Financial Shocks and Optimal Policy *

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Abstract

In this paper, we study the positive and normative implications of financial shocks in a standard New Keynesian model that includes banks and *frictions* in the market for bank capital. We show how such frictions influence materially the effects of liquidity shocks and the properties of optimal policy. In particular, they limit the scope for countercyclical monetary policy in the face of bank liquidity shocks and induce large adjustments in the money supply (a property reminiscent of Poole's analysis). They also call for a fiscal policy that complements monetary policy by offsetting the balance-sheet effects of liquidity shocks.

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1 Introduction

The 2007-2009 financial crisis was the impetus for major changes in the practice of central banking, and in our models of monetary policy.[1] The new models, understandably, focused mostly on analyzing the origins of this particular crisis or the policy responses that had already taken shape. Now, with the crisis hopefully behind us, it seems natural to ask how it has changed our understanding of stabilization policy and the role of banks in the transmission mechanism, during normal times. How should monetary policy react to an increase in the default rate on bank loans? How are liquidity problems affecting the funding side of banks (say, in the interbank market) transmitted to the lending side, and what is the appropriate policy response? Is there an appropriate role for fiscal or quasi-fiscal policy tools (like a capital infusion into the banking sector) during normal times?

The answers to these questions depend on what we assume about the presence and nature of frictions that banks face in debt and equity markets. The goal of this paper is to make the role of such frictions transparent using a simple New Keynesian model with banks, and to highlight issues that we think remain to be addressed before we can move towards quantitative models of monetary policy with a banking sector.

It seems intuitive (and our model will illustrate) that a fiscal instrument, allowing a cash infusion into banks, can be a valuable policy tool if a friction in equity markets prevents banks from recapitalizing themselves. Absent such a friction, the funding and lending sides of banks are decoupled (in a theoretical model where the Modigliani-Miller theorem applies), and a "liquidity crunch" is harder to model. In this case, a simple model with no externalities and information asymmetries would tell us that stock holders will fund any lending projects that are worthwhile. And, the case for policy intervention seems harder to make; in particular, a fiscal transfer to banks may simply induce them to pay more dividends, without altering their lending or other activities.[2] Similarly, giving banks access to any frictionless source of funding (say, commercial paper) would suffice to decouple their funding and lending sides in a simple theoretical model.

The 2007-2009 crisis essentially shut down the funding side of banks in the interbank, securitization, and commercial-paper markets simultaneously. The sheer magnitude and breadth of the crisis apparently convinced policymakers that banks were not in a position to recapitalize themselves in equity markets.[3] Gertler and Kiyotaki (2010) model the effects of shutting down the interbank market in

[1] Since the standard New Keynesian (NK) model [e.g., Woodford (2003)] abstracted from money and banking, a rapidly growing literature introduced banks into models of monetary policy to address topical issues. Contributions include Gertler and Karadi (2011), Gertler and Kiyotaki (2010), Hobijn and Ravenna (2010), Meh and Moran (2010), among others.

[2] This was indeed the presumption of some economists [e.g., Mulligan (2008)] who argued against the US bank-bailout plan informally, asserting that it was simply a transfer from taxpayers to the owners of banks.

[3] Our impression, based on conversations with central bankers in the United States and Europe, is that banks argued against issuing new equity on the grounds that the equity premium was unreasonably large at the time, and recapitalization via the stock market would not be in the interest of current shareholders.

a model with no market for bank equity. In their model– and in the models of Gertler and Karadi (2011), Meh and Moran (2010), and others– bankers have some personal net worth (they cannot issue equity) and face a borrowing limit due to an agency problem. This is why a liquidity crunch affects bank lending and has real effects in the models.

How would we extend or modify the models of the crisis to a setting where banks have access to equity finance? We do not, presently, have a well articulated and quantifiable model of frictions in the market for bank equity to guide our models of optimal policy during normal times. The only work we know along these lines is Jermann and Quadrini's (2009, 2012) work on the nonfinancial business sector. Their estimates suggest that a shock impinging on the ability of firms to borrow plays a major role in US business cycles.[4]

The banks in our model issue equity, pay dividends, and maximize their stock-market value. Absent frictions in the equity market, it may be optimal to make the equity payout negative– which amounts to paying negative dividends (in the model) and corresponds to new equity issues (in reality)– under some realizations of shocks. To illustrate the role of an equity-market friction, we compare the frictionless model to the same model under the dividend-smoothing specification of Jermann and Quadrini's (2009, 2012).[5] This ad-hoc feature allows us to show how optimal policy changes as we vary the smoothing parameter; but our model is not suitable for a quantitative exercise. We should note, on this front, that the other models we mentioned above involve assumptions that are equivalent to our model with dividend smoothing.[6]

For our specifications with and without dividend smoothing, we will characterize optimal (Ramsey) monetary policy and jointly optimal responses, to financial shocks, of monetary policy and a fiscal instrument used to make transfers to banks. The financial shock we use to make our main points causes an increase in demand for bank reserves. It may be motivated by Gertler and Kiyotaki's (2010) analysis of a freeze in the interbank market, but we need to model it as a shock (rather than a discrete event) because we want to characterize the Ramsey policy responses. The effects of this shock and policy responses to it do not depend in a fundamental way on our choice to model the liquidity crunch as an increase in demand for bank reserves; we could make the same qualitative points for any shock that tightens our banks' balance sheets.

The version of our model with a frictionless equity market has strong implications because it allows banks to recapitalize themselves easily. In this setting, the lending and borrowing sides of banks

[4] Jermann and Quadrini (2012) find that this financial shock accounts for 46% of the volatility of the growth rate of output, when they add the shock and their equity-market friction to the Smets and Wouters (2007) model driven by seven other shocks.

[5] In the corporate finance literature, the observation that managers smooth dividends goes back to Lintner (1956). Jermann and Quadrini (2012), drawing on earlier work, motivate it as a shortcut for agency problems associated with the equity payout.

[6] In particular, dividends are smooth in the models of Gertler and Karadi (2011), Gertler and Kiyotaki (2010), and Gertler, Kiyotaki and Queralto (2010), since banks only pay dividends when they are hit by a random exit shock (which hits the same fraction of banks each period).

become decoupled. The spread between the lending rate and the risk-free (CCAPM) rate does not depend on the liquidity shock affecting the demand for excess reserves. Furthermore, the decoupling of the lending and borrowing sides eliminates the need for fiscal intervention. By contrast, in the version of our model with an equity-market friction (dividend smoothing), a liquidity shock (an increase in the demand for excess reserves) increases the spread between the lending rate and the risk-free (CCAPM) rate, and reduces the volume of loans. A fiscal cash infusion reduces the spread and increases the volume of loans. Indeed, in our model, the availability of a fiscal instrument serves precisely to undo the constraint that the equity-market friction imposes on optimal monetary policy. That is, optimal policy with the fiscal and monetary instruments under the equity-market friction reproduces exactly the optimal equilibrium under a frictionless equity market (in which case, the fiscal instrument is redundant).

Casual observations about our results – and Jermann and Quadrini's (2012) evidence for the nonfinancial business sector– make us view the model with the equity-market friction as more "plausible" than the model without the friction. Articulating the nature of the friction, however, is a necessary step for assessing its quantitative relevance for policy. To this end, we discuss the motivations for similar frictions offered in the literature. Most notably, Gertler, Kiyotaki and Queralto (2010) attribute the friction to an agency problem between large and small share holders. Alternatively, we will argue, the friction may reflect a tax distortion that makes debt finance cheaper than equity finance for banks.

We also consider a second financial shock, which increases the default rate on bank loans.[7] Its effects, and the optimal policy response, do not depend on what is assumed about equity-market frictions. In our model, firms borrow from banks, so variation in the interest rate affects the cost of production. Because of this cost channel, a default shock is like an adverse supply shock, and the optimal policy response is to increase the interest rate slightly.[8].

In what follows, Sections 2 and 3 present our model and the parameter values used for our simulations. Section 4 reports our results on Ramsey policy, and comparisons with simple rules for monetary policy. In Section 5, we discuss perspectives, from the existing literature, that may offer a more structural alternative for our dividend smoothing assumption. Section 6 contains a brief summary and conclusions.

2 Model

We consider an economy populated with infinitely-lived households, monopolistically competitive banks and firms producing differentiated intermediate goods, perfectly competitive firms producing

[7] Like C úrdia and Woodford (2009) we treat default as an exogenous shock. The aggregate rate of default is known to the banks when they make the loan decision.

[8] See Ravenna and Walsh (2006) for a similar characterization of optimal monetary policy against adverse supply shocks in the presence of a cost channel. And also for empirical evidence on the relevance of the cost channel

the final good, and fiscal and monetary authorities. Our rendition of households and their demand for money is closely related to the standard Lucas and Stokey (1983) setup with cash goods and credit goods, often used in the normative literature [e.g., Chari, Christiano, and Kehoe (1991); Correia, Nicolini, and Teles (2008)]. To incorporate a demand for deposits in the model, we assume that the consumption good is a Cobb-Douglas aggregate over a good that can be bought with cash and a good that can be bought using deposits. We let "leisure" implicitly serve as the credit good in our model.

Each period is divided into two subperiods: a financial exchange followed by a goods exchange. In the financial exchange, after the realization of current shocks, retailers borrow from banks to buy the intermediate goods and assemble the final good to be sold to consumers, the government, and banks (in the version of the model with costly banking); households pay taxes and choose their asset portfolios, acquiring the money and deposits that they plan to use in the subsequent goods exchange; and firms producing intermediate goods pay wages and dividends with the proceeds of their sales to retailers. In the goods exchange, households use money and deposits to buy goods from the retailers that have not been hit by a default shock (those who have been hit by the shock end up not producing anything). We assume that the government buys goods with cash (although this is inconsequential for our analysis). Retailers must wait until the following financial exchange to use the cash and liquidate the deposits that they acquire; so, they are indifferent between these means of payment and set the same price for cash and deposit goods.

2.1 Households

The representative household gets utility from consumption and disutility from work:

$$U_t = E_t \left\{ \sum_{j=0}^{+\infty} \beta^j \left[\Phi \ln\left(c_{t+j}^M\right) + (1-\Phi) \ln\left(c_{t+j}^D\right) - \frac{1}{1+\chi} h_{t+j}^{1+\chi} \right] \right\}$$

with $0 < \beta < 1$, $0 < \Phi < 1$ and $\chi > 0$, where c_t^M and c_t^D denote consumptions of cash goods and deposits goods at date t respectively, and h_t stands for hours worked (in the intermediate-goods sector).

The household's budget constraint, in real terms, is:

$$\begin{aligned} \left(\frac{1+R_{t-1}^A}{\Pi_t}\right) a_{t-1} + \left[\left(\frac{1+R_{t-1}^D}{\Pi_t}\right) d_{t-1} - \frac{c_{t-1}^D}{\Pi_t}\right] + \left(\frac{m_{t-1}^H}{\Pi_t} - \frac{c_{t-1}^M}{\Pi_t}\right) \\ + w_t h_t + \pi_t^I + z_t - a_t - m_t^H - d_t - t_t \geq 0, \end{aligned} \tag{1}$$

where $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ is the inflation rate, d_t deposits, $1+R_t^D$ the gross nominal interest rate on deposits, m_t^H money balances held by the household, w_t wages, π_t^I the profits of firms producing intermediate goods, z_t the dividends paid by banks, and t_t a lump-sum tax. The variables are represented by a lower-case letter when expressed in real terms and by an upper-case letter when expressed in nominal

terms. The asset a_t represents the household's portfolio of nominally risk-free bonds, and $1 + R_t^A$ is the gross nominal CCAPM interest rate. Risk-free nominal bonds may be issued by the government, banks, or other households (although, in equilibrium, the latter will be in zero net supply). In our simple setup securitization of loans (with banks absorbing any default cost) is equivalent to banks issuing risk-free bonds. So, we can also include in a_t any securitization of bank loans.[9]

The households' optimization problem is

$$\underset{a_t, c_t^M, c_t^D, m_t^H, d_t, h_t}{Max} U_t$$

subject to the cash- and deposits-in-advance constraints

$$\begin{aligned} m_t^H - c_t^M &\geq 0, \\ d_t - c_t^D &\geq 0, \end{aligned}$$

and the budget constraint (1). The first-order conditions of this optimization problem are:

$$\begin{aligned} \frac{\Phi}{c_t^M} - \mu_t^M - \beta E_t \left\{ \frac{\lambda_{t+1}}{\Pi_{t+1}} \right\} &= 0, \\ \frac{1-\Phi}{c_t^D} - \mu_t^D - \beta E_t \left\{ \frac{\lambda_{t+1}}{\Pi_{t+1}} \right\} &= 0, \\ \mu_t^M + \beta E_t \left\{ \frac{\lambda_{t+1}}{\Pi_{t+1}} \right\} - \lambda_t &= 0, \\ \mu_t^D + \beta \left(1 + R_t^D\right) E_t \left\{ \frac{\lambda_{t+1}}{\Pi_{t+1}} \right\} - \lambda_t &= 0, \\ -h_t^\chi + w_t \lambda_t &= 0, \\ \beta \left(1 + R_t^A\right) E_t \left\{ \frac{\lambda_{t+1}}{\Pi_{t+1}} \right\} - \lambda_t &= 0, \end{aligned} \tag{2}$$

where λ_t is the Lagrange multiplier associated with the household's budget constraint.

2.2 Intermediate goods producers

There is a unit mass of monopolistically competitive firms producing intermediate goods. Firm j operates the production function:

$$x_t(j) = h_t(j) \exp\left(z_t^p\right),$$

where z_t^p is an exogenous productivity shock. We assume that firms set their prices à la Calvo.

[9] Securitization is equivalent to risk-free debt in our model because the aggregate default rate is predictable and there are no information asymmetries in the model. In equilibrium, a_t will consist of bank liabilities (we can think of it as commercial paper or securitized loans) because we will assume the government maintains a balanced budget.

2.3 Final goods producers

Producers of the final good– henceforth, "retailers"– are perfectly competitive. They use $x_t(j)$ units of each intermediate good $j \in [0,1]$ to produce y_t units of the final good with

$$y_t = \left(\int_0^1 x_t(j)^{\frac{\varepsilon-1}{\varepsilon}} \, dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{3}$$

where $\varepsilon > 1$. Firms may be hit by a default shock, in which case they use their inputs but don't produce any output.

Intermediate good j sells for the nominal price $P_t^X(j)$. We break the retailer's optimization problem into two parts. First, the cost minimization problem involves choosing $x_t(j)$ for all $j \in [0,1]$ to minimize

$$\int_0^1 P_t^X(j) x_t(j) dj$$

given y_t and subject to the constraint imposed by the production function (3). This implies

$$x_t(j) = \left(\frac{P_t^X(j)}{P_t^X} \right)^{-\varepsilon} y_t, \tag{4}$$

where

$$P_t^X \equiv \left(\int_0^1 P_t^X(j)^{1-\varepsilon} \, dj \right)^{\frac{1}{1-\varepsilon}} \tag{5}$$

is the marginal (and average) cost of producing y_t.

Second, retailers must borrow from banks to buy intermediate goods:[10]

$$\frac{P_t^X}{P_t} x_t = l_t, \tag{6}$$

where P_t is the price of the final good. The zero-profit condition of retailers implies

$$P_t = \left(1 + R_t^L\right) \, P_t^X. \tag{7}$$

So, P_t is just a markup over the cost P_t^X of acquiring the goods, and the markup factor is the interest rate on loans. The zero profit condition of retailers has the following interpretation. A one-period entrant at time t could borrow L_t, buy intermediate goods and sell them for $P_t y_t$. Next period, the potential entrant would have exactly $P_t y_t = \left(1 + R_t^L\right) L_t$ to pay off the bank loan with no profit or loss.

2.4 Banks

Banks are owned by households and have some market power in setting the interest rates on deposits and loans.[11] Gerali et. al. (2010) motivate the following setup. A bank setting the gross nominal

[10] The retailers need funding in our model's financial exchange to buy intermediate goods (and the sellers of these goods use the funds to pay wages and dividends). As usual, our assumption that these funds are borrowed from banks (rather than households) amounts to endowing banks with some monitoring skills that are necessary to avoid fraud, etc.

[11] The only reason we assume banks have market power is to remove the period-by-period zero-profit condition that would be implied by a perfectly competitive banking sector. We could not have random taxation (or fiscal transfers)

interest rate, $1+R_t^L$, that it charges on its loans, l_t, faces the demand curve for loans

$$l_t = \left(\frac{1+R_t^L}{1+\overline{R}_t^L}\right)^{-\sigma_l} \bar{l}_t \tag{8}$$

with $\sigma_l > 1$. Similarly, a bank setting the gross nominal interest rate, $1+R_t^D$, paid on its deposits, d_t, faces

$$d_t = \left(\frac{1+R_t^D}{1+\overline{R}_t^D}\right)^{\sigma_d} \bar{d}_t \tag{9}$$

with $\sigma_d > 1$. The variables with an upper bar ($\bar{d}_t$, $\bar{l}_t$, $\overline{R}_t^D$, $\overline{R}_t^L$) denote the corresponding average variables. All banks are identical and set the same interest rates in a symmetric equilibrium.

Banks hold reserves m_t^B to manage the liquidity of deposits:

$$m_t^B = d_t \exp(z_t^d), \tag{10}$$

where z_t^d is an exogenous reserves demand shock. The representative bank chooses z_t, a_t, m_t^B , R_t^D and R_t^L to maximize its stock-market value

$$E_t \left\{ \sum_{j=0}^{+\infty} \beta^j \lambda_{t+j} z_{t+j} \right\}$$

subject to (8), (9), (10), and the cash-flow constraint

$$\begin{aligned} z_t \quad = \quad & a_t + d_t + (1-\delta_{t-1}) \left(\frac{1+R_{t-1}^L}{\Pi_t}\right) l_{t-1} + \frac{1}{\Pi_t} m_{t-1}^B \\ & -\frac{\Phi_a}{2}(a_t - a^*)^2 - \left(\frac{1+R_{t-1}^A}{\Pi_t}\right) a_{t-1} - \left(\frac{1+R_{t-1}^D}{\Pi_t}\right) d_{t-1} \\ & -l_t - m_t^B - \tau_t - \frac{\Phi_z}{2}(z_t - z^*)^2 \end{aligned} \tag{11}$$

with $\Phi_a \geq 0$ and $\Phi_z \geq 0$, where δ_t is the default rate, and τ_t a tax (when positive) or transfer (when negative) financed by taxing households. To study the responses of endogenous variables to a fiscal transfer to banks, we set

$$\tau_t = \tau_{ss} - \varepsilon_t^\tau, \tag{12}$$

where ε_t^τ is an exogenous shock and, for any variable v_t, v_{ss} denotes the steady-state value of v_t. Setting $\Phi_a = 0$ leads to a standard setup with a frictionless market for nominally riskless debt or securitization. With $\Phi_a > 0$, our banks would face a cost of issuing an amount of securities a_t different from a^*. In our simulations, $\Phi_a > 0$ corresponds to the case where banks face increasing marginal costs of borrowing (or securitizing) amounts above a^*. This is a smooth version of the borrowing limit implied by the agency problem in the models of Gertler and Karadi (2011), Gertler and Kiyotaki

in the banking sector while satisfying a zero-profit condition at every date. Nor could we model dividend smoothing if our banks made zero profits.

(2010), Gertler, Kiyotaki and Queralto (2010), and Meh and Moran (2010).[12] When $\Phi_z > 0$, banks face a cost of setting dividends different from z^*. In our simulations, $\Phi_z > 0$ corresponds to the case where paying dividends below z^* hurts the stock-market value of banks.

In a symmetric equilibrium, the first-order conditions of this maximization problem are:

$$\begin{aligned}
\lambda_t - \lambda_t^z \left[1 + \Phi_z \left(z_t - z^*\right)\right] &= 0, && (13)\\
\lambda_t^z \left[1 - \Phi_a \left(a_t - a^*\right)\right] - \beta \left(1 + R_t^A\right) E_t \left\{\frac{\lambda_{t+1}^z}{\Pi_{t+1}}\right\} &= 0, && (14)\\
\left(\frac{1 + R_t^L}{1 + R_t^A}\right) \left[1 - \Phi_a \left(a_t - a^*\right)\right] \left(1 - \delta_t\right) - \frac{\sigma_l}{\sigma_l - 1} &= 0, && (15)\\
\frac{1 - \Phi_a \left(a_t - a^*\right)}{1 + R_t^A} - 1 + \frac{\lambda_t^d}{\lambda_t^z} &= 0,\\
\left(\frac{1 + R_t^D}{1 + R_t^A}\right) \left[1 - \Phi_a \left(a_t - a^*\right)\right] - \frac{\sigma_d}{\sigma_d + 1} \left(1 - z_t^d \frac{\lambda_t^d}{\lambda_t^z}\right) &= 0,
\end{aligned}$$

where λ_t^d and λ_t^z are the Lagrange multipliers associated with equations (10) and (11) respectively. Note that there is a monopoly markup on the lending rate and a monopoly "mark-down" on the deposit rate.

2.5 Government

Government purchases g_t are exogenous and follow an AR(1) process. For concreteness, we assume that the fiscal authority uses cash to pay for its purchases,

$$m_t^G = g_t,$$

but this does not matter for our results. Since Ricardian Equivalence holds in our model, we don't need to model the dynamics of public debt explicitly.[13] We can just assume that the fiscal authority maintains a balanced budget and sets

$$t_t = g_t - \tau_t.$$

When we consider the model under a simple monetary policy rule, we will use a rule like

$$\left(1 + R_t^A\right) = \left(1 + R_{t-1}^A\right)^{\rho} \left[\left(1 + R_{ss}^A\right) \left(\frac{\Pi_t^X}{\Pi_{ss}}\right)^{\theta_m}\right]^{1-\rho}, \qquad (16)$$

where $\Pi_t^X \equiv \frac{P_t^X}{P_{t-1}^X}$, $0 \leq \rho < 1$, $\theta_m > 0$, or the equivalent rule reacting to CPI inflation. We will compare these rules to optimal (Ramsey) policy.

[12] The borrowing limit would represent a kink making the marginal cost infinite at a^*.

[13] But these bonds are implicitly present because our monetary authority trades them in open market operations.

2.6 Market clearing conditions

The goods market clearing condition is

$$(1-\delta_t)\, y_t = c_t + g_t + \frac{\Phi_a}{2}\left(a_t - a^*\right)^2 + \frac{\Phi_z}{2}\left(z_t - z^*\right)^2$$

and the money market clearing condition is

$$m_t = m_t^H + m_t^B + m_t^G.$$

2.7 Shock processes

We assume that ε_t^τ is a white noise (with standard deviation σ_τ) and that the other shocks follow autoregressive processes of order one:

$$\begin{aligned}
z_t^p &= \rho_p z_{t-1}^p + \varepsilon_t^p, \\
\log(g_t) &= (1-\rho_g)\log(g_{ss}) + \rho_g \log(g_{t-1}) + \varepsilon_t^g, \\
z_t^d &= (1-\rho_d)\, z_{ss}^d + \rho_d z_{t-1}^d + \varepsilon_t^d, \\
\log(\delta_t) &= (1-\rho_\delta)\log(\delta_{ss}) + \rho_\delta \log(\delta_{t-1}) + \varepsilon_t^\delta,
\end{aligned}$$

where ρ_p, ρ_g, ρ_d, ρ_δ are parameters between zero and one, while ε_t^p, ε_t^g, ε_t^d and ε_t^δ are white noises (with standard deviations σ_p, σ_g, σ_d and σ_δ).

2.8 Frictionless Equity Market

The special case of our model with a frictionless equity market ($\Phi_z = 0$) has a number of strong implications. In this case, (13) implies $\lambda_t = \lambda_t^z$. Then, combining (14) with (2), we see that the marginal cost of borrowing (or securitization) is zero. If we set $a^* = 0$ (so that any borrowing or securitization is costly), banks will not borrow or issue securities. Note that this implication is not due to the functional forms we assume for costs. The more general point is that banks should not undertake costly borrowing or securitization if they can issue equity (freely adjust dividends), get funds at the CCAPM rate from their owners, and save the costs of borrowing or securitization.

Also, in this case, (15) implies that the spread between the lending rate and the risk-free (CCAPM) rate fluctuates only in response to default shocks, and does not depend on the other shocks in our model. Moreover, in this case, the lump-sum tax or transfer τ_t has no effect, except on the banks' dividend payments z_t. All these implications of the model are removed once we allow for a friction in the equity market ($\Phi_z > 0$).

3 Parametrization

Our model has a number of parameters that are hard to calibrate. These parameter values do not play an important role for our results because our presentation will highlight qualitative features of optimal policies.[14] Most importantly, we don't have any strong priors for setting our dividend-smoothing parameter Φ_z. Jermann and Quadrini (2009, 2012) provide three different values, ranging from essentially 0 to 0.46 , for the US nonfinancial business sector (using the same data set starting in the 1980s but three different approaches to estimation or calibration). We will set $\Phi_z = 0.25$ in our benchmark model (allowing for dividend smoothing by banks). We will also set $\Phi_a = 0.25$ in our benchmark model. These are arbitrary choices, and our discussion will compare the benchmark model to an alternative model setting $\Phi_z = \Phi_a = 0$.[15] The default rate is 0.86 percent in the steady state (the average charge-off rate for US bank loans from 1985Q1 to 2008Q3). We set $\Phi = 0.43$ as the share of cash goods in consumption, following Chari, Christiano, and Kehoe (1991). Given this value, the model pins down the steady-state level of deposits and their share in funding bank loans.

We set $a^* = a_{ss}$ and treat it as securitization. Banks securitize 19 percent of their loans in the steady state (the ratio of securitized consumer and real estate loans to bank credit, for US commercial banks, in August 2008). We assume bank reserves are 7.6 percent of deposits in the steady state (the ratio of aggregate reserves of depository institutions to deposits in the US in August 2008, where deposits are measured as M1 minus currency outside banks). The bank's balance sheet identity then pins down the value of z_{ss}. We set $z^* = z_{ss}$. We set σ_d to make the interest rate on deposits 2 percent per annum. We set σ_l to make the interest rate on loans 8.4 percent per annum [so, adjusting for the default rate our Prime rate would be 5 percent per annum, close to the average Prime rate after 1980]. In our simple rule for monetary policy we set the inertia parameter to 0.8 and the (long-run) response to inflation to 1.5. Finally, we set the steady-state gross inflation rate per quarter to its optimal value, equal to 0.9996. We explain later how this value is obtained and comment upon it.

The standard deviations of our shocks to productivity and government purchases take standard values. Our tax shock (fiscal transfer to the banking sector) is only for illustrative purposes and its size does not matter for our analysis.[16] For each shock following an AR(1) process, we set the inertia parameter equal to 0.9.

We set the standard deviation of our default shock innovation such that an increase (in the charge-off

[14] We don't pursue quantitative results because our stylized model cannot match basic features of banking sector data anyway. For example, in US data, deposits and bank loans are three to four times the size of quarterly consumption; in our model, consumption of "deposit goods" has to be smaller than total consumption, and loans have to be about as large as output.

[15] Setting Φ_z and Φ_a larger than 0.25 would make banks less willing to adjust dividend payments and borrowing (securitization); this would make the effects of the liquidity shock larger under all the policies we consider below, but it would not affect the qualitative features or comparisons across policies that we will highlight.

[16] We deactivate this shock throughout, except when we use impulse responses to highlight its transmission mechanisms.

rate) of the magnitude observed during the recent financial crisis would occur on average once in 80 years in our model. In the data, the average charge-off rate from 1985Q1 to 2008Q3 was 0.86 percent; the rate grew to 2.88 percent in 2009Q3. Under our parametrization, an increase of this magnitude over 4 quarters has probability $\frac{1}{320}$, given our AR(1) process and assuming that the innovation has a Gaussian distribution.[17] So, a randomly selected quarter may be the start of a large 4-quarter increase in the default rate on average every 320 quarters or 80 years, which roughly corresponds to the time elapsed between the Great Depression and the recent crisis.

Similarly, we set the standard deviation of the reserves-demand shock innovation such that, starting from its steady-state value of 7.6 percent (the August 2008 figure), the reserves-to-deposits ratio reaches at least 107 percent (the August 2009 figure) in one year's time with probability $\frac{1}{320}$.

The parameter values are shown in Table 1.

4 Numerical Results

We used Michel Juillard's software Dynare to log-linearize and simulate our model. We solved for the optimal (Ramsey) policy using Dynare and the program Get Ramsey developed by Levin and López-Salido (2004). The optimal steady-state rate of inflation in our model has to strike a balance between two forces, as Khan, King, and Wolman (2003) point out in the context of their model with a monetary friction and price rigidity. First, since a positive nominal interest rate distorts the household's labor-leisure decision, optimal policy would follow the Friedman Rule– a deflationary policy keeping the nominal interest rate equal to zero– if prices were fully flexible. Second, price rigidity, by itself, would call for price stability– keeping the inflation rate equal to zero– if there were no monetary distortion (as in standard NK models). In our model– as in several earlier models like Khan, King, and Wolman (2003)– optimal steady-state inflation is close to zero; so, the normative force calling for price stability dominates the monetary frictions that call for the Friedman Rule.[18]

4.1 Benchmark Model

Figures 1 to 4 display the impulse-response functions (IRFs) of selected variables in response to shocks in our benchmark model with $(\Phi_a, \Phi_z) = (0.25, 0.25)$ (i.e. in the presence of equity market frictions). Each Figure shows the responses under our two simple rules, reacting to the inflation measures Π and Π^X, and under optimal (Ramsey) monetary policy. We do not optimize over the fiscal instrument (we set the transfer equal to zero) for the results reported in these Figures.

[17] More precisely, the standard deviation σ_δ of the default shock innovation is set such that a variable having a Gaussian probability distribution with mean zero and variance $\sigma_\delta^2\left(1+\rho_\delta^2+\rho_\delta^4+\rho_\delta^6\right)$ exceeds $\ln(2.88)-\ln(0.86)$ with probability $\frac{1}{320}$, where $\rho_\delta = 0.9$ denotes the inertia in the default shock.

[18] More precisely, the optimal steady-state deflation rate is about 0.04 percent per quarter, in all versions of our model.

Table 1: Calibration

Parameter	Description	Value
	Preferences	
β	Discount factor	0.99
χ	Inverse of Frisch elasticity of labor supply	1
Φ	Share of cash goods in consumption	0.43
	Technology	
σ	Elasticity in the goods aggregator	7
	Nominal rigidities	
α	Probability Calvo fairy does not visit price setter	0.75
	Banking aspects	
σ_d	Elasticity in the deposits aggregator	230
σ_l	Elasticity in the loans aggregator	420
Φ_a	Adjustment-cost parameter for securities	0 or 0.25
Φ_z	Adjustment-cost parameter for dividends	0 or 0.25
	Monetary policy	
ρ	Degree of inertia in interest-rate rule	0.8
θ_m	Coefficient on inflation in interest-rate rule	1.5
	Steady-state values	
π_{ss}	Steady-state gross inflation rate per quarter	0.9996
δ_{ss}	S.-s. default rate per quarter	0.0086
z^d_{ss}	S.-s. reserve ratio	0.076
$\frac{g_{ss}}{(1-\delta_{ss})y_{ss}}$	S.-s. share of government purchases in output	0.25
$\frac{a_{ss}}{l_{ss}}$	S.-s. ratio of bank borrowings (securities) to loans	0.19
τ_{ss}	S.-s. lump-sum tax on banks	0
	Shock processes	
ρ_p	inertia in productivity shock	0.9
ρ_g	inertia in government-expenditures shock	0.9
ρ_d	inertia in shock to demand for reserves	0.9
ρ_δ	inertia in default shock	0.9
σ_p	standard deviation of productivity shock innovation	0.0086
σ_g	stand. dev. of gov.-expenditures shock innovation	0.010
σ_d	stand. dev. of reserves-demand shock innovation	0.56
σ_δ	stand. dev. of default shock innovation	0.26
σ_τ	stand. dev. of fiscal transfer to banks	0.010

The solid lines show the IRFs under a simple rule reacting to CPI inflation (Π). The responses to familiar shocks (in Figures 1 and 2) are in accordance with conventional wisdom. A positive productivity shock raises output and lowers inflation. A positive government-expenditures shock raises output, lending, inflation and interest rates, but decreases private consumption due to the familiar Ricardian effect. A positive default shock (Figure 3) decreases output and hours at first. Output and hours per producing firm (y and h) rebound after two quarters, but aggregate output and hours (which have the same pattern of responses as the one we show for consumption) remain below their steady-state values for over 20 quarters. CPI inflation and interest rates rise and the volume of lending falls. Despite the decrease in output, the increase in inflation is accompanied by a small increase in the growth rate of the monetary base. Note that the effects of a positive default shock are isomorphic to those of an adverse productivity shock. Finally, following a positive shock to the demand for reserves (Figure 4), output, hours, private consumption and lending decrease while inflation and interest rates rise.

Why is an increase in the demand for reserves inflationary in our model? When banks need more reserves, their balance sheets tighten and they want to lend less. Lending rates rise and the associated cost increases the price of final goods. The higher prices curb aggregate demand and reduce consumption, output and hours. These effects, and the effect on prices of intermediate goods, however, are fairly small.[19] The responses in Figures 3 and 4 illustrate that default shocks and shocks to demand for reserves work like adverse supply shocks in our model.

Our stylized model may well overstate some consequences of a simple rule that reacts to CPI inflation. In the model, banks raise the lending rate when they are less eager to lend and retailers pass on the cost of borrowing to consumers right away (there is no rigidity in retail prices). So, the CPI inflation rate in our model is quite sensitive to financial shocks. If monetary policy responds to this measure of inflation, then the effects of shocks on endogenous variables also reflect the resulting changes in the policy stance. The dashed lines in Figures 1 to 4 show the corresponding IRFs assuming that the simple monetary rule responds to inflation in the price index for intermediate goods (Π^X), as specified in (16). Since Π^X is less sensitive to financial shocks, these IRFs do not reflect endogenous monetary responses as much as the solid lines (the IRFs under the simple rule responding to CPI inflation) do. Also, the conventional wisdom of NK models linking optimal policy to inflation targeting applies more naturally to our simple rule reacting to inflation in the price index for intermediate goods, Π^X.

The dashed and dotted lines show the IRFs under optimal (Ramsey) monetary policy. In Figure 1, optimal policy allows somewhat larger increases in output and consumption and opts for a smaller decrease in inflation than our simple rule targeting CPI inflation. In particular, optimal policy essen-

[19] Some of the small responses in our IRFs also reflect general-equilibrium interactions that we don't highlight in the text. For example, after an increase in demand for reserves, the interest rate on deposits rises (because banks try to tap the deposit market more as their balance sheets tighten) and consumers switch from buying cash goods to buying deposit goods. This reduces household demand for money.

tially keeps inflation in the price index for intermediate goods unchanged but tolerates some volatility in CPI inflation. This property is due to the fact that the CPI, unlike intermediate goods inflation, is affected through the cost channel. And we know from Ravenna and Walsh (2006) that the presence of a cost channel introduces a trade off between output and price stability. Note that optimal policy also keeps Π^X closer to zero in response to a shock to government purchases (Figure 2).

The responses to a default shock, in Figure 3, show how a simple rule reacting to CPI inflation (Π) may be undesirable. Optimal policy raises output and hours *per producing firm* (y and h)– albeit by small amounts– while the simple rule allows these variables to fall upon impact. Although aggregate output and hours (which have the same pattern of responses as that of consumption) still fall, optimal policy opts for a smaller contraction, than the simple CPI rule does, in response to a default shock. The optimal monetary policy response to the default shock highlights the fact that this shock is like an adverse productivity shock.

Following a shock that increases the demand for reserves, optimal policy (Figure 4) allows output, consumption, labor hours, and lending to fall. To bring about the decrease in the volume of loans as an equilibrium outcome, lending rates must rise; and this increases CPI inflation. Optimal policy cuts the policy rate (slightly) and allows a large monetary expansion in response to the increase in demand for reserves. Compared to optimal policy, our simple rule responding to CPI inflation tolerates much larger contractions in output, consumption, and hours, when the demand for reserves increases. The difference arises from the fact that the simple rule raises the policy rate to fight inflation, while optimal policy cuts the policy rate to moderate the contraction. Once again, the simple rule reacting to Π^X comes closer to optimal policy.

We calculate the welfare losses from simple rules relative to optimal policy, and express these welfare losses as consumption equivalents following Lucas (2003). The computed welfare losses are quite small. For instance, the rule involving a response to inflation in the price index for intermediate goods only entails a welfare loss of 0.03 percent compared to optimal policy. That is, augmenting consumption by 0.03 percent each period would be enough to compensate consumers for living under the simple rule, instead of having the fully optimal policy in effect. In this sense, the normative punch line of simple NK models applies to our model: a simple rule that stabilizes the "right" measure of inflation is optimal, or very close to optimal.

We also consider a rule that sets an almost constant growth rate for the money supply.[20] The welfare cost of this policy is 1.26 percent of consumption per period. This is not surprising: as we saw above, optimal policy allows money growth to fluctuate considerably in response to liquidity shocks in our model. A money supply rule hinders such optimal variation in the money supply and can lead to significant welfare losses (as discussed by Collard and Dellas, 2005.)

[20] More precisely, we set nominal money growth equal to 1.15 times the steady-state inflation rate minus 0.15 times last-quarter's inflation rate. We need this negative response to lagged inflation to get determinacy in our model.

4.2 Frictionless Equity Market

Although the preceding results from our benchmark model mostly accord with familiar views, we obtained these results by setting $\Phi_a = \Phi_z = 0.25$. What happens if we set $\Phi_a = \Phi_z = 0$, instead? The optimal responses to shocks to productivity, government purchases, and the default rate do not change. Figure 5 shows that optimal responses to our default shock in frictionless markets are essentially the same as those in Figure 3 with frictions. This is because the friction only matters for whether or not shocks to the funding side are transmitted to the lending side, while a default shock directly affects the lending side of banks in our model.

Optimal responses to our liquidity shock (increase in demand for reserves), however, change when we remove the equity-market friction (Figure 6). First of all, compared to Figure 4, the contractionary effects of this liquidity shock on output, consumption and hours are an order of magnitude smaller. In Figure 4 (with the equity-market friction) the contraction reflected the increase in bank lending rates in response to tighter balance sheet conditions. In Figure 6 (without the equity-market friction), balance sheet conditions don't play a role, and lending rates actually fall (by a small amount). [21] In this case, the increase in money demand has the familiar (but small) deflationary effect.[22]

As we pointed out earlier (based on the relevant first-order conditions), banks do not engage in costly securitization (or borrowing) if they have access to funds in a frictionless equity market. If we set $\Phi_z = 0$, and $\Phi_a > 0$, our model implies $a_t = a^*$. And if we set $\Phi_z > 0$, and $\Phi_a = 0$, our banks adjust a_t in response to our liquidity shock.

4.3 The Fiscal Instrument

As we noted earlier, a fiscal transfer to banks has no effect in the absence of the equity-market friction– it is simply paid out as dividends. To provide some intuition for the potential role of fiscal policy in the presence of funding frictions, Figure 7 shows the effects of a fiscal transfer to banks, reducing τ in (12) from its steady-state value of 0 to -0.01. This transfer increases the bank's cash flow and makes them more willing to lend. So, they cut the interest rate on loans which reduces consumer prices upon impact and stimulates spending.

We consider again optimal policy under funding frictions, with $\Phi_a = \Phi_z = 0.25$, but this time assume the fiscal instrument can be used in addition to monetary policy. Optimal policy makes a transfer to banks when the demand for reserves increases. This shock, however, also calls for a monetary response. In Figure 8, this monetary response and the responses of other variables virtually coincide with the ones under optimal monetary policy in the absence of a friction in the equity market. For example,

[21] This reflects a small general-equilibrium interaction. The contraction of output reduces the demand for loans, and banks compete to attract borrowers by cutting the interest rate on loans.

[22] We suspect that the small contraction in consumption reflects the wealth effect of the decrease in bank profits.

under jointly optimal policies there is a small increase in output, as is the case under optimal monetary policy in the frictionless model. By contrast, lacking the fiscal instrument, optimal monetary policy has to tolerate a decrease in output when there is a friction in the equity market. These findings are intuitive. The fiscal instrument is essentially used to offset the friction in the equity market, and optimal monetary policy opts for essentially the same solution that it would choose in the absence of this friction.

As we noted above, optimal responses to a default shock are much the same with or without the friction in the market for bank equity. For this shock, the IRFs under optimal fiscal and monetary policy (not displayed) virtually coincide with the IRFs under optimal monetary policy (in Figures 3 and 5). This is because our fiscal instrument is redundant given that this shock has no effect on the funding side of our banks.

5 Structural Interpretations

In our model, the positive and normative implications of liquidity shocks (shocks that increase the demand for bank reserves) depend critically on the presence of funding frictions that banks face in the debt and equity markets. The friction we considered in the debt (or securitization) market is a smooth version of the debt limit that, following Kiyotaki and Moore (1997), is often used to pin down the financial structure of firms (or banks).[23] Gertler and Karadi (2011), Gertler and Kiyotaki (2010), and Meh and Moran (2010), among others, develop models in which this agency problem puts a lower bound on the banks' capital ratio (the ratio of bank capital to loans). These contributions assume that banks cannot issue equity. So, the lower bound on the capital ratio and the evolution of the bankers' personal net worth pin down the banks' financial structure.

Gertler, Kiyotaki, and Queralto (2010) consider an analogous agency problem between bank managers (or inside equity holders) and (outside) share holders. They retain the basic structure of Gertler and Kiyotaki (2010) in which each banker is a member of a particular household (serving as a model proxy for inside share holders) but also allow banks to issue equity to other households. An agency problem analogous to the one in Kiyotaki and Moore (1997) puts an upper bound on the amount of equity finance, given the banker's personal net worth. In the model, bankers have an incentive to raise the maximum amount of funds, subject to the limit on obligations that they can commit to honor, in the markets for debt and equity. So, this model corresponds to setting very high adjustment-cost parameters in our dividend-smoothing framework.

In Collard, Dellas, Diba, and Loisel (2011)– henceforth, CDDL– we articulate an alternative way of

[23] Most applications involve additional model features that turn the inequality constraint, implied by the debt limit, into an equality constraint. We worked instead with a smooth version to avoid solving a Ramsey problem subject to an inequality constraint.

pinning down the capital structure of banks: prudential policy sets a minimum capital ratio and the tax advantage of debt finance (over equity finance) gives banks an incentive to rely on debt finance as much as they can. In CDDL we focus on different conceptual issues (don't consider policy responses to liquidity shocks), but our framework is in sharp contrast to models with debt limits in that our banks can readily change their financial structure; they just find equity finance expensive.

Jermann and Quadrini's (2009, 2012) work on the nonfinancial business sector considers a tax distortion like the one in CDDL as well as adjustment costs as in the model of the present paper. The estimates in Jermann and Quadrini (2009) suggest that the tax distortion is the only relevant factor (the estimate of the dividend smoothing parameter is essentially zero), but the estimates in Jermann and Quadrini (2012) contradict this finding (suggest a positive dividend smoothing parameter).

Studying the nature and degree of frictions in the market for bank equity seems like an important topic for future research on quantitative models of monetary policy.

6 Conclusions

In this paper we have added banks and frictions in the market for bank capital, to the standard New Keynesian model. We have used this model to study the positive and normative implications of two financial shocks. Our two shocks represent what we think are two distinct lines of research motivated by the 2007-2009 financial crisis.

Our shock to demand for reserves serves to illustrate the effects of liquidity shocks, and the seminal contribution of Gertler and Kiyotaki (2010). The existence of an equity market friction matters significantly for the effects of this shock and the properties of optimal monetary policy. Our first finding is that for shocks that increase banks' demand for liquidity, optimal monetary policy accepts an output contraction. This would not have been the case in the absence of the friction. Hence, monetary policy becomes less accommodating to liquidity shocks under equity market frictions. Second, optimal policy involves large adjustments in the money supply, a property reminiscent of Poole's analysis. Consequently, restrictions on the quantity of money supplied by the central bank can carry significant welfare costs in times of financial turbulence. And third, the presence of financial frictions and financial shocks do not invalidate the well known implication of the standard NK model that a simple interest-rate rule that targets inflation is close to the optimal policy. There is a caveat here, though. Namely, that such a rule should target a measure of inflation that is relatively insensitive to financial shocks.

Adding a fiscal instrument that allows making transfers to banks, serves to remove the equity-market friction in our model. That is, optimal policy with the two (fiscal and monetary) instruments in the presence of the friction leads to the same equilibrium that optimal monetary policy would implement absent the friction.

The main weakness of the present analysis lies in its specification of the bank equity market friction. Extensions that would model such a friction in a more compelling fashion appear to us to be of high value added both from a positive and a normative point of view, especially regarding the properties of jointly optimal fiscal and monetary policies.

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Figure 1: Responses to productivity shock

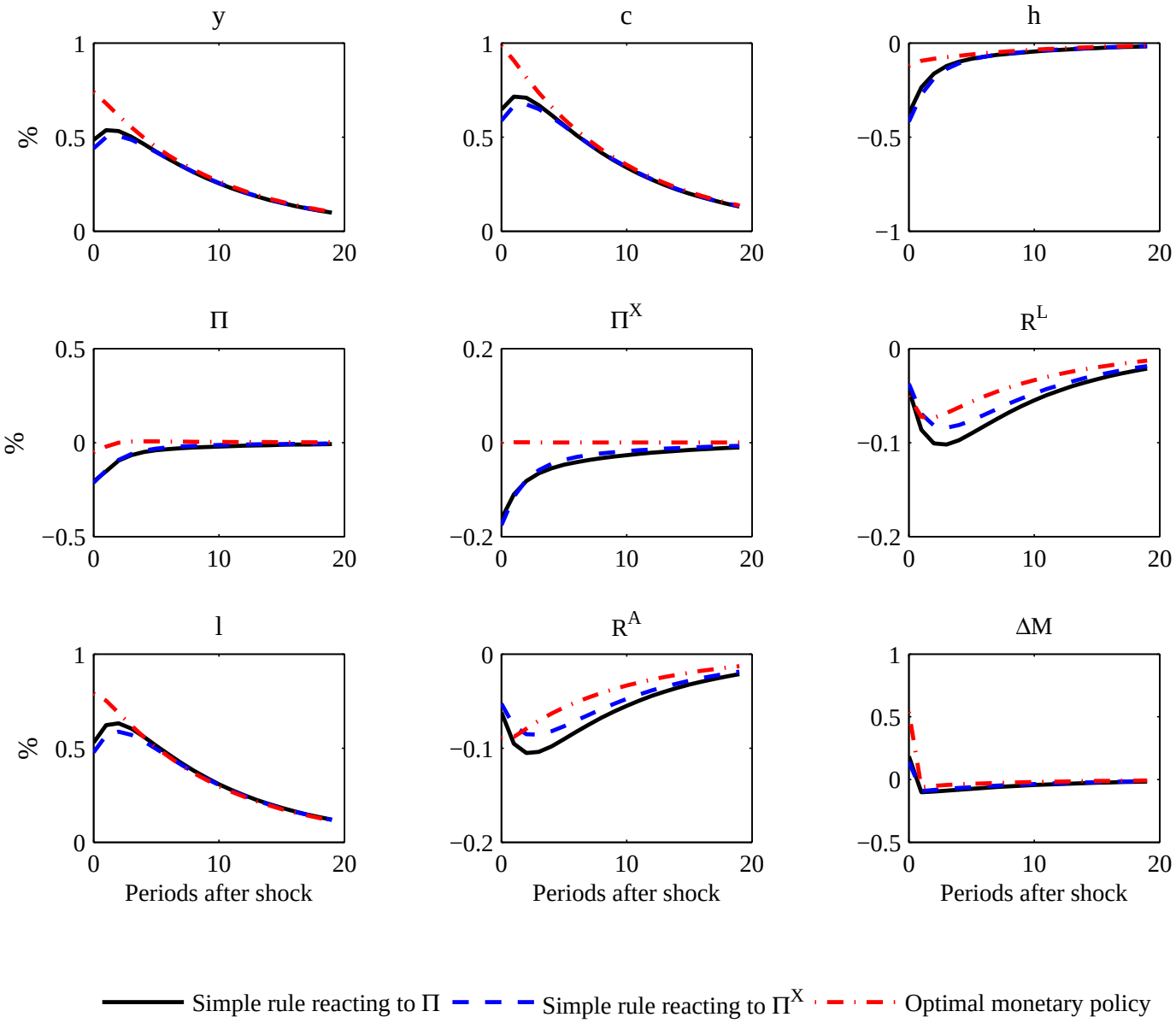

Figure 2: Responses to government-expenditures shock

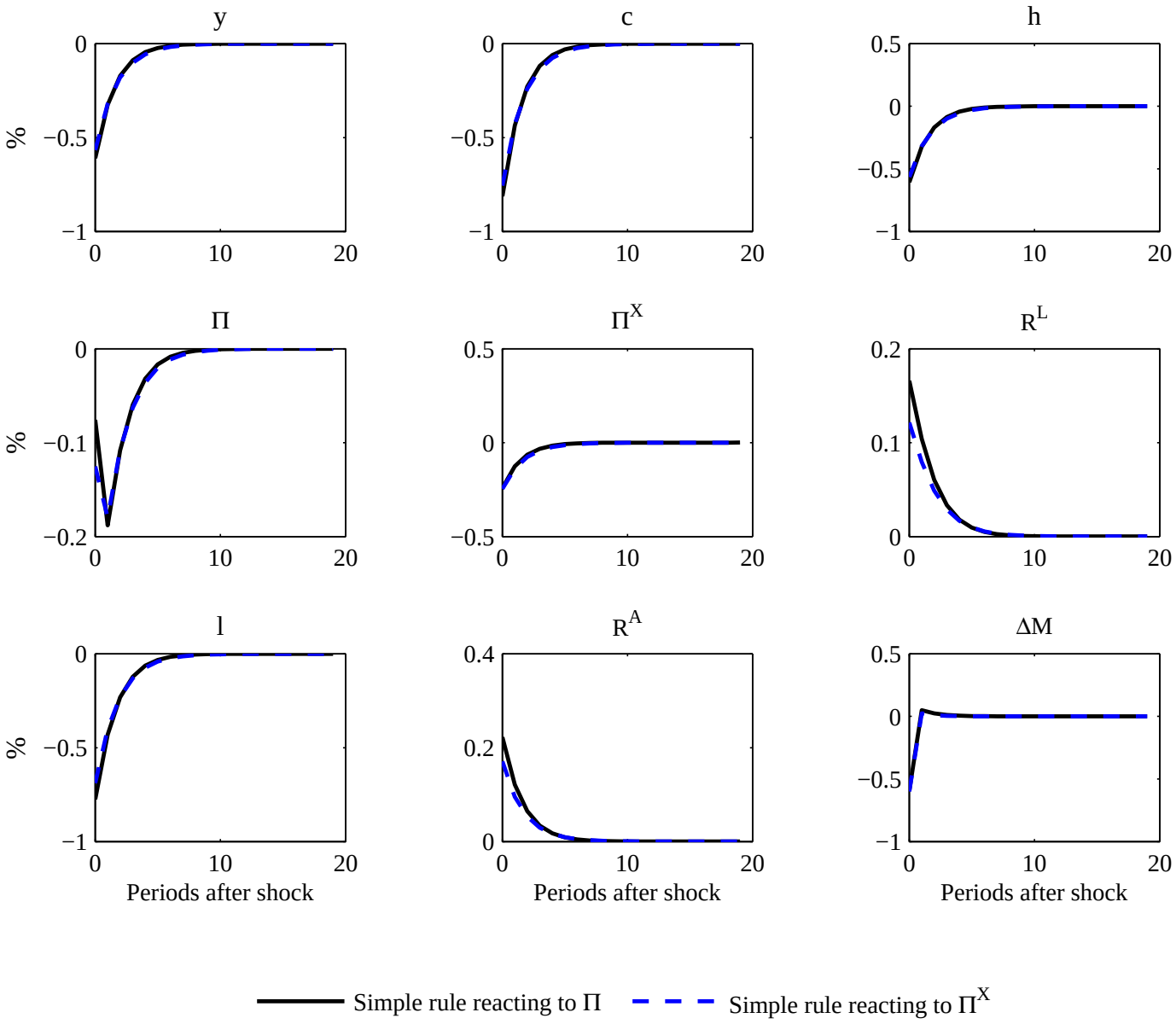

Figure 3: Responses to default shock

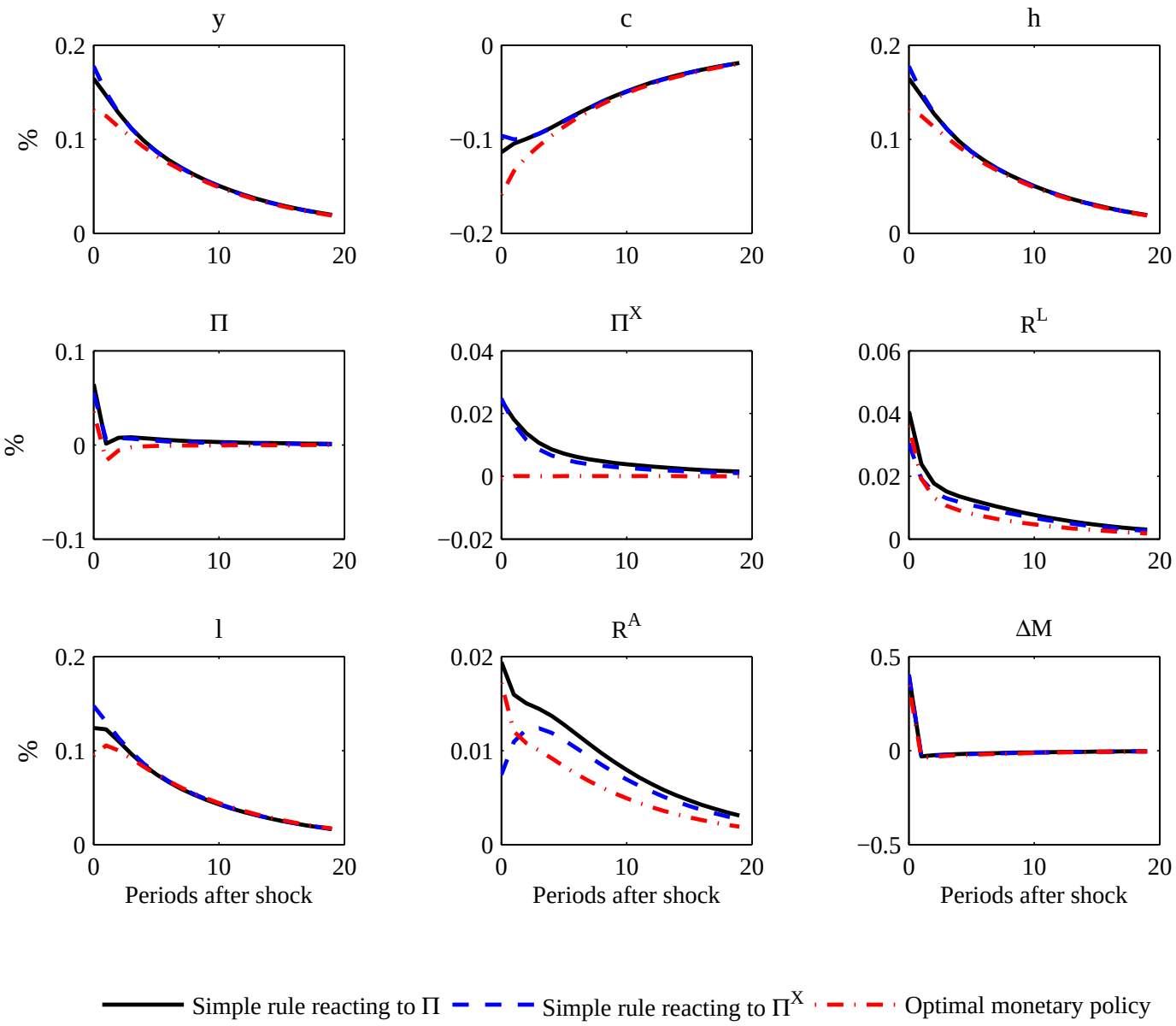

Figure 4: Responses to shock to demand for reserves

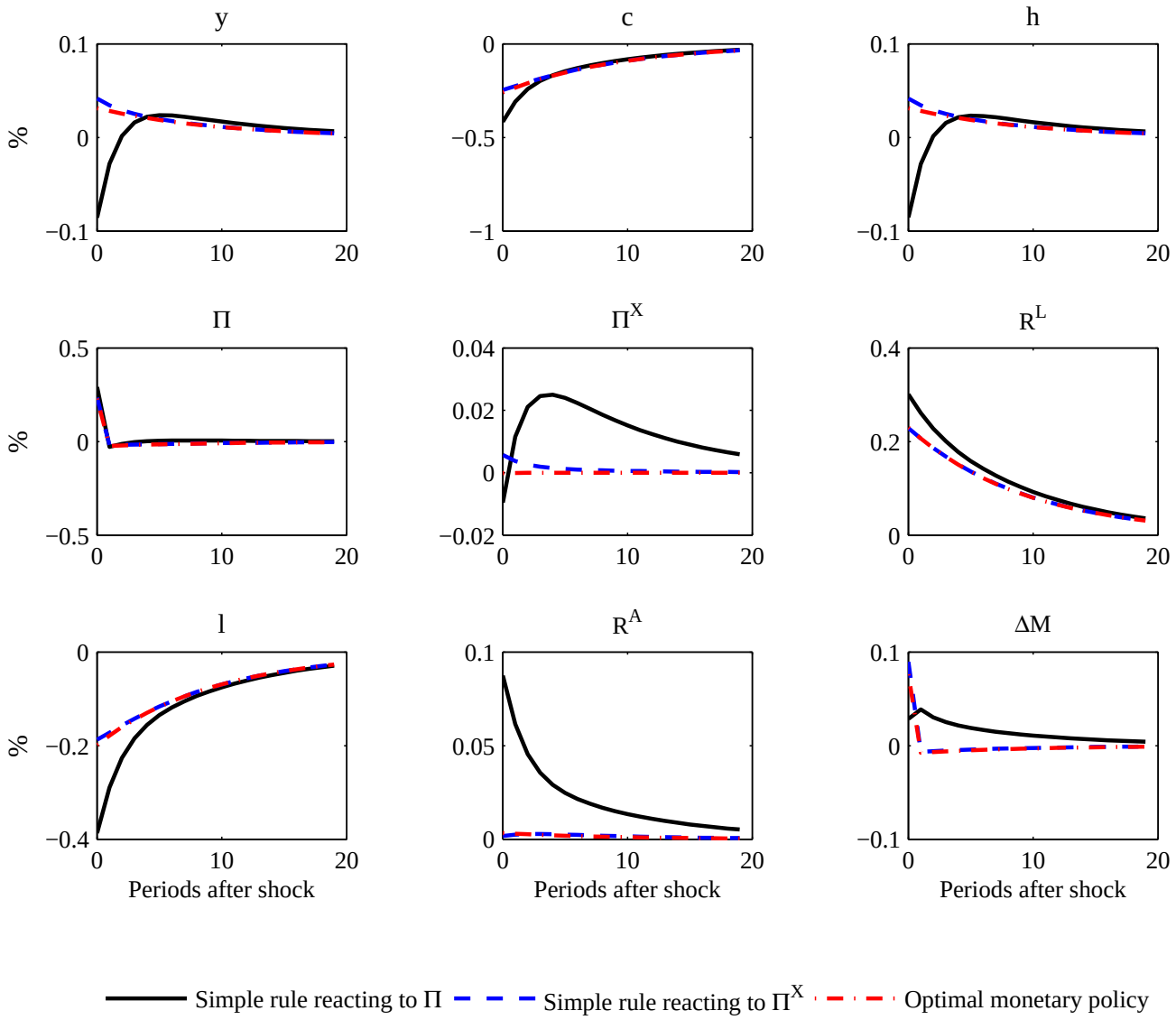

Figure 5: Responses to default shock in the absence of equity market frictions

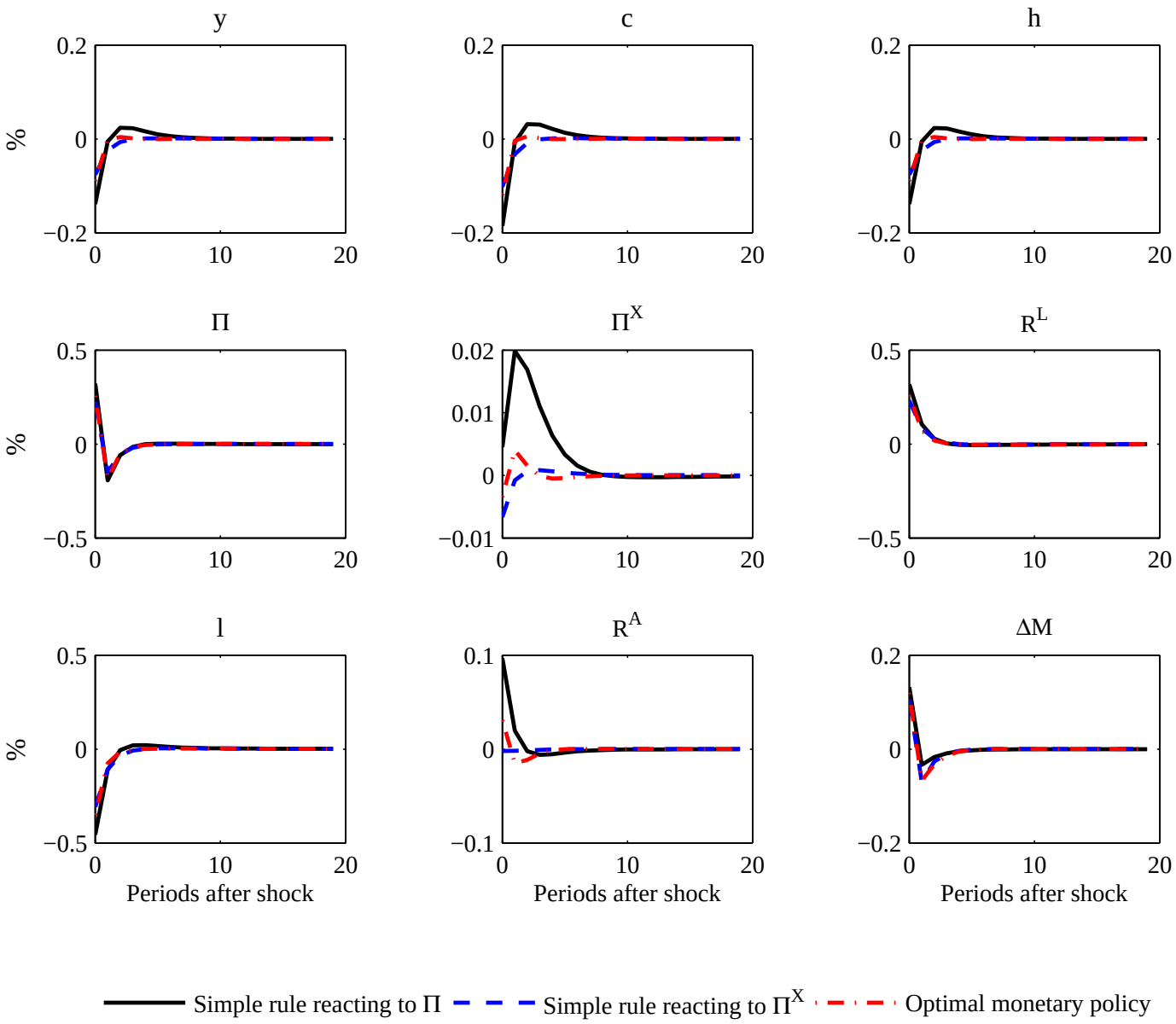

Figure 6: Responses to shock to demand for reserves in the absence of equity market frictions

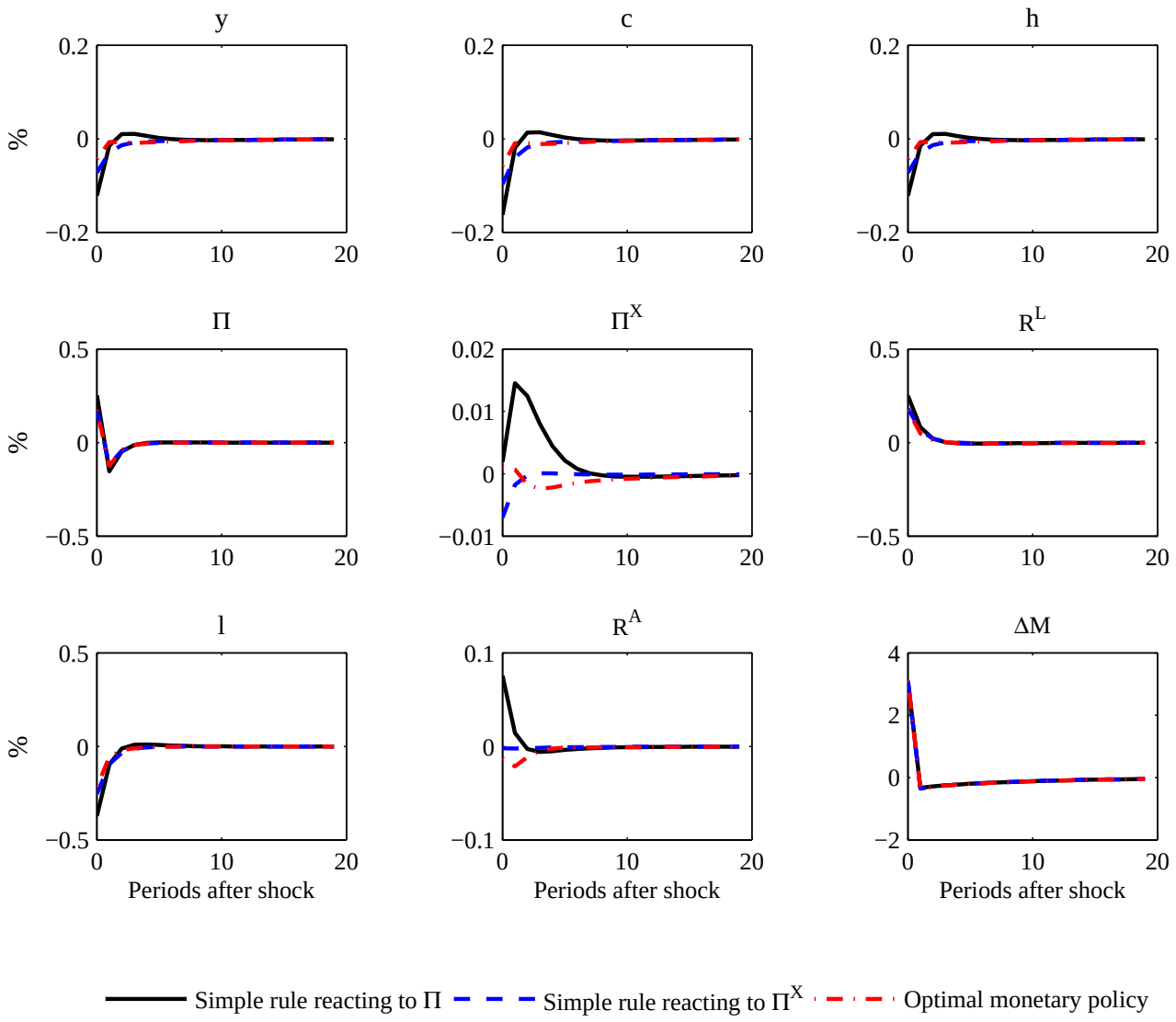

Figure 7: Responses to fiscal transfer to banks

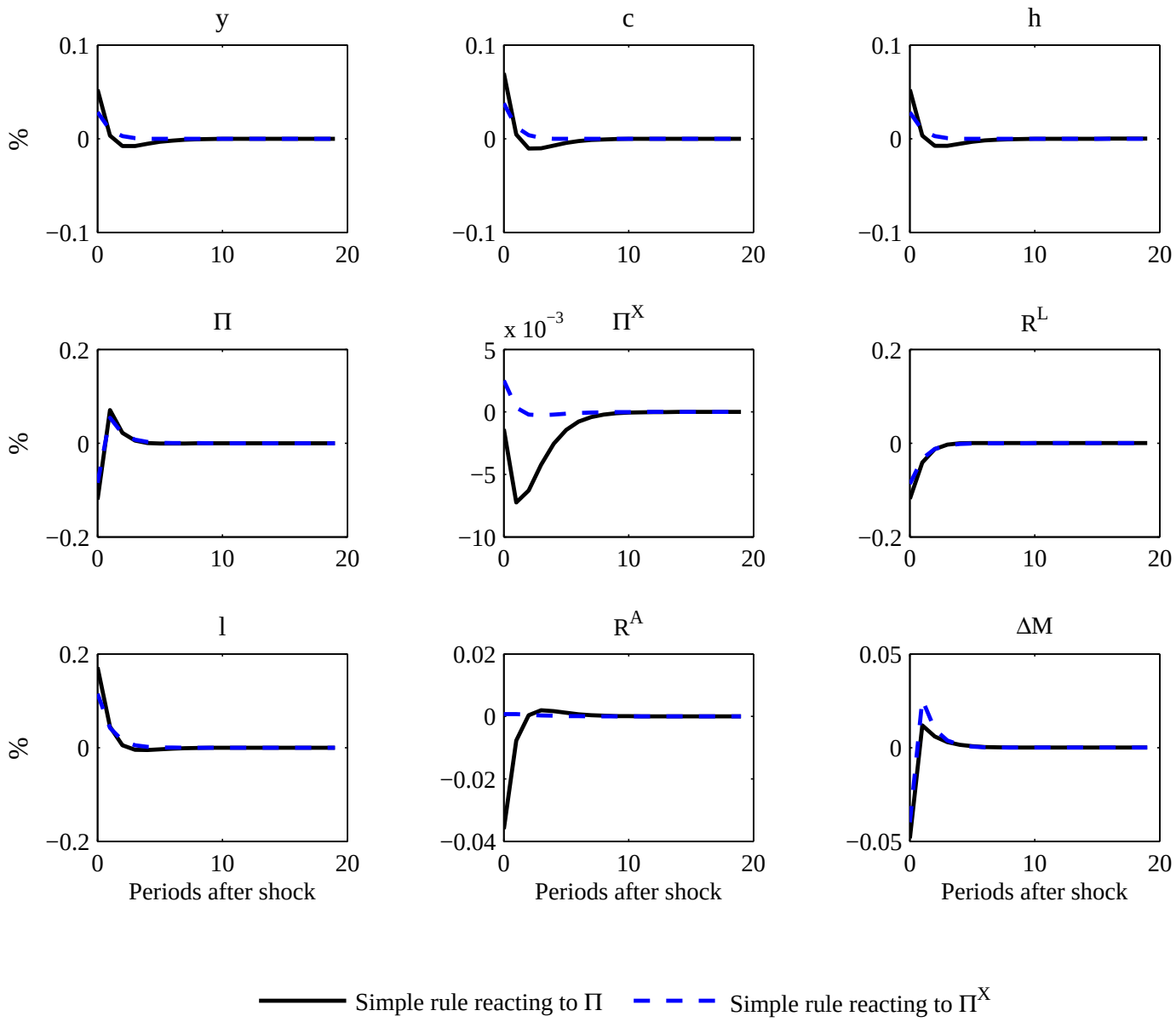

Figure 8: Responses to shock to demand for reserves