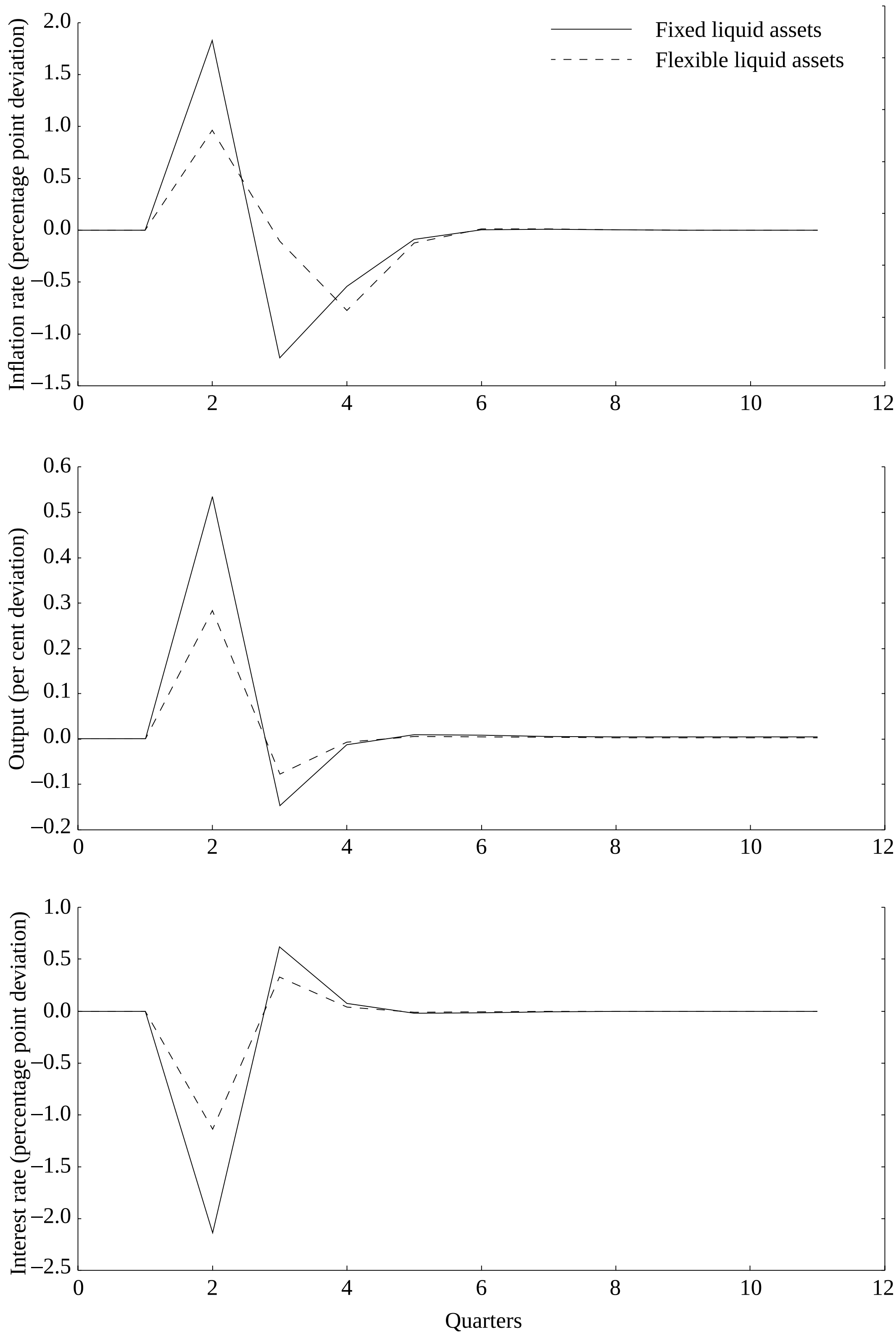


Figure 7
Partial information, non-policy shock



in the commodity market. The information friction is the main factor that determines the persistence of the liquidity effect in this type of models.

In sum, the effects of monetary policy actions in this class of models depend on the degree to which information frictions exist, and on banks' ability to adjust their lending behaviour in view of such frictions. More generally, these results suggest the importance of incorporating a meaningful financial sector in monetary general-equilibrium models; this would generate dynamic responses that correspond better to empirical results. Finally, we do not consider that our contribution completely explains the monetary transmission mechanism. Rather, we believe our model provides insights into episodes when there is much noise about the intent of monetary policy, and the role that financial intermediaries may play in these situations.

Appendix A1
Calibrating the Money-growth Process

The way we calibrate the money-growth process is very similar to that used in Andolfatto, Hendry, and Zhang (1999). As described in the main text, the money growth process includes two components—policy and non-policy—which agents do not observe individually.

$$x_t = x + x_t^p + x_t^{np} \tag{A1.1}$$

Specifically, the policy component follows an AR(1) process, and the non-policy component follows this MA(3) process:

$$x_t = \rho x_{t-1}^p + \varepsilon_t + \varepsilon_t^{np} + b_1\varepsilon_{t-1}^{np} + b_2\varepsilon_{t-2}^{np} + b_3\varepsilon_{t-3}^{np}. \tag{A1.2}$$

Assume that the policy and non-policy components are orthogonal,

$$cov(x_t, x_{t-1}) = E[x_t^p x_{t-1}^p] + E[x_t^{np} x_{t-1}^{np}]. \tag{A1.3}$$

Divide both sides of the above equation by the variance of the x_t. We get

$$corr(x_t, x_{t-1}) = corr(x_t^p, x_{t-1}^p) \cdot \frac{var(x_t^p)}{var(x_t)} + corr(x_t^{np}, x_{t-1}^{np}) \cdot \frac{var(x_t^{np})}{var(x_t)}. \tag{A1.4}$$

Define

$$a \equiv \frac{var(x_t^p)}{var(x_t)} \tag{A1.5}$$

and

$$\eta \equiv corr(x_t^{np}, x_{t-1}^{np}). \tag{A1.6}$$

Given that the correlation coefficient of x_t is 0.53 in Canada,

$$\eta = \frac{0.53 - a \cdot \rho}{1 - a}. \tag{A1.7}$$

From

$$var(x_t^p) = \frac{\sigma_\varepsilon^2}{1 - \rho^2} \tag{A1.8}$$

and

$$var(x_t^p) = a \cdot var(x_t) = (0.013)^2 \cdot a, \quad \text{(A1.9)}$$

the policy shock is determined by

$$\sigma_\varepsilon^2 = (0.013)^2 \cdot a \cdot (1 - \rho^2). \quad \text{(A1.10)}$$

The non-policy component follows an MA(3), so:

$$\begin{aligned} var(x_t^{np}) &= \sigma^2 + b_1^2 \cdot \sigma^2 + b_2^2 \cdot \sigma^2 + b_3^2 \cdot \sigma^2 \\ &= (1 - a) \cdot var(x_t). \end{aligned} \quad \text{(A1.11)}$$

This allows us to pin down the value of the variants of non-policy shocks to

$$\sigma^2 = \frac{(0.013)^2 \cdot (1 - a)}{1 + b_1^2 + b_2^2 + b_3^2}. \quad \text{(A1.12)}$$

Appendix A2
Solution Method

The model is solved using two different methods, each providing a check on the other. The first method preserves the non-linearities present in the equations of the model, whereas the second forms a linear approximation to those equations. The differences between the impulse responses obtained using these two methods are negligible. Below, we briefly describe both solution methods. Details can be obtained from the authors.

Non-linear method

The first method is the simplest in design. Let the system be defined by n equations representing the first-order conditions and the equilibrium relations of the system. These n equations must each be satisfied for every period $t = 1, \ldots, T$. Imagine we are in a perfect-foresight framework, where a sequence of shocks from $t = 1, \ldots, T$ is perfectly anticipated. The starting values of the state variables give the system its initial conditions. Requiring the system to be back at steady state after T periods delivers terminal conditions. We are thus left with a system of nT equations in nT unknowns (the values of the n variables in each of the T periods). Provided n and T are not too big, an equation solver can easily find the solution to such a perfect-foresight problem.

The model presented in this paper is stochastic. However, we can use a combination of several perfect-foresight problems to arrive at a solution. To do so, define, in the first round, the perfect-foresight sequence of shocks as follows: the actual shock for the first period, and the expected shocks generated by the updated beliefs of agents for the $T-1$ remaining periods. Solve the T-periods system with these shocks. This delivers a solution that contains the actual values of the endogenous variables for the first period and these variables' expected paths from period 2 on. Keep the first period's solution. The second round picks up the end-of-period-1 values as the initial conditions, defines a new sequence of shocks (with the actual period-2 shocks and the expected shocks for period 3 on), and solves the $T-1$ system. The solution gives the actual value of the variables at time 2 and the variables' expected paths from period 3 on. Continuing this process until T rounds have been finished completely solves the stochastic problem.

Linear method

The second solution method forms a linear approximation to the system. The algorithm used is an extension to those presented in King and Watson

(1995). The extension is necessary to account for the agents' imperfect information and the process by which their beliefs evolve. In King and Watson, the solution takes the following form:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \Pi \cdot \begin{bmatrix} k_t \\ \delta_{t-1} \end{bmatrix} + \eta_1 \cdot \varepsilon_t \qquad \text{(A2.1)}$$

and

$$\begin{bmatrix} k_{t+1} \\ \delta_{t+1} \end{bmatrix} = M \cdot \begin{bmatrix} k_t \\ \delta_t \end{bmatrix} + \eta_2 \cdot \varepsilon_t, \qquad \text{(A2.2)}$$

where the vector y_t represents the endogenous variables of the system and k_t the predetermined state variables. Exogenous shocks are arranged according to a state-space representation. As in Hamilton (1994), the observed variables from that state-space system are x_t, the state variables are δ_t, and the innovations to these state variables are ε_t.

King and Watson's algorithm assumes that agents can perfectly observe the state vector δ_t. By contrast, in the model presented in this paper, agents do not observe perfectly δ_t, but instead form expectations of these variables, according to both the information received previously and their initial beliefs. The Kalman filtering described in the main text governs the way these beliefs are updated. In every period, the value of all endogenous variables now depends both on the current beliefs and the current shocks, and the weight is placed on the beliefs depending on the severity of the information problem. Denoting $\hat{\delta}_t = E[\delta_t | \Omega_{1t}]$ with Ω_{1t} representing the information set available to agents at the very beginning of period t, the system now evolves according to this process:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \Pi^* \cdot \begin{bmatrix} k_t \\ \hat{\delta}_t \\ \delta_{t-1} \end{bmatrix} + \eta^*_1 \cdot \varepsilon_t \qquad \text{(A2.3)}$$

and

$$\begin{bmatrix} k_{t+1} \\ \hat{\delta}_{t+1} \\ \delta_t \end{bmatrix} = M^* \cdot \begin{bmatrix} k_t \\ \hat{\delta}_t \\ \delta_{t-1} \end{bmatrix} + \eta^*_2 \cdot \varepsilon_t. \qquad \text{(A2.4)}$$

Details on the exact form of these matrices and the way to compute them are available on request from the authors.

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Discussion

Paul Gomme

Amano, Hendry, and Zhang contribute to a general research agenda that aims to understand how the monetary transmission mechanism works within monetary dynamic general-equilibrium models to gain greater confidence in policy advice based on this class of models. What evidence do they wish to explain? Using their estimated VAR, they show that following a positive innovation to money growth, there is:

- a buildup of liquid assets at chartered banks
- a decline in the nominal interest rate lasting three quarters
- a hump-shaped response in output peaking five quarters after the shock
- a peak response in inflation at 15 quarters

While Amano, Hendry, and Zhang estimate their VAR using Canadian data, U.S. data would reveal a similar pattern (although some measure of reserves typically takes the place of liquid assets in the U.S. VARs).

The authors used the limited-participation model of Lucas (1990) and Fuerst (1992). Most work in this area has focused on the interest rate and output responses to a monetary shock. Models of this class typically have difficulty generating much persistence in the interest rate and output responses. The key innovation in Amano, Hendry, and Zhang's work is to introduce liquid assets into an otherwise standard limited-participation model. The authors model the demand for liquid assets as arising from different stochastic processes governing the policy and non-policy components of money growth, and the possible confusion by banks concerning the source of the money shock. By delving further into how exactly changes on the central bank's balance sheet are transmitted to the real economy via the banking system, the authors clearly hope to address some of the deficiencies of the limited-participation model. This is, indeed, a tall order!

Banks wish to end each period with zero liquid assets. Should a bank end a period with negative liquid assets, it must borrow from the central bank at a penalty rate that is above the rate that the bank pays on its deposits. On the other hand, should a bank have a positive liquid-asset position at the end of a period, the return offered by the central bank is below that earned on its loans to firms.

However, within a period, a bank may wish to have a liquid-asset position different from zero. To start, consider the full-information case. A positive innovation to money growth in the first subperiod will lead to a positive innovation to money growth in the second subperiod owing to the positive autocorrelation in the policy component. Since banks want to end the period (that is, the second subperiod) with zero liquid assets, they will commit (in the first subperiod) to a level of loans that exhausts deposits plus the innovations to money growth in the two subperiods. That is, banks will have a *negative* liquid-asset position at the end of the first subperiod.

Now, suppose that the source of the money growth innovation in the first subperiod is the non-policy component. Then banks know that this innovation will be completely reversed in the second subperiod, since the non-policy component follows a negative first order moving average process (with a coefficient on past innovations of –1). In this case, banks will run up their liquid asset position in the first subperiod and will not change the level of loans in response to this shock. The second subperiod money shock then "drains" the banks' liquid assets from the system.

Next, consider the imperfect information case. Banks must now infer the source of a money shock in the first subperiod based on observed money growth (and knowledge of the underlying stochastic processes governing the behaviour of the policy and nonpolicy components). In general, banks will place some weight on both the policy and non-policy components. Since the authors assume that the predominant source of variability in money growth is the non-policy component, one would anticipate that banks would place a much higher weight on the likelihood that the source of a money shock is the non-policy component. In the face of a money growth innovation in the first subperiod banks will loan out a small part (since they place some weight on the policy component) and will run up their liquid-asset position (since they place a large weight on the non-policy component). Should the true source of the money shock be the policy component, banks will end the period with a positive liquid-asset position (they did not lend out "enough"). However, if the source of the shock is the non-policy component, banks will end with a negative liquid asset position (they lent out a small part of the first subperiod injection).

The first and second subperiod notation is somewhat clumsy. Consider an alternative specification of money growth. As in Amano, Hendry, and Zhang, let money growth be divided into a policy and non-policy component:

$$x_t = x_t^p + x_t^{np} + \bar{x}, \tag{1}$$

where $\bar{x}$ is the long run average money-growth rate. Further suppose that the policy component is positively autocorrelated:

$$x_t^p = \rho x_t^p + \varepsilon_{1t}, \quad 0 < \rho < 1. \tag{2}$$

Next, let the non-policy component be "noise":

$$x_t^{np} = \varepsilon_{2t}. \tag{3}$$

Finally, suppose that at the start of the period, a signal of money growth, π_t, is revealed:

$$\pi_t = x_t + \varepsilon_{3t}. \tag{4}$$

Assume that $\varepsilon_t \equiv [\varepsilon_{1t} \quad \varepsilon_{2t} \quad \varepsilon_{3t}]' \sim N(0, \Sigma)$ where Σ is diagonal (which implies that the shocks are independent). Banks must commit to the level of loans based on the signal π_t.

This information structure is identical to that of Kydland and Prescott (1982). Consequently, their formulas describing the signal extraction process can be applied directly.

An advantage of the proposed information structure is that there is *no need* to take a stance on the (relative) lengths of the two subperiods in Amano, Hendry, and Zhang. This issue is problematic in their paper since, at one point, they assume that the first subperiod is "short enough so that no return is earned." Yet in their calibration section, the authors assume that the two subperiods are of equal length. In the formulation above, all that is needed is an assumption that banks commit to loans based on the signal π_t (whenever that signal may be received).

A further advantage of the proposed information structure is that one can separate out the noisy signal (π_t) from the confusion over the policy and non-policy components of money growth by playing around with the variances of the ε shocks.

Calibration: Money Growth

For the most part, the authors' calibration is similar to that in the existing dynamic general-equilibrium literature. An exception is the set of parameters governing the money-growth process, summarized in Table 1.

The first two parameters are chosen to match Canadian M1 growth (its average growth and volatility). Appendix A1 suggests that Amano, Hendry, and Zhang also use the first-order autocorrelation of Canadian M1 growth to identify one of the parameters in Table 1. However, unlike Andolfatto and Gomme (1999), it seems unlikely that the authors will be able to use univariate time series techniques to pin down all of their free parameters. The key parameter is how much the policy component contributes to overall variability in money growth. While the authors perform some sensitivity analysis over this parameter, it is difficult to gauge the reasonableness of the values they consider.

Impulse Responses

Given that the innovation in Amano, Hendry, and Zhang is the introduction of liquid assets to a limited-participation model, it is disappointing that they present only one figure showing the model's prediction for this series.

The paper is also largely silent on the size of the shocks used in the impulse responses. In the calibration, the policy component contributes only 10 per cent to the overall volatility of money growth. Yet, the responses to the policy shock are of the same order of magnitude as those to non-policy shock. One might have expected the policy shock to generate responses an order of magnitude smaller than the non-policy shock. During the conference, it became clear that the authors used shocks of the same size for the policy and non-policy experiments. An interpretation that could potentially reconcile this apparent conflict is that the policy shocks simply occur less frequently. However, such an interpretation is *inconsistent* with the description of the money-growth process in the rest of the paper. There is a difference between small, frequent shocks on the one hand and large, infrequent shocks on the other.

Table 1
Period length: Six weeks

Average money growth	0.55%
Money variability, SD(x)	0.0013
Relative variability, SD(x^p)/SD(x)	10%
Autoregression (AR) coefficient on x^p	0.5
Moving average (MA) order for x^{np}	1

Summing Up

The authors set a difficult task for themselves: Construct a monetary dynamic general-equilibrium model that can explain the behaviour of chartered bank liquid assets, the nominal interest rate, output, and inflation. Accounting for the behaviour of the interest rate and output—particularly the persistence following a monetary disturbance—has generally proved difficult; see, for example, Christiano (1991). Adding liquid assets to the mix raises the bar considerably.

As a first pass at this problem, the authors do a good job. There is, of course, room for improvement. For example, their model would seem to predict that chartered banks should hold, on average, zero liquid assets. Yet, in footnote 1 they report that "liquid assets comprise, on average, a significant 12 per cent of Canadian dollar assets." (See page 283.) Presumably, banks hold liquid assets as more than a simple buffer against the policy and non-policy shocks considered by Amano, Hendry, and Zhang. It would also be desirable to bring more evidence to bear on the authors' choice of the parameters governing the policy and non-policy components of money growth. No doubt, future work, including Andolfatto et al. (1999), will address these and other issues.

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Discussion

Sylvain Leduc

Amano, Hendry, and Zhang study an important and interesting question: How does financial intermediation affect the monetary transmission mechanism? They extend the standard liquidity model by:

- modelling more specifically the investment decisions by banks, allowing them to allocate funds between longer-term loans and shorter-term liquid assets; and
- assuming that private banks have imperfect information.

The idea behind their study comes, in part, from empirical evidence from VARs that shows that the ratio of banks' liquid assets to total assets rises following a monetary expansion. (Bernanke and Blinder [1992] found similar results for the United States.) The paper's underlying theme is that the nature of monetary shocks is not always transparent: Banks may have difficulty distinguishing whether or not the movements in monetary aggregates will be long-lasting. Therefore, if they consider the possibility that movements in monetary aggregates will be reversed soon after they have been observed, they will hold more liquid assets to use as a buffer against this uncertainty.

The authors find that these two factors, in an otherwise standard liquidity model, can significantly alter the economy's response to changes in monetary policy. In particular, they dampen and prolong the effects of monetary shocks. Of course, the quantitative importance of their results will depend, to a large extent, on how quickly private banks learn about the cause of movements in monetary aggregates. However, Amano, Hendry, and Zhang do not calibrate the parameter dictating the speed of learning and arbitrarily set it so that banks learn slowly. I will suggest a way of calibrating the belief process, and I will argue that, based on this calibration, it appears likely that the effects of financial intermediation on the monetary transmission mechanism, in their model, will be quantitatively small. As a result, it seems unlikely that their framework will provide a satisfactory explanation for the empirical evidence from their VARs.

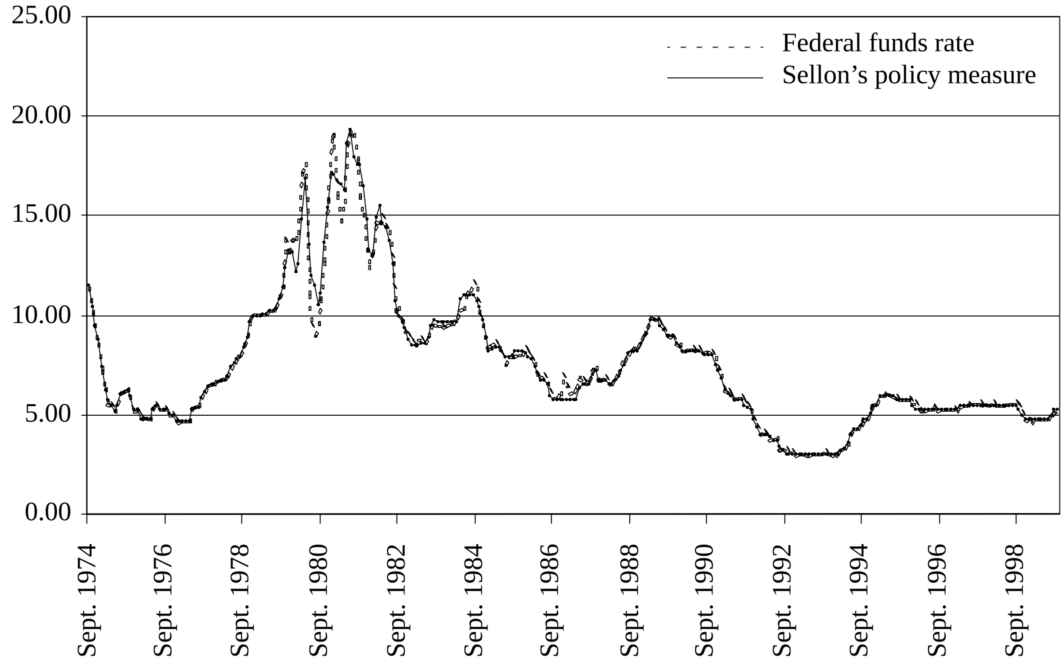
However, first let me briefly review part of the structure behind the paper. The authors assume that the stock of money in the economy, X, can result from two different components: a policy component, X^p, and a non-policy component, X^{np}. X^p is assumed to follow an AR(1) process with a persistence parameter equal to 0.5. On the other hand, X^{np} is assumed to follow a negative moving average process, so any change in that component will be reversed in the subsequent few periods. Again, it is assumed that only the central bank knows why the stock of money changed in the economy. Banks, however, must form beliefs about the part of a given change in X that comes from a change in X^p or X^{np}. Here, banks will extract information about X^p and X^{np}, based on a Kalman filter.

What will be critical for the quantitative results (although it does not change the qualitative aspect of the paper) is the calibration of the learning process. It turns out that the ratio of the policy component's variance to the variance of the money stock will dictate the learning speed. The authors set this ratio to 0.1, implying that agents learn slowly about policy shocks. They are very clear about this parameterization, and are not trying to argue that it is particularly realistic. However, I wondered about how often we actually see reversals in monetary aggregates and how important the policy component is relative to the monetary aggregate. One way of calibrating the learning speed would be by first assuming that the central bank uses an interest rate rule. Although this is not necessary, it will make my discussion easier. A lot of research has been done trying to decompose the part of the effective federal funds rate that is due to policy changes. Here, the approach adopted by Sellon (1994) could be helpful, and I will use his research, since he reconstructed a policy component for the federal funds rate from 1974 onward.[1]

Sellon develops a measure of policy changes for each operating regime in the 1974–93 period and then links them in a single, comprehensive measure of policy actions. From the mid-1970s to October 1979, the Fed targeted the federal funds rate and used open market operations to keep the funds rate within the targeted range. But, since policy changes were not publicly announced during this period, Sellon relies on weekly reports on open market operations by the trading desk of the New

1. Note that the authors calibrated their model to the Canadian economy. Using the policy measure for the United States can, nevertheless, provide some indications on the likely speed of learning in Canada.

Figure 1
Federal funds rate and Sellon's policy measure



York Fed to construct a measure of policy changes. Starting in October 1979, the Fed shifted to a nonborrowed reserves target. Again, Sellon uses information from the weekly reports on open market operations by the trading desk for information on changes in the nonborrowed reserve path. According to him, these reports separate policy from non-policy changes and provide the size of each change. From October 1982 to 1989, the Fed started watching borrowed reserves. Sellon uses borrowing targets to construct a measure of policy actions in that period. Finally, beginning in December 1989, the series is constructed using the federal funds rate series.[2] The final policy measure is constructed by translating policy changes in the nonborrowed reserve path and borrowing targets into an equivalent change in a federal funds rate target.

Figure 1 shows both the effective federal funds rate and the measure of policy changes. Obviously, both series are nearly identical. Therefore, if we were to conduct the authors' exercise in terms of the federal funds rate, we would say that banks observe the effective rate, but not policy changes. However, since the variances of both series are close to 1, this would suggest that banks would learn very quickly: The parameter *a* would be close to 1,

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2. In 1994, the Fed started announcing policy changes at the end of FOMC meetings and, in 1997, it began to publicly announce its explicit federal funds rate target.

rather than 0.1. Consequently, using Sellon's policy measure, the authors could calibrate their learning process more realistically and present a more convincing quantitative analysis of the effect of financial intermediation on the monetary transmission mechanism.

Therefore, it is likely that U.S. banks learned fairly quickly about monetary policy changes from 1974 to 1999. As a result, the dampening and the prolonging impact of the imperfect information of banks and their investment behaviour are likely to be quantitatively small. With faster learning, financial intermediaries in the model will not accumulate a lot of liquid assets in response to an expansionary monetary shock. Therefore, I have some doubts that the channel emphasized by the authors can account for the empirical evidence from their VARs that shows an increase in banks' holdings of liquid assets following a positive monetary shock. Therefore, in an otherwise standard liquidity model, the effects on the monetary transmission mechanism of assuming that banks have imperfect information about the persistence in the movements in monetary aggregates is likely to be quantitatively small. However, this being said, I still view the qualitative channel investigated by Amano, Hendry, and Zhang as significant, especially when central banks lack clarity on their designated objectives.

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General Discussion

In response to the discussants' comments about the slow calibration of the money-growth process, Scott Hendry noted that they tried to estimate policy responses for Canada, but that the standard errors were quite large. He pointed out that the model misses many types of uncertainty about monetary policy, which could make the slow bank-learning process in the model seem less extreme. He argued that the policy response in the model should be interpreted as episodic, since policy shocks can be unclear in certain circumstances. Zhang added that, in fact, financial markets misinterpreted three out of four of the Fed's last policy moves. The transparency of monetary policy is still an important issue to policy-makers and financial intermediaries.

A few participants commented on several shortcomings of the model's institutional structure. David Laidler, of the University of Western Ontario, noted that money is used as a policy instrument in the model, but in reality it is a liability of financial institutions. Thomas Rymes, of Carleton University, pointed out that under the current procedure of setting operating bands for the overnight rate, changes in the bands do not initiate an adjustment of liquid assets, because borrowing or lending by the banks is not affected. Chuck Freedman, of the Bank of Canada, also commented that the institutional structure in the paper is more relevant to that of the 1950s. He said that monetary policy actions taken now are not liquidity injections, but changes in the overnight rate that the banking sector then responds to by adjusting liquid assets.

Hendry agreed that money creation was needed in the model and that the institutional structure in the model was not in line with the current

* Prepared by Ron Lange.

framework. He noted that in the current environment, the central bank operates in the short-term market, while the public operates in the longer end of the market. He emphasized, however, that the purpose of the current specification is only to capture the importance of portfolio choice by financial institutions.

Lawrence Christiano, of Northwestern University and the Federal Reserve Bank of Chicago, noted that there is a signal-extraction problem with endogenous money, because the monetary policy process is exogenous. He felt that the policy responses from the model should be compared with some measure of exogenous money and not compared with the VAR impulse responses, since these responses also include the reaction of money to other factors. Zhang agreed that it was not appropriate to directly compare the VAR and model responses. The empirical VAR results serve as only a qualitative guideline in the paper.