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Monetary Policy and the Financing of Firms†

By Fiorella De Fiore, Pedro Teles, and Oreste Tristani*

How should monetary policy respond to changes in financial conditions? We consider a simple model where firms are subject to shocks which may force them to default on their debt. Firms' assets and liabilities are nominal and predetermined. Monetary policy can therefore affect the real value of funds used to finance production. In this model, allowing for inflation volatility in response to aggregate shocks can be optimal; the optimal response to adverse financial shocks is to lower interest rates and to engineer some inflation; and the Taylor rule may implement allocations that have opposite cyclical properties to the optimal ones. (*JEL* G32, E31, E43, E44, E52)

During financial crises, credit conditions tend to worsen for all agents in the economy. In the press, there are frequent calls for a looser monetary policy stance, on the grounds that low nominal interest rates reduce the costs of external finance, thus countering the effects of the tightening of credit standards. Arguments tracing back to Irving Fisher (1933) can also be used to call for some degree of inflation during financial crises so as to avoid an excessive increase in firms' leverage through a devaluation of their nominal liabilities.

It is less clear, however, whether these arguments would withstand a more formal analysis. In this paper, we present a model that can be used to evaluate them. Our set up has three main features. First, firms' internal and external funds are imperfect substitutes. This is due to the presence of information asymmetries between firms and banks regarding firms' productivity, and to the fact that monitoring is a costly activity for banks. Second, firms' internal and external funds are nominal assets. Third, those funds, both internal and external, as well as the interest rate on bank loans, are predetermined when aggregate shocks occur. The last two features, combined, distinguish our analysis from previous literature, in particular, Ben S. Bernanke, Mark Gertler, and Simon Gilchrist (1999) and Charles T. Carlstrom and Timothy S. Fuerst (2001), and allow us to address issues related to the conduct of monetary policy when debt deflation or debt overhang are major policy concerns.

*De Fiore: European Central Bank, Directorate General Research, Postfach 160319, D-60066 Frankfurt am Main (e-mail: fiorella.de_fiore@ecb.int); Teles: Banco de Portugal, R. Francisco Ribeiro N. 2 1150 Lisboa, Portugal, Universidade Catolica Portuguesa, and Centre for Economic Policy Research (e-mail: pteles@ucp.pt); Tristani: European Central Bank, Directorate General Research, Postfach 160319, D-60066 Frankfurt am Main (e-mail: oreste.tristani@ecb.int). We wish to thank Kosuke Aoki, Isabel Correia, Skander Van den Heuvel, Alistair Milne, Stephanie Schmitt-Grohe, Kevin Sheedy, and the referees for very useful comments and suggestions. We also thank participants at seminars where this paper was presented. Teles gratefully acknowledges the financial support of Fundação de Ciência e Teconologia. The views expressed here are personal and do not necessarily reflect those of the ECB or of the Banco de Portugal.

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More specifically, we address the following questions: How should monetary policy respond to financial shocks? How should it respond to other shocks when financial conditions affect macroeconomic outcomes? Should monetary policy engineer inflation during recessions in order to reduce real debt liabilities? How relevant is the zero bound on the nominal interest rate?

We find that, for the Ramsey planner, allowing for short-term inflation volatility in response to exogenous shocks can be optimal. In response to technology shocks, for example, the price level should move to adjust the real value of total funds. If the shock is negative, the price level increases on impact to lower real funds as well as the real wage. Subsequently, the price level falls in order to increase the real wage at the same pace as productivity, in the convergence back to the steady state. Along the adjustment path, deposit and loan rates, spreads, financial markups, leverage, and bankruptcy rates remain stable.

The optimal response to a financial shock that reduces firms' internal funds, increasing firms' leverage, also involves an increase in the price level on impact. Because funds are predetermined, the shock only increases leverage with a delay. On impact it is optimal to generate inflation in order to reduce the real value of total funds, lowering production, and increasing markups. Profits are higher, and there is a faster accumulation of internal funds. Firms can deleverage more quickly.

In the baseline version of our model, where the level of government consumption is exogenous, the optimal policy rate is zero, corresponding to the Friedman rule. In these economies, however, because assets are nominal and predetermined, a set path for the nominal interest rate does not pin down equilibrium allocations. Policy can additionally affect allocations through ex post volatility of the price level.

To analyze the optimal interest rate reaction to shocks, we introduce government consumption as an exogenous share of production. This assumption generates a rationale for proportionate taxation. Since the nominal interest rate acts as a tax on consumption, the optimal steady-state interest rate becomes positive.

When the optimal average interest rate is away from the lower bound, it may be optimal for the interest rate to respond to shocks. This is indeed the case for financial shocks but not for technology shocks. In response to technology shocks, it is optimal to keep rates constant even if they could be lowered. For financial shocks, instead, the flexibility of moving the nominal interest rate downward allows policy to speed up the adjustment process. Moreover, the effect of these shocks on output can be considerably mitigated. For instance, a shock that reduces the availability of internal funds is persistently contractionary when the short-term nominal rate is kept fixed at zero, while it is less contractionary and has very short-lived effects on output when the average interest rate is away from the lower bound and can be reduced.

The negative shock to internal funds increases the distortion associated with the information asymmetry. This means that bankruptcy rates are higher, and also that spreads are higher. The effects of higher spreads can be partially offset by a cut in the policy rate. The total financial distortion is higher, but not as high as when the policy rate cannot be lowered. Instead, in response to a technology shock, it is feasible and optimal to fully stabilize the financial distortion. The proportionate distortion associated with the information asymmetry is not affected, and the policy rate does not have to move.

Compared to the optimal Ramsey plan, a policy response according to a simple Taylor-type rule can be costly, in the sense of inducing more persistent deviations in real variables from their optimal values and higher bankruptcy rates. In response to technology shocks, bankruptcies become countercyclical under the simple rule, while they are acyclical under the optimal policy. In response to a financial shock that reduces internal funds, there is deflation initially, which increases the real value of total funds and leads to a larger increase in leverage. Initially, the reduction in output is smaller than under the optimal policy, and markups decrease, inducing higher bankruptcy rates.

This paper contributes to the literature that analyzes the effects of financial factors on the transmission of shocks. Financial factors play a role because of agency costs, as in Bernanke, Gertler, and Gilchrist (1999) and Carlstrom and Fuerst (1997, 1998, 2001). In Bernanke, Gertler, and Gilchrist (1999), agency costs are added to an otherwise standard New Keynesian model, where monetary policy has real effects because of the presence of sticky prices. In Carlstrom and Fuerst (2001), prices are flexible, but money affects real activity because of a cash-in-advance constraint on households' purchases. In our model, prices are flexible, but monetary policy has real effects because firms must use funds to pay wages, and these funds are nominal and predetermined.

Our work is most closely related to a recent literature that analyzes optimal monetary policy in models with financial frictions (see e.g., Federico Ravenna and Carl E. Walsh (2006); Vasco Cúrdia and Michael Woodford (2009); De Fiore and Tristani (2009); Carlstrom, Fuerst, and Matthias Paustian (2010); and Ester Faia (2008)).[1] Ravenna and Walsh (2006) characterize optimal monetary policy when firms need to borrow to finance production, but there is no default risk and the cost of financing is the risk-free rate. Cúrdia and Woodford (2009) consider a model where financial frictions matter for the allocation of resources because of the heterogeneity in households' spending opportunities. In their setup, credit spreads arise because loans are costly to produce, but they are linked to macroeconomic conditions through a flexible reduced-form function. Instead, credit spreads emerge as the outcome of an optimal financial contract in De Fiore and Tristani (2009) and Faia (2008), while Carlstrom, Fuerst, and Paustian (2010) model agency costs as a constraint on the firm's hiring of labor. In all these papers, prices are assumed to be sticky. The main lesson from this literature is that, in the presence of financial frictions, both financial and nonfinancial shocks create a trade-off between inflation and output gap stabilization. Although perfect price stability is in general not optimal, under reasonable calibrations, the welfare gains associated with price stability are much larger than those associated with mitigating the financial distortions.

The main distinguishing feature between these models and ours is the assumption that firms' financing conditions are predetermined when aggregate shocks occur. In our model, the stock of internal funds, the amount of bank loans, and the interest rate on bank loans are not contingent on the realization of aggregate shocks. This enables us to study how changes in the inflation rate may have an impact on the dynamics of

[1] See also Lawrence Christiano, Roberto Motto, and Massimo Rostagno (2003).

firms' leverage. To study this particular channel of transmission of monetary policy, we abstract from other frictions, such as sticky prices.

Building upon the setup in Bernanke, Gertler, and Gilchrist (1999), Gilchrist and John V. Leahy (2002) and Faia and Tommaso Monacelli (2007) find that the presence of financial frictions does not provide a justification for an interest rate rule reacting to asset prices directly. They show that a policy where the interest rate reacts strongly to inflation closely approximates the optimal policy. This policy is not optimal in our model, as it comes close to implementing price stability. It is still better, however, than the outcome of the simple Taylor rule, where prices are not stabilized but move in the wrong direction.

The paper proceeds as follows. In Section I, we first describe the model and define the equilibria. Then, we derive implementability conditions and characterize optimal monetary policy. In Section II, we provide numerical results on the response of the economy to various shocks. We compare the case where the optimal interest rate policy is the Friedman rule to the case where because government consumption is assumed to be a fixed share of output, the optimal average interest rate is away from zero. We describe results both under the optimal monetary policy and a suboptimal (Taylor) rule. In Section III, we conclude.

I. Model

We consider a model where firms need internal and external funds to produce, and they fail if they are not able to repay their debts. Both internal funds and firm debt are nominal assets. Funds are decided for the following period, implying that they are predetermined.[2]

In the economy there are households, entrepreneurs that own the firms, banks that intermediate loans, and a government or central bank. The households have preferences over consumption, labor, and real money. For convenience, we assume separability for the utility in real balances.[3]

Production uses labor only with a linear technology. Aggregate productivity is stochastic. In addition, each firm faces an idiosyncratic shock whose realization is private information. The shock can be observed by the banks at a cost.

Entrepreneurs need to borrow in advance to finance production. The payments on outstanding debt are not state contingent. Entrepreneurs are risk-neutral, patient agents that die with some probability. They postpone consumption to the time of death. The death rate ensures that internal funds are not accumulated to the point where there would be no need for external finance.

Entrepreneurs pay a constant consumption tax, which does not affect their marginal decisions. We consider the limiting case where consumption is fully taxed, so that the weight of the entrepreneurs in the social welfare function is not relevant.

Banks are financial intermediaries. They are zero profit, zero risk operations. Banks take deposits from households and allocate them to entrepreneurs on the

[2] This is the timing of transactions in Lars E. O. Svensson (1985).

[3] We also assume a negligible contribution of real balances to welfare. This does not mean that the economy is cashless since firms face a cash-in-advance constraint.

basis of a debt contract, where the entrepreneurs repay their debts if production is sufficient and default otherwise, handing in total production to the banks, provided these pay the monitoring costs. Because there is aggregate uncertainty, we assume that the government can make lump sum transfers between the households and the banks to ensure that banks make zero profits in every state.[4] This way the banks are able to pay a risk-free rate on deposits.

The banks are owned, but not controlled,[5] by the entrepreneurs. They behave as risk neutral agents, which is convenient since the financial contract is then between two risk-neutral agents.

Monetary policy can affect the real value of total funds available for the production of firms, but it can also affect the real value of debts that need to be repaid. Furthermore, monetary policy also affects the deposit and loan rates.

In the timing of events, it is important that idiosyncratic shocks are revealed after production takes place, and that financial decisions are made after production decisions. To make this clear, we consider three subperiods. In the first subperiod, aggregate shocks are revealed. Entrepreneurs hire labor, supplied by the households. They pay the wage bill using total funds, internal and external, brought in from the previous period. They enter into production. In the second subperiod, the outcome of production—the idiosyncratic shock—is revealed to each entrepreneur. The entrepreneur either sells the produced goods or declares bankruptcy, in which case the bank appropriates production. Entrepreneurs make consumption decisions and a tax is levied on their consumption. Households also purchase consumption goods and pay lump sum taxes. In the third subperiod, households make financial decisions. They allocate their wealth to money, nominal state-contingent bonds, and deposits. Entrepreneurs that did not declare bankruptcy pay debts to banks. Lump sum taxes/subsidies are levied on banks to ensure that profits are zero ex post. Banks lend to entrepreneurs, entering nominal debt contracts that are noncontingent on aggregate shocks.

A. *Households*

The aggregate uncertainty in period $t \geq 0$ is described by the random variable $s_t \in S_t$, where S_t is the set of possible events at t. The history of its realizations up to period t, or state at t, is $s^t \in S^t$. We assume that s_t has a discrete distribution. $\Pr(s^{t+1} \mid s^t)$ is the probability of state s^{t+1}, conditional on s^t. We index variables by the subscript t when they are a function of the state s^t.

At the end of period t, households decide on holdings of money M_t that they will be able to use at the beginning of period $t + 1$, and on one-period deposits denominated in units of currency D_t that will pay $R_t^d D_t$ at the end of period $t + 1$. Deposits are riskless, in the sense that banks do not fail. The households also decide on nominal state-contingent bonds, $B_{t,t+1}$, each paying a unit of currency in a particular state in period $t + 1$ and each costing $Q_{t,t+1}$ units of money at t.

[4] We assume that the monitoring activities of banks can be observed, in order to keep the incentives to monitor unaffected by the insurance scheme. This amounts to assuming that bank supervision can be exercized at zero cost.
[5] Each entrepreneur owns an arbitrarily small share of each bank.

The budget constraint in period t is

$$M_t + \sum_{s^{t+1}|s^t} Q_{t,t+1} B_{t,t+1} + D_t \leq B_t + R^d_{t-1} D_{t-1} + M_{t-1} - P_t c_t + W_t n_t - T^h_t, \tag{1}$$

where c_t is the amount of the final consumption good purchased; P_t is its price in units of money, n_t is hours worked; W_t is the nominal wage; and T^h_t are lump sum taxes, in nominal units, collected by the government.

The household's problem is to maximize utility, defined as

$$E_0\left\{\sum_0^\infty \beta^t [u(c_t, m_t) - \alpha n_t]\right\}, \tag{2}$$

subject to (1) and to a non-Ponzi games condition. Here, $u_c > 0$, $u_m \geq 0$, $u_{cc} < 0$, $u_{mm} < 0$, $\alpha > 0$, and $m_t \equiv M_{t-1}/P_t$ denote real money balances. Throughout we will assume that the utility function is separable in real money, m_t, and that the contribution of money to welfare is negligible.

Optimality requires that the following conditions must hold:

$$\frac{u_c(t)}{\alpha} = \frac{P_t}{W_t}, \tag{3}$$

$$\frac{u_c(t)}{\beta \Pr(s^{t+1}|s^t) u_c(t+1)} = Q^{-1}_{t,t+1} \frac{P_t}{P_{t+1}}, \tag{4}$$

$$\frac{u_c(t)}{P_t} = R^d_t E_t \frac{\beta u_c(t+1)}{P_{t+1}}, \tag{5}$$

$$E_t \frac{u_m(t+1)}{P_{t+1}} = E_t \frac{u_c(t+1)}{P_{t+1}} (R^d_t - 1). \tag{6}$$

$u_c(t)$ is the marginal utility of consumption in state s^t, and similarly for the other marginal utilities.

B. *Production*

The production sector is composed of a continuum of firms/entrepreneurs, indexed by $i \in [0, 1]$. Each firm is endowed with a stochastic technology that transforms $N_{i,t}$ units of labor into $\omega_{i,t} A_t N_{i,t}$ units of output. The random variable $\omega_{i,t}$ is independently and identically distributed across time and across firms, with distribution Φ, density ϕ, mean 1, and standard deviation $\sigma_{\omega,t}$. $\ln A_t$ is an AR (1) aggregate productivity shock. Aggregate shocks are observed at the beginning of the period, before production. The idiosyncratic shock $\omega_{i,t}$ is observed by each entrepreneur after production, and is private information. Its realization can be observed by the financial intermediary at the cost of a share μ_t of the firm's output.

The entrepreneurs decide, at the end of period $t-1$, the amount of internal funds to be available in period t, $Z_{i,t-1}$. Lending occurs through the financial intermediary.

The existence of aggregate shocks occurring during the duration of the contract implies that the intermediary's return from the lending activity is not safe, regardless of its ability to differentiate across the continuum of firms facing independently and identically distributed shocks. We assume the existence of a deposit insurance scheme that the government implements by completely taxing away the intermediary's profits whenever they are positive, and by providing subsidies whenever profits are negative. Such a scheme is financed with lump sum taxes and transfers to the household. It guarantees that the intermediary is always able to repay the safe return to the household, thus insuring households' deposits from aggregate risk.

The Financial Contract.—The firms must pay wages in the beginning of the period, before receiving the sales from production. They have to bring in nominal funds from the previous period in order to do so. Each firm is, thus, restricted to hire and pay wages according to

$$W_t N_{i,t} \leq X_{i,t-1}, \tag{7}$$

where $X_{i,t-1}$ are total funds, internal plus external, decided at the end of period $t-1$, to be available in period t. The firms have internal funds $Z_{i,t-1}$ and borrow $X_{i,t-1} - Z_{i,t-1}$.

At the beginning of period t, firms observe the aggregate shocks and decide whether to produce, before observing the idiosyncratic shock. We impose conditions under which it is efficient to use the funds for production, and the optimal contract guarantees that the firm will produce.

The informational structure in the economy corresponds to a costly state verification problem. The optimal debt contract stipulates a fixed payment of $R^l_{i,t-1}(X_{i,t-1} - Z_{i,t-1})$, when the firm is able to meet those payments, i.e., when $\omega_{i,t} \geq \overline{\omega}_{i,t}$. $\overline{\omega}_{i,t}$ is the minimum productivity level such that the firm is able to pay the fixed return to the bank, so that

$$P_t A_t \overline{\omega}_{i,t} N_{i,t} = R^l_{i,t-1}(X_{i,t-1} - Z_{i,t-1}). \tag{8}$$

If $\omega_{i,t} < \overline{\omega}_{i,t}$, the firm goes bankrupt, and hands out all the production $P_t A_t \omega_{i,t} N_{i,t}$. In this case, a constant fraction μ_t of the firm's output is destroyed in monitoring, so that the bank gets $(1-\mu_t) P_t A_t \omega_{i,t} N_{i,t}$. $R^l_{i,t-1}$ cannot depend on the idiosyncratic shock at t, but we also impose that it does not depend on the aggregate shocks at t.

We define the average share of production accruing to the firms and to the bank, after the repayment of the debt, respectively, as

$$f(\overline{\omega}_{i,t}) = \int_{\overline{\omega}_{i,t}}^{\infty} (\omega_{i,t} - \overline{\omega}_{i,t}) \Phi(d\omega) \tag{9}$$

and

$$g(\overline{\omega}_{i,t}; \mu_t) = \int_0^{\overline{\omega}_{i,t}} (1-\mu_t)\omega_{i,t} \Phi(d\omega) + \int_{\overline{\omega}_{i,t}}^{\infty} \overline{\omega}_{i,t} \Phi(d\omega). \tag{10}$$

Total output is split between the firm, the bank, and monitoring costs

$$f(\overline{\omega}_{i,t}) + g(\overline{\omega}_{i,t};\mu_t) = 1 - \mu_t G(\overline{\omega}_{i,t}), \tag{11}$$

where $G(\overline{\omega}_{i,t}) = \int_0^{\overline{\omega}_{i,t}} \omega_{i,t}\Phi(d\omega)$. $\mu_t G(\overline{\omega}_{i,t})$ is the expected output lost in monitoring.

The optimal contract is a vector $(R^l_{i,t-1}, X_{i,t-1}, \overline{\omega}_{i,t}, N_{i,t})$ that solves the problem of maximizing the expected production accruing to firms, after repaying the debt,

$$\max\ E_{t-1}\left[f(\overline{\omega}_{i,t})\,P_tA_tN_{i,t}\right],$$

subject to

$$W_tN_{i,t} \leq X_{i,t-1} \tag{12}$$

$$E_{t-1}[g(\overline{\omega}_{i,t};\mu_t)P_tA_tN_{i,t}] \geq R^d_{t-1}(X_{i,t-1} - Z_{i,t-1}) \tag{13}$$

$$E_{t-1}[f(\overline{\omega}_{i,t})P_tA_tN_{i,t}] \geq R^d_{t-1}Z_{i,t-1}, \tag{14}$$

where $g(\overline{\omega}_{i,t};\mu_t)$ and $f(\overline{\omega}_{i,t})$ are given by (9) and (10), respectively, and $\overline{\omega}_{i,t}$ is given by (8).[6]

The optimal contract maximizes the entrepreneur's expected return subject to the borrowing constraint for firms, (12); the financial intermediary receiving an amount not lower, on average, than the repayment requested by the household (the safe return on deposits), (13); and the entrepreneur being willing to sign the contract, (14).

The decisions on $X_{i,t-1}$ and $Z_{i,t-1}$ are made at the end of period $t - 1$. We can replace $N_{i,t} = X_{i,t-1}/W_t$ and divide the constraints by $X_{i,t-1}$ to get

$$\max\ E_{t-1}\left[\frac{P_tA_t}{W_t}X_{i,t-1}f(\overline{\omega}_{i,t})\right], \tag{15}$$

subject to

$$E_{t-1}\left[\frac{P_tA_t}{W_t}g(\overline{\omega}_{i,t};\mu_t)\right] \geq R^d_{t-1}\left(1 - \frac{Z_{i,t-1}}{X_{i,t-1}}\right) \tag{16}$$

$$E_{t-1}\left[\frac{P_tA_t}{W_t}f(\overline{\omega}_{i,t})\right] \geq R^d_{t-1}\frac{Z_{i,t-1}}{X_{i,t-1}}, \tag{17}$$

where $f(\overline{\omega}_{i,t})$ and $g(\overline{\omega}_{i,t};\mu_t)$ are given by (9) and (10), respectively, and where $\overline{\omega}_{i,t}$, defined by (8), can be rewritten as $\overline{\omega}_{i,t} = (R^l_{i,t-1}/(P_tA_t/W_t))\,(1 - (Z_{i,t-1}/X_{i,t-1}))$.

[6] The problem is written under the restriction that the firm will use the funds for production, after observing the aggregate shock. This is optimal for both the firm and the bank, as long as $[1 - \mu_t(G\overline{\omega}_t)]P_tA_tN_{i,t} \geq X_{i,t-1}$. The firm can be induced to produce by an optimal contract stipulating that if it does not, the bank will appropriate all the funds. If it is optimal for the firm to produce, then the financial constraint (12) holds with equality. Then, it is efficient that the firm produces provided $P_tA_t/W_t \geq 1/(1 - \mu_tG(\overline{\omega}_t))$. As long as the economy is sufficiently distorted (because the deposit rate and/or the credit spreads are high enough), and shocks are small, this condition will be satisfied (see condition (30)).

Given that $Z_{i,t-1}$ is exogenous to this problem and is predetermined, we can multiply and divide the objective by $Z_{i,t-1}$, so that the problem is written in terms of $Z_{i,t-1}/X_{i,t-1}$, $R^l_{i,t-1}$, and $\overline{\omega}_{i,t}$ only. The objective and the constraints of the problem are the same for all firms. The only firm-specific variable would be $Z_{i,t-1}$ in the objective, but this would be irrelevant for the maximization problem. Hence, the solution for $Z_{i,t-1}/X_{i,t-1}$, $R^l_{i,t-1}$, and $\overline{\omega}_{i,t}$ is the same across firms.

We define

$$z_{t-1} \equiv \frac{Z_{i,t-1}}{X_{i,t-1}}, \text{ and } v_t \equiv \frac{P_t A_t}{W_t}. \tag{18}$$

We can then rewrite $\overline{\omega}_{i,t}$ as

$$\overline{\omega}_{i,t} \equiv \overline{\omega}_t = \frac{R^l_{t-1}(1 - z_{t-1})}{v_t}. \tag{19}$$

This condition, defining the bankruptcy threshold, together with the first-order conditions of the optimal contract problem, which can be written as[7]

$$E_{t-1}[v_t f(\overline{\omega}_t)] = \frac{R^d_{t-1}}{1 - \dfrac{E_{t-1}[\mu_t \overline{\omega}_t \phi(\overline{\omega}_t)]}{E_{t-1}[1 - \Phi(\overline{\omega}_t)]}} z_{t-1} \tag{20}$$

and

$$E_{t-1}[v_t g(\overline{\omega}_t; \mu_t)] = R^d_{t-1}(1 - z_{t-1}), \tag{21}$$

characterizes the optimal $(R^l_{t-1}, z_{t-1}, \overline{\omega}_t)$.

C. *Entrepreneurs*

The assumptions on the entrepreneurs are as in Bernanke, Gertler, and Gilchrist (1999). Entrepreneurs die with probability γ_t. They have linear preferences over consumption with discount factor β^e. We assume β^e sufficiently high so that the return on internal funds is always higher than the rate of time preference, $(1/\beta^e) - 1$. It follows that the entrepreneurs postpone consumption until the time of death. When entrepreneurs die, or go bankrupt, they are reborn, or restart, with ε funds that can be made arbitrarily small, transferred to them from the government.

For reasons that will become clear when we discuss optimal policy, we depart from Bernanke, Gertler, and Gilchrist (1999) in assuming that consumption of entrepreneurs is taxed at a constant rate τ. The constant consumption tax rate does not affect their marginal decisions.

The entrepreneurs put all of their funds into production and keep the share $f(\overline{\omega}_t)$ of production. The aggregate accumulation of internal funds is given by

$$Z_t = f(\overline{\omega}_t) P_t A_t N_t - (1 + \tau) P_t c^e_t, \tag{22}$$

[7] This is shown in Appendix A.

where the aggregate expenditure on consumption by the entrepreneurs, gross of consumption taxes, $(1+\tau)P_t c_t^e$, is equal to the funds of the entrepreneurs that die, so that

$$c_t^e = \frac{\gamma_t f(\overline{\omega}_t) A_t N_t}{1+\tau}, \tag{23}$$

and

$$Z_t = (1-\gamma_t) f(\overline{\omega}_t) P_t A_t N_t. \tag{24}$$

The accumulation of funds can also be written as

$$Z_t = (1-\gamma_t) f(\overline{\omega}_t) \frac{v_t}{z_{t-1}} Z_{t-1}. \tag{25}$$

We consider the limiting case where consumption of entrepreneurs is fully taxed. As the tax rate is made arbitrarily large, the consumption of the entrepreneurs approaches zero, $c_t^e \to 0$, and the consumption tax revenue, $T_t^e = \tau\gamma_t f(\overline{\omega}_t) P_t A_t \times N_t/(1+\tau)$, approaches the total funds of the entrepreneurs that die. The consumption taxes do not affect the accumulation of funds. They only affect how much the entrepreneurs consume out of those funds.[8]

D. *Government*

We assume that government consumption is a share g of production net of the monitoring costs. The accumulation of liabilities by the government is governed by the period t constraint

$$M_t^s + \sum_{s^{t+1}/s^t} Q_{t,t+1} B_{t,t+1}^s \geq B_{t-1,t}^s + M_{t-1}^s + g P_t A_t N_t [1 - \mu_t G(\overline{\omega}_t)] - T_t, \tag{26}$$

where $T_t = T_t^h + T_t^e + T_t^b$. T_t^b are the taxes/subsidies on the profits/losses of banks. M_t^s and $B_{t,t+1}^s$ are the supply of money and state contingent assets, respectively.

E. *Equilibria*

The equilibrium conditions are given by equations (3)–(6), (7) holding with equality, (19), (20), (21),

$$Z_{i,t} = z_t X_{i,t}, \tag{27}$$

together with (25), the resource constraints

$$c_t = (1-g) A_t N_t [1 - \mu_t G(\overline{\omega}_t)], \tag{28}$$

[8] In the steady state, real internal funds are constant, meaning that $(1-\gamma) f(\overline{\omega})(v/z)/\Pi = 1$, where Π is steady state gross inflation. For the individual entrepreneur, the decision to postpone consumption in the steady state requires $1/\beta^e < f(\overline{\omega})(v/z)/\Pi$, so that $1/\beta^e < 1/(1-\gamma)$.

and the remaining market clearing conditions

$$M_t + Z_t = M_t^s$$

$$B_{t,t+1} = B_{t,t+1}^s$$

$$D_t = X_t - Z_t,$$

$$\int N_{i,t} di = N_t = n_t,$$

where $\int Z_{i,t} di = Z_t$, $\int X_{i,t} di = X_t$, and where $f(\overline{\omega}_t)$ and $g(\overline{\omega}_t; \mu_t)$ are given by (9) and (10), respectively, with $\overline{\omega}_t$ replacing $\overline{\omega}_{it}$.

Aggregating across firms, imposing market clearing, and using the definition of the mark up v_t in (18), we can write conditions (7) holding with equality, and (27) as

$$\frac{Z_{t-1}}{P_t} = z_{t-1} \frac{A_t}{v_t} n_t,$$

and

$$z_t = \frac{Z_t}{X_t}. \tag{29}$$

The equilibrium conditions are summarized in Appendix B, where we also show that, given a set path for the price level, there is a unique equilibrium for all the other variables.

Using (18) and the households intratemporal condition (3), we can write

$$v_t = \frac{u_c(t) A_t}{\alpha}.$$

v_t is a measure of the wedge between the marginal rate of substitution of consumption for leisure, $u_c(t)/\alpha$, and the marginal rate of transformation without taking into account the financial frictions, A_t. We can then combine the conditions of the contract, (20) and (21), together with $f(\overline{\omega}_t) = 1 - \mu_t G(\overline{\omega}_t) - g(\overline{\omega}_t; \mu_t)$, obtained from (11), to obtain

$$E_{t-1}\left[\frac{u_c(t)A_t}{\alpha}\left[1 - \mu_t G(\overline{\omega}_t) - f(\overline{\omega}_t)\frac{E_{t-1}[\mu_t \overline{\omega}_t \phi(\overline{\omega}_t)]}{E_{t-1}[1 - \Phi(\overline{\omega}_t)]}\right]\right] = R_{t-1}^d, t \geq 1. \tag{30}$$

This condition is useful to understand how the wedge $u_c(t)A_t/\alpha$ is affected by shocks and by policy.

F. *Optimal Policy*

We consider optimal Ramsey policy with commitment. The assumption of commitment is relevant since the Ramsey policy is not time consistent. At any point in time, it would be possible to lower the price level to increase the real value of funds, and lower the distortion associated with the costly state verification and limited internal funds. This would be optimal ex post but not necessarily ex ante. At time zero, it would be optimal to do it once and for all. We abstract from the optimal policy at time zero, in accordance with the timeless perspective in Michael Woodford (2003).

The objective of policy is to maximize the welfare of the households. We have allowed for a constant consumption tax on the entrepreneurs that acts as a lump sum tax. We consider the limiting case where entrepreneurs are fully taxed. Entrepreneurs' consumption is zero, their utility is zero, and therefore their weight in the welfare function does not matter.

We do not include the entrepreneurs in the social welfare function because we do not want to think of them as actual agents, but as a way to introduce the financial friction that we are interested in. In order to give entrepreneurs zero weight in the welfare function, we should also not have them consume. Otherwise optimal policy would be affected in unreasonable ways. If they were to consume because they are risk neutral, the planner would use policy to try to insure the risk averse households against aggregate shocks. The planner would also use policy to distribute away from the entrepreneurs to the households. In particular, the average nominal interest rate, which taxes entrepreneurs because they need to use funds in advance of production, would be higher for that reason.

We have assumed that government consumption is a share of production net of monitoring costs. This assumption has important implications for the optimal average nominal interest rate. Since the share of production g is wasted, it is optimal to distort production at a rate that is approximately equal to g. This way the waste in resources is internalized. When $g = 0$,[9] the Friedman rule is optimal in steady state, $R^d = 1$, as we show below, analytically. The Friedman rule is also optimal in response to shocks, in the calibrated version we analyze below.[10] Instead, when $g > 0$, as also shown below, it is optimal to distort the consumption-leisure margin, even if lump sum taxes are available. Since the nominal interest rate acts as a consumption tax, it is optimal to set it higher than zero.[11]

We compute the optimal allocations, as well as the prices and policies that support them. We abstract from the issue of how to implement the optimal allocation. It is well known that, in monetary economies, setting the path for the nominal interest rate does not uniquely pin down equilibrium price levels. Because, in the economies we study here, the funds are nominal and predetermined, the allocations are also not uniquely pinned down. If the path for the price level is set exogenously, then there is a unique equilibrium. One way to think of policy would be that the central bank picks the path of interest rates as well as the price level in some, but not all, states. How the price level can be targeted with policy instruments other than the short-term nominal interest rate, is a question that is beyond the scope of this paper.

[9] If the level, and not the share, of government consumption was exogenous, the results would be as in the case of $g = 0$.

[10] This is the case if shocks are small.

[11] This is not a justification for positive average nominal interest rates, but rather it is a device to allow for movements in the nominal interest rate. If there were consumption or labor income taxes, the Friedman rule would again be optimal.

Bernardino Adão, Isabel Correia, and Teles (2010) is one of the many papers where implementation issues such as this are discussed.

Optimal Steady-State Policy.—In order to show that, when $g = 0$, the Friedman rule is optimal in the steady state, we first show that steady-state bankruptcy rates are independent of monetary policy.

Let R^e denote the gross return on internal funds for the entrepreneurs, which in the steady state is $f(\overline{\omega})v/z$. The following steady-state conditions determine R^e, R^d, v, z, $\overline{\omega}$, and R^l, given gross inflation Π, which is determined by policy:[12]

$$\frac{1}{\beta} = \frac{R^d}{\Pi} \tag{31}$$

$$\Pi = (1 - \gamma)\frac{f(\overline{\omega})v}{z} \tag{32}$$

$$R^e \equiv \frac{f(\overline{\omega})v}{z} = \frac{R^d}{1 - \mu\dfrac{\overline{\omega}\phi(\overline{\omega})}{1 - \Phi(\overline{\omega})}} \tag{33}$$

$$\frac{g(\overline{\omega})v}{1 - z} = R^d \tag{34}$$

$$\overline{\omega} = \frac{R^l(1 - z)}{v}. \tag{35}$$

The first condition is the intertemporal condition for the households, (5), in the steady state, stating that the real return on deposits has to be equal to the rate of time preference. The second condition restricts the accumulation of internal funds in the steady state, obtained from (25). In order for real internal funds to remain constant, the growth rate of nominal internal funds, $(1 - \gamma)f(\overline{\omega})v/z$, has to be equal to inflation, Π. $f(\overline{\omega})v/z$ is the gross nominal return on internal funds, which is the rate at which they would be accumulated if it was not for the death rate of entrepreneurs γ. The higher the death rate, the higher the return on internal funds. The third and fourth conditions are the steady-state conditions of the contract, (20) and (21). The third condition states that the gross nominal return for the entrepreneurs is equal to the deposit rate augmented by the spread $\mu\overline{\omega}\phi(\overline{\omega})/(1 - \Phi(\overline{\omega}))$. The fourth condition states that the gross average return for the banks has to be equal to the gross deposit rate, in order to ensure zero profits for the banks. Finally, the last condition is the definition of the bankruptcy threshold, (19), in the steady state.

From these conditions, we obtain

$$\frac{1 - \gamma}{\beta} = 1 - \frac{\mu\overline{\omega}\phi(\overline{\omega})}{1 - \Phi(\overline{\omega})}. \tag{36}$$

It is clear that higher average inflation in this economy is transmitted one-to-one to the deposit rate, and also to the lending rate. The markup, v, increases, also in

[12] These conditions are the same regardless of the value of g.

the same proportion, because of the intratemporal distortion created by the higher opportunity cost of funds for the firms. Higher average inflation does not affect the conditions of the contract ($\overline{\omega}$ is unaffected), so that the bankruptcy rate and the leverage rate are unchanged. Average inflation is neutral as far as those financial variables are concerned.[13]

The equilibrium restrictions in the steady state can be simplified as the implementability condition

$$\frac{u_c A}{\alpha} = \frac{R^d}{1 - \mu G(\overline{\omega}) - f(\overline{\omega})\frac{\mu\overline{\omega}\phi(\overline{\omega})}{1 - \Phi(\overline{\omega})}}, \tag{37}$$

the condition that $\overline{\omega}$ does not depend on policy, (36), and the resource constraint,

$$(1 - g)AN[1 - \mu G(\overline{\omega})] = c, \tag{38}$$

together with the restriction that the nominal interest rate cannot be negative, $R^d \geq 1$. The objective of policy is to maximize steady-state utility $u(c) - \alpha n$, subject to those restrictions.

We consider first the case where $g = 0$. For an exogenous $\overline{\omega}$, which is independent of policy, suppose we were to maximize utility, subject to the steady-state resource constraint (38) only. Then, optimality would require that

$$\frac{u_c A}{\alpha} = \frac{1}{1 - \mu G(\overline{\omega})}.$$

From (37), this could only be satisfied if either $\mu = 0$ or $\overline{\omega} = 0$, and $R^d = 1$. When credit frictions are present, and $\mu\overline{\omega}\phi(\overline{\omega})/(1 - \Phi(\overline{\omega})) \neq 0$, there is a reason to subsidize consumption. That could be done if interest rates could be negative. Since nominal interest rates must be positive, the optimal policy is the zero bound, $R^d = 1$. The Friedman rule is optimal.

The reason why it is optimal to subsidize production in the steady state is to undo the distortion caused by the spread between the return on internal funds and the deposit rate. In order to see this more clearly, it is useful to start with the condition on the sharing of production across entrepreneurs, banks, and monitoring costs, (11), which, in the steady state, is $f(\overline{\omega}) = 1 - \mu G(\overline{\omega}) - g(\overline{\omega})$. Multiplying through by the markup $v = u_c A/\alpha$, and using (33) and (34), we can write

$$\frac{u_c A[1 - \mu G(\overline{\omega})]}{\alpha} = \left[1 + \left(\frac{R^e}{R^d} - 1\right)z\right]R^d, \tag{39}$$

where, from (33) and (36),

$$\frac{R^e}{R^d} = \frac{1}{1 - \mu\frac{\overline{\omega}\phi(\overline{\omega})}{1 - \Phi(\overline{\omega})}} = \frac{\beta}{1 - \gamma}. \tag{40}$$

[13] Since $v = u_c A/\alpha$, for the case in which the utility function is logarithmic, an increase in Π lowers consumption in the same proportion.

There are two distortions affecting the margin between the marginal rate of substitution, u_c/α, and the marginal rate of transformation that takes into account the costs of monitoring, $A[1 - \mu G(\overline{\omega})]$. One distortion is caused by inflation which is translated into higher R^d, higher lending rate by the banks, and higher nominal return for the entrepreneurs. This distortion affects all of production. There is another distortion though, measured by the spread between the return on the internal funds and the deposit rate, and applying only to the share z of labor costs. This distortion is there because internal funds are scarce; and funds are scarce because entrepreneurs die. The higher the death rate of entrepreneurs is, the scarcer the funds, and the higher the return on them. This increases the average markup creating a larger distortion in the margin between consumption and leisure.

The distortion caused by inflation can be eliminated, setting the policy rate to zero, corresponding to $R^d = 1$. The distortion caused by the high return on internal funds cannot be eliminated with monetary policy.

With g sufficiently greater than zero, it is optimal to tax, on average. The same argument as above cannot go through. The optimal condition just using the resource constraint would require that

$$\frac{u_c A}{\alpha} = \frac{1}{(1 - g)[1 - \mu G(\overline{\omega})]}. \tag{41}$$

In spite of the reason to subsidize, due to $\mu\overline{\omega}\phi(\overline{\omega})/(1 - \Phi(\overline{\omega}))$ in equation (37), if g is high enough, it is optimal to tax. Then, as we show in the simulations below, it will be optimal to tax at different rates in response to financial shocks.

Debt Deflation.—In this economy, there is a role for debt deflation or inflation in response to shocks. Notice that the bankruptcy threshold for each firm i, defined in equation (8), implies

$$A_t \overline{\omega}_t N_{i,t} = \frac{R^l_{t-1}(X_{i,t-1} - Z_{i,t-1})}{P_t}.$$

Debt deflation, which occurs when there is a fall in the price level, P_t, directly increases the bankruptcy rate, $\overline{\omega}_t$, provided hired labor does not move. Ex post movements in the price level, by affecting the real value of outstanding debt, can have a role in stabilizing bankruptcy rates in response to shocks.

Notice, however, that total funds must satisfy

$$W_t N_{i,t} = X_{i,t-1}.$$

Substituting $N_{i,t}$ in the expression for the bankruptcy threshold above, we have

$$\frac{P_t A_t}{W_t}\overline{\omega}_t = R^l_{t-1}\left(1 - \frac{Z_{i,t-1}}{X_{i,t-1}}\right).$$

This makes it clear that what matters for bankruptcy rates is not the price level but the markup $v_t = P_t A_t / W_t$. High markups correspond to low bankruptcy rates. If the price level is reduced, but nominal wages are also reduced, keeping the markup constant, then labor goes up and nothing happens to the bankruptcy rate.

II. Optimal Cyclical Policy: Numerical Results

The model calibration is very standard. We assume utility to be logarithmic in consumption and linear in leisure. Following Carlstrom and Fuerst (1997), we calibrate the volatility of idiosyncratic productivity shocks and the steady-state death probability γ, so as to generate an annual steady-state credit spread of approximately 2 percent and a quarterly bankruptcy rate of approximately 1 percent.[14] The monitoring cost parameter μ is set at 0.15 following Andrew T. Levin, Fabio M. Natalucci, and Egon Zakrajsek (2004).

In the rest of this section, we focus on adverse shocks, i.e., shocks which tend to generate a fall in output. Impulse responses under optimal policy refer to an equilibrium in which policy is described by the first-order conditions of a Ramsey planner deciding allocations for all times $t \geq 1$, but ignoring the special nature of the initial period $t = 0$. Responses under a Taylor rule refer to an equilibrium in which policy is set according to the following simple interest rate rule:

$$\hat{r}_t^d = 1.5 \cdot \hat{\pi}_t, \tag{42}$$

where $r_t^d \equiv \ln R_t^d$, $\pi_t \equiv \ln(P_t/P_{t-1})$, and hats denote logarithmic deviations from the nonstochastic steady state.

In all cases, we only study the log-linear dynamics of the model.

A. *Impulse Responses under Optimal Policy*

Optimal policy in the calibrated version of the model entails setting the nominal interest rate permanently to zero, as long as $g = 0$. This restriction is imposed when computing impulse responses.

Technology Shocks.—Figure 1 shows the impulse response of selected macroeconomic variables to a negative, 1 percent technology shock under optimal policy, for $g = 0$. The variables are the technology process $a_t \equiv \ln A_t$, output $y_t \equiv \ln(A_t N_t)$, real internal funds $\bar{z}_t \equiv \ln(Z_{t-1}/P_t)$, and inflation π_t. Bankruptcy rates, markups, spreads, and leverage are not represented because there is no effect of the shock on those under the optimal policy.

It is important to recall that the model includes many features which could potentially lead to equilibrium allocations that are far from the first best: monitoring costs and limited internal funds; the predetermination of financial decisions; and the nominal denomination of debt contracts. At the same time, the presence of nominal predetermined contracts implies that monetary policy is capable of affecting allocations by choosing appropriate sequences of price levels.

[14] The exact values are 1.8 percent for the annual spread and 1.1 percent for the bankruptcy rate.

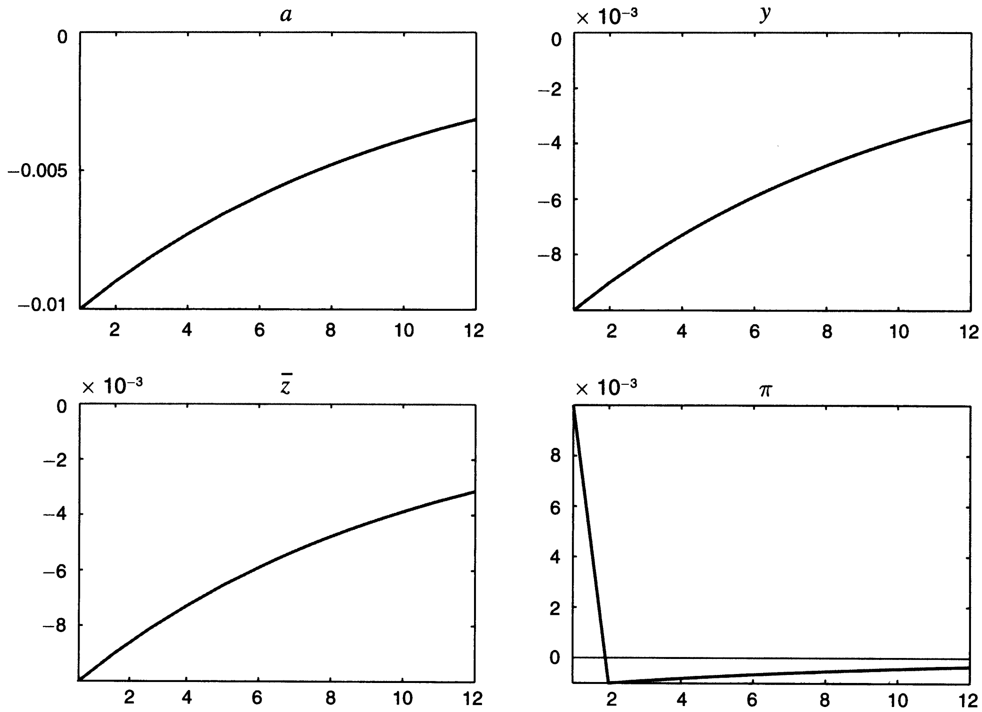

FIGURE 1. IMPULSE RESPONSES TO A NEGATIVE TECHNOLOGY SHOCK UNDER OPTIMAL POLICY

Notes: Logarithmic deviations from the nonstochastic steady state. Correlation of the shock: 0.9.

Figure 1 illustrates that optimal policy replicates the first-best response of consumption and labor allocations to a technology shock.[15] In response to the negative technology shock, since nominal internal and external funds are predetermined, optimal policy generates inflation for one period. As a result, the real value of total funds needed to finance production falls exactly by the amount necessary to generate the correct reduction in output.

In subsequent periods, the real value of total funds is slowly increased through a mild reduction in the price level. Along the adjustment path, leverage and bankruptcy rates remain constant. Consumption moves one-to-one with technology, while hours worked remain constant. With constant labor and an equilibrium nominal wage that stays constant, the restriction that funds are predetermined is not relevant. The price level adjusts so that the real wage is always equal to productivity. Since total funds are always at the desired level, the accumulation equation for nominal funds never kicks in.

The impulse responses in Figure 1 would obviously be symmetric after a positive technology shock. Hence, perfect inflation stabilization—i.e., an equilibrium in which inflation is kept perfectly constant at all points in time—is not optimal (we

[15] The allocations are distorted, but the responses are as in the first best. In an economy without any distortions, in response to a technology shock, labor would be constant and consumption and output would adjust in the same proportion to the shock.

show below that this is the case for all shocks, not just technology shocks). Allowing for short-term inflation volatility is useful to help firms adjust their funds, both internal and external, to their production needs. In the case of technology shocks, this policy also prevents any undesirable fluctuations in the economy's bankruptcy rate, financial markup, or the markup resulting from the predetermination of assets.

The result that inflation stabilization is not optimal is robust to a number of perturbations of the model. It also holds if there are reasons not to keep the nominal interest rate at zero. And it holds in a model where internal and external funds are perfect substitutes.

To provide intuition for these results, it is useful to consider condition (30), which, at the zero bound for the deposit rate, is

$$E_{t-1}\left[\frac{u_c(t)A_t}{\alpha}\left[1 - \mu_t G(\overline{\omega}_t) - f(\overline{\omega}_t)\frac{E_{t-1}[\mu_t \overline{\omega}_t \phi(\overline{\omega}_t)]}{E_{t-1}[1 - \Phi(\overline{\omega}_t)]}\right]\right] = 1. \tag{43}$$

$u_c(t)A_t/\alpha$ is the wedge between the marginal rate of substitution of consumption for leisure and the marginal rate of transformation in production (without taking into account financial costs). The inverse of the term in square brackets $1 - \mu_t G(\overline{\omega}_t) - f(\overline{\omega}_t)(E_{t-1}[\mu_t \overline{\omega}_t \phi(\overline{\omega}_t)]/E_{t-1}[1 - \Phi(\overline{\omega}_t)])$ is the financial markup due to the costly state verification and limited internal funds. If internal funds were not limited, there would be no such markup. The wedge has to be equal to the financial markup, on average, but not always in response to shocks.

One of the frictions in this economy is the predetermination of funds, which is a nominal rigidity. If this was the single friction, meaning that $\mu_t = 0$, and the nominal interest rate was zero, then condition (43) would be written as

$$E_{t-1}\left[\frac{u_c(t)A_t}{\alpha}\right] = 1. \tag{44}$$

The reason why this equilibrium condition is in expectation is precisely because of the predetermination of nominal assets. In this case, the goal of policy would be to move the price level so that the markup $u_c(t)A_t/\alpha$ would be exactly equal to one. Policy would be able to eliminate the single friction in the economy, neutralizing the nominal rigidity.

The nominal rigidity associated with the predetermination of nominal assets can be eliminated, as well as the distortion associated with a positive nominal interest rate due to the restriction that wages must be paid before firms receive production. The financial friction associated with the costly state verification and limited internal funds cannot be fully eliminated. This economy is in a second or third best, where all these frictions interact.[16] It turns out that, in response to technology shocks, it is optimal to neutralize the friction due to the predetermination of nominal assets, and to stabilize bankruptcy rates. In response to financial shocks, that is no longer the case, as will be seen below.

[16]The restriction that government spending is a share of production can also be seen as another distortion.

For logarithmic preferences, the optimal policy in response to technology shocks is to fully stabilize the financial markup, therefore keeping bankruptcy rates constant, and setting the wedge equal to the constant financial markup. Given that utility is logarithmic, consumption is proportional to the technology shock, which implies that labor does not move. From (12), we have that $X_{t-1} = (P_t A_t / \nu_t) N_t$. Since $N_t = N$, $\nu_t = \nu$, and X_{t-1} does not vary with shocks in t, it must be that the price level is inversely proportional to the technology shock. Since nominal funds are predetermined and labor does not move, the optimal policy is to keep the nominal wage constant and adjust the price level to the movements in the real wage.

Financial Shocks.—We can analyze the impulse responses to three types of financial shocks. The first is an increase in γ_t, namely a shock which generates an exogenous reduction in the level of internal funds. The second one is a shock to the standard deviation of idiosyncratic technology shocks, $\sigma_{\omega t}$, which amounts to an increase in the uncertainty of the economic environment. The third shock is an increase in the monitoring cost parameter μ_t. In the text, we focus on the first shock. The other two shocks are analyzed in Appendix C.

Contrary to the case of Figure 1, bankruptcy rates, markups, spreads, and leverage are not constant after financial shocks. In all these cases, therefore, we also report impulse responses of the log of internal to total funds, $z_t \equiv \ln(Z_t/X_t)$; log-consumption, c_t; the share of firms that go bankrupt, $\Phi(\overline{\omega}_t)$; the log-markup, ν_t; and the spread between the lending and the deposit rate, $\Delta_t \equiv \ln(R_t^l/R_t^d)$.

The impulse responses to γ_t in Figure 2 are interesting because they generate, at the same time, a reduction in output and an increase in leverage. Leverage can be defined as the ratio of external to internal funds used in production, i.e., as $1/z_t - 1$, and it is therefore negatively related to z_t. To highlight the different persistence of the effects of the shock, depending on the prevailing policy rule, we focus on a serially uncorrelated shock. The shock is standardized to generate approximately a 10 percent fall in internal funds.

The higher γ_t does not have an effect on funds on impact because of the predetermination of financing decisions, but it represents a fall in internal funds at $t + 1$, which leads to an increase in firms' leverage.

We will see that under a Taylor rule this shock brings about a period of deflation, which would be quite persistent if the original shock were also persistent. The optimal policy response, instead, is to create a short-lived period of inflation. The impact increase in the price level lowers the real value of total funds, so as to decrease labor and production levels. As a result of lower labor and production, markups increase on impact, so that the future cut in internal funds can be partially offset. The higher profits allow firms to quickly start rebuilding their internal funds. The adjustment process is essentially complete after three years. When consumption starts growing toward the steady state, the real rate must be higher. For given nominal interest rate, there must be a period of mild deflation.

The financial shock raises the distortion associated with the scarcity of internal funds. With the nominal interest rate at the zero bound, all monetary policy can do is to use price level policy to increase markups on impact and induce a faster accumulation of internal funds. But the financial markup is still high and variable. We will

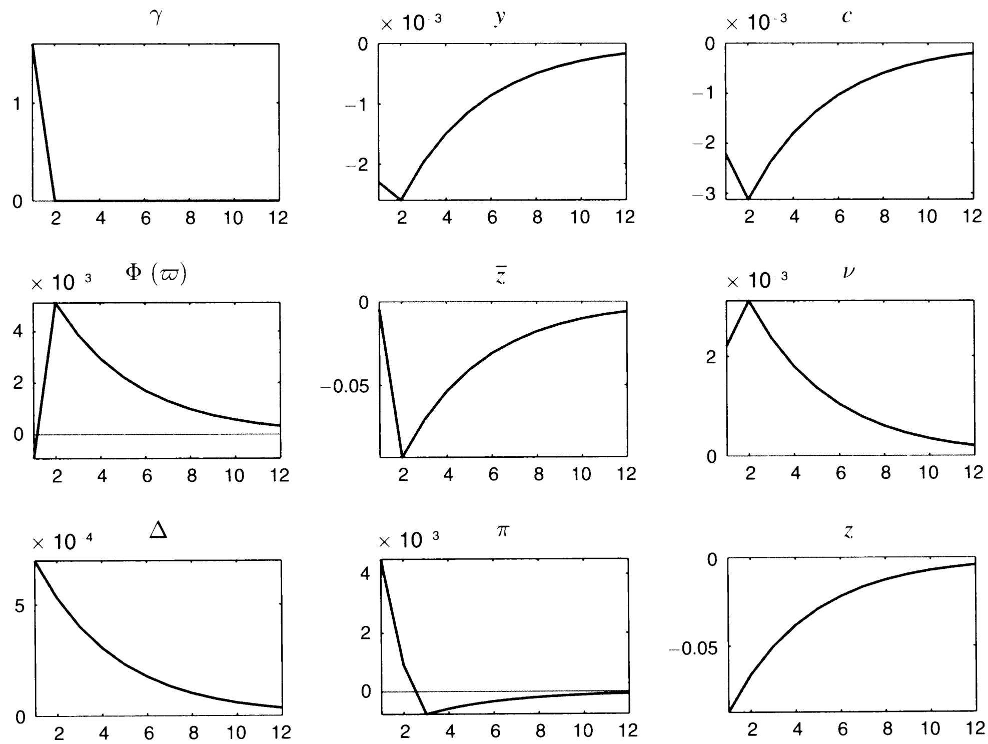

FIGURE 2. IMPULSE RESPONSES TO A FALL IN THE VALUE OF INTERNAL FUNDS UNDER OPTIMAL POLICY

Notes: Logarithmic deviations from the nonstochastic steady state. Serially uncorrelated shock.

see next that a cut in the nominal interest rate can offset the effects of the financial markup, stabilizing total markups, and inducing a less pronounced and much shorter lived downturn.

B. *Optimal Policy Away from the Zero Bound*

In this section, we explore to which extent the optimal policy recommendations described above are affected by the nominal interest rate being kept constant at zero. In the calibration, we keep all other parameters unchanged, but we assume that there is a fixed share of government consumption $g > 0$. As discussed above, the optimal steady-state level of the nominal interest rate is approximately equal to g. We therefore calibrate the government consumption share to generate a reasonably small steady-state value of the nominal interest rate, namely $g = 0.02$.

Technology Shocks.—In spite of the availability of the nominal interest rate as a policy instrument, the optimal response to a technology shock is the same as before. Policy replicates the response of the allocations which would be attained in a frictionless model, whether nominal interest rates can be moved or not. This result is striking because it implies that, in reaction to technology shocks, the zero bound on nominal interest rates does not represent a constraint for monetary policy in our model.

When the share of government spending is positive because it is optimal to set a positive nominal interest rate, $R_t^d > 1$, the relevant equilibrium condition is no longer (43) but (30), where the wedge between the marginal rate of substitution and the marginal rate of transformation in production, $u_c(t)A_t/\alpha$, is, on average, not only affected by the financial markup but also by the nominal interest rate.

On impact the nominal interest rate cannot be moved, but it can be in the future. The deterministic path of the equilibrium variables will then be described by

$$\frac{u_c(t)A_t}{\alpha} = \frac{R_{t-1}^d}{1 - \mu_t G(\overline{\omega}_t) - f(\overline{\omega}_t)\dfrac{\mu_t \overline{\omega}_t \phi(\overline{\omega}_t)}{1 - \Phi(\overline{\omega}_t)}}. \tag{45}$$

The policy rate can be moved to offset the movements in the financial markup, stabilizing the wedge $u_c(t)A_t/\alpha$.

In response to a technology shock, price-level policy on impact can fully stabilize the financial markup. Optimal policy does, indeed, stabilize the financial markup and the wedge $u_c(t)A_t/\alpha$, without movements in the nominal interest rate.

Similar results to this, that it is optimal to keep wedges constant in response to technology shocks, can be found in the second-best, sticky price literature. For the preferences and production technology that we consider here, it is also the case in that literature that it is optimal to stabilize markups even in a second-best environment where the economy is distorted by monopolistic competition.[17] There are also similarities between these results and the results on uniform taxation in the second-best, optimal taxation literature. The conditions under which it is optimal to tax at the same rate across states are conditions of separability in leisure and homotheticity in consumption that we have also assumed here.

As discussed next, the zero bound does represent a constraint for monetary policy in response to financial shocks. In response to a financial shock, which has a direct effect on the financial markup, the nominal interest rate adjusts to smooth the effects of the financial markup on the wedge $u_c(t)A_t/\alpha$.

Financial Shocks.—For all financial shocks, the flexibility of using the nominal interest rate allows policy to speed up the adjustment after financial shocks. The effect of these shocks on output is considerably mitigated. We illustrate this general result with a serially uncorrelated shock to γ_t (of the same size as in Figure 2).

The impulse responses to this shock under the optimal policy are shown in Figure 3, together with the impulse responses in the case where the Friedman rule is optimal. The most striking result is that the impact of this shock on output, which is persistently contractionary when the short-term nominal rate is kept fixed at zero, is less contractionary and very short-lived when the interest rate can be reduced.

The reduction in policy rates improves credit conditions directly because it also reduces loan rates—the increase in the credit spread is largely comparable to the case when the Friedman rule is optimal. After decreasing on impact, output can

[17] See Adão, Correia, and Teles (2003).

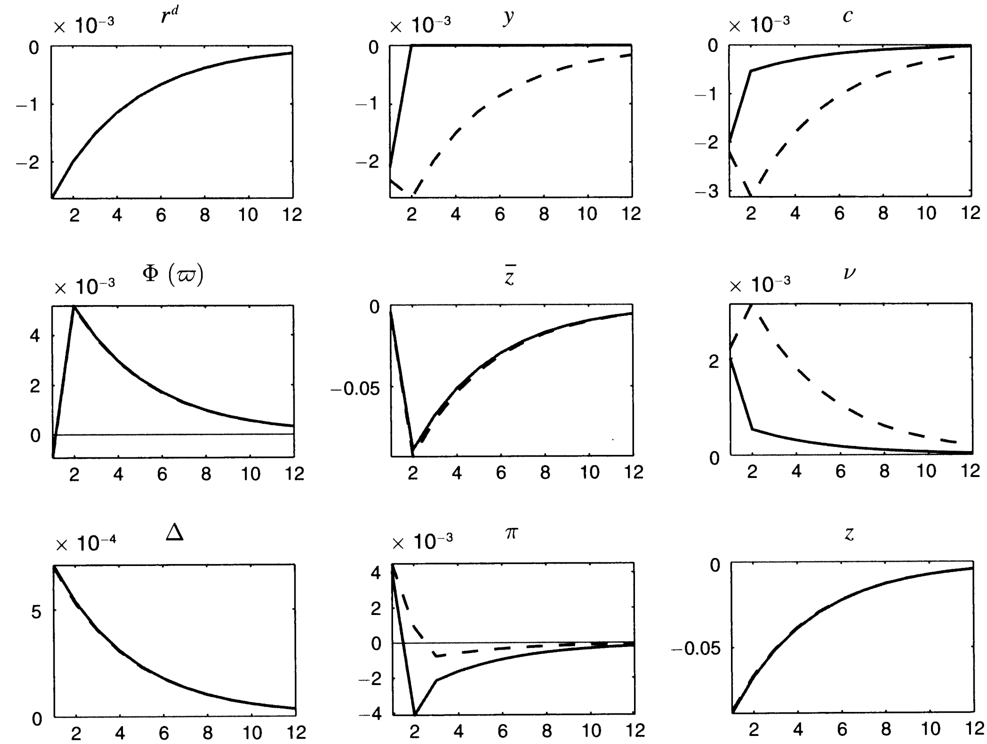

FIGURE 3. IMPULSE RESPONSES TO A FALL IN THE VALUE OF INTERNAL ASSETS UNDER OPTIMAL POLICY

Notes: Logarithmic deviations from the nonstochastic steady state. Uncorrelated shock. The solid lines indicate impulse responses under optimal policy when $g > 0$. The dashed lines report impulse responses under optimal policy already shown in Figure 2.

immediately return to the steady state, while consumption has to adjust at a lower pace because of the increase in aggregate monitoring costs. The mildly positive rate of growth of consumption along the adjustment path implies that the real interest rate must also be positive. Given the protracted fall in the policy interest rate, inflation must also fall persistently—and by slightly more than the nominal interest rate—after its impact increase.

The impact effect of the shock on markups is comparable to the case in which the Friedman rule is optimal, but the adjustment process is much faster.

To understand more clearly the difference between the two cases, it is useful, again, to take into account conditions (30) and (43), which restrict the markups in each case. The deposit rate is predetermined, and therefore cannot be adjusted on impact. After impact, the gross nominal interest rate can be moved in one case, directly affecting the markup, while in the other case it is always equal to one. The conditions are satisfied without expectations, after the impact period. The effects on output, consumption, and inflation are very different because the reduction in the deposit rate can offset the effects on the financial variables, and directly stabilize the markups $u_c(t)A_t/\alpha$.

When there is a negative financial shock, credit conditions worsen, and the distortion created by the scarcity of internal funds is higher. In this case, it is optimal to

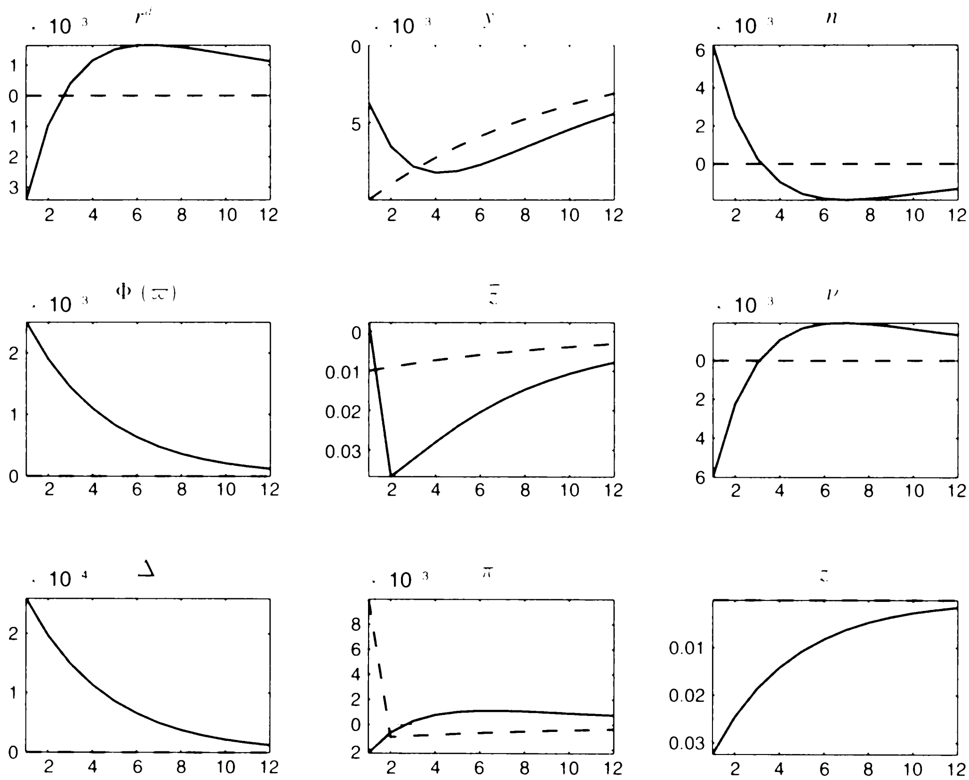

FIGURE 4. IMPULSE RESPONSES TO A NEGATIVE TECHNOLOGY SHOCK UNDER A TAYLOR RULE

Notes: Logarithmic deviations from the nonstochastic steady state. Correlation of the shock: 0.9. The solid lines indicate impulse responses under the Taylor rule. The dashed lines report the impulse responses under optimal policy already shown in Figure 1.

cut the nominal interest rate to partially undo the effects of that higher distortion and reduce the fluctuations in the wedge between the marginal rate of substitution and marginal rate of transformation.

C. *Taylor Rule Policy*

We now compare the impulse responses under optimal policy and $g > 0$ with those in which policy follows the simple Taylor rule in equation (42).

Technology Shocks and the Cyclicality of Bankruptcies.—In response to a negative technology shock, the simple Taylor rule tries to stabilize inflation (see Figure 4). The large amount of nominal funds that firms carry over from the previous period, therefore, has high real value. Given the available funds, firms hire more labor, and the output contraction is relatively small compared to what would be optimal at the new productivity level. As a result, the wage share increases and firms make lower profits, hence they must sharply reduce their internal funds. Leverage goes up, and so do the credit spread and the bankruptcy rate. In the period after the shock, firms start accumulating funds again, but accumulation is slow and output keeps falling for a whole year after the shock. It is only in the second year after the shock that the recovery begins.

Figure 4 illustrates how our model is able to generate realistic, cyclical properties for the credit spread and the bankruptcy rate. An increase in bankruptcies is almost a definition of recession in the general perception, while the fact that credit spreads are higher during NBER recession dates is documented, for example, in Levin, Natalucci, and Zakrajsek (2004). Generating the correct cyclical relationship between credit spreads, bankruptcies, and output is not straightforward in models with financial frictions. For example, spreads are unrealistically procyclical in the Carlstrom and Fuerst (1997, 2001) framework. The reason is that, in those papers, firms' financing decisions are state contingent. Firms can choose how much to borrow from the banks *after* observing aggregate shocks. Should a negative technology shock occur, they would immediately borrow less and try to cut production. This would avoid large drops in their profits and internal funds, so that their leverage would not increase. As a result, bankruptcy rates and credit spreads could remain constant or decrease during the recession.

In our model, economic outcomes are reversed because of the predetermination in financial decisions. Firms' loans are no longer state contingent, hence they cannot be changed after observing aggregate shocks. This assumption implies that firms are constrained in their impact response to disturbances. After a negative technology shock, firms find themselves with excessive funds, and their profits fall because production levels do not fall enough. The reverse would happen during an expansionary shock, when production would initially increase too little and profits would be high.

The model also generates a realistically hump-shaped impulse response of output and consumption without the need for additional assumptions, such as habit persistence in households' preferences. Once a shock creates the need for changes in internal funds, these changes can only take place slowly. Compared to the habit persistence assumption, our model implies that the hump shape in impulse responses is policy-dependent. After a technology shock, optimal policy keeps internal funds at their desirable level at any point in time. Firms do not need to accumulate or decumulate internal funds, and, as a result, the hump in the response of output and consumption disappears.

A notable feature of Figure 4 is that the Taylor rule generates the "wrong" reaction of prices to the negative technology shock compared to optimal policy—a small deflation on impact, rather than inflation. The reason is related to the hump-shaped response of consumption, which implies that the real interest rate must fall for a few quarters after the shock. If inflation increased on impact, the policy rate would have to increase by less than inflation in order to bring about a negative real interest rate. However, this policy response would be inconsistent with the rule in equation (42), which requires the interest rate to increase more than inflation. The fall in the real interest rate must therefore be implemented through a reduction in the nominal interest rate and a period of deflation.

This result is independent of the size of the inflation response coefficient in the Taylor rule—provided that the rule is consistent with a determinate equilibrium. If the inflation response coefficient were higher (lower), deflation would simply be smaller (larger). In the limiting case of an arbitrarily large response coefficient, the outcome would be price stability.

An implication of this result is that, after a technology shock, the higher the inflation response coefficient in the Taylor rule, the closer is the Taylor rule to optimal policy. Intuitively, price stability is closer to the inflationary outcome produced by optimal policy than the deflation rate generated by the Taylor rule. This property of the Taylor rule in our model is reminiscent of the results in Gilchrist and Leahy (2002) and Faia and Monacelli (2007), where a Taylor rule with a high inflation response coefficient delivers superior outcomes. The overall properties of the Taylor rule, however, are very different. Gilchrist and Leahy (2002) and Faia and Monacelli (2007) also assume sticky prices, and price stability is optimal in that environment. In our model, allocations under price stability would remain far away from the optimum. After a negative technology shock, the real level of funds would still be too high, so that production and consumption would come down in a hump-shape manner, rather than on impact as they should.

Shocks to the Value of Internal Assets.—A reduction in the value of internal assets leads to an increase in leverage, the economy's bankruptcy rate and credit spreads (see Figure 5, which shows impulse responses to a shock of the same size as in Figure 2). As in the case of optimal policy (when $g > 0$), the Taylor rule prescribes a fall in the policy interest rate. For similar reasons to those applying in the case of technology shocks, however, the Taylor rule brings about deflation, rather than inflation. Deflation keeps output too high on impact and generates a fall in markups. As a result, the impact increase in leverage is more pronounced than under optimal policy. Compared to the optimal policy case, the recession is more persistent, and it comes at the cost of higher bankruptcy rates and higher credit spreads.

Under a Taylor rule, this shock leads to a situation akin to the "initial state of over-indebtedness" described in Fisher (1933), in which firms' leverage increases and deflation ensues. In Fisher's theory, firms try to deleverage through a fast debt liquidation and the selling tends to drive down prices. If monetary policy accommodates this trend, the price level also falls and the real value of firms liabilities increase further, leading to even higher leverage and further selling. In our model, over-indebtedness and leverage are also exacerbated by deflation, but the mechanics of the model are different. Deleveraging occurs through an accumulation of assets, rather than a liquidation of debt.

III. Conclusions

The model described in this paper represents an attempt to clarify the policy incentives created by the nominal denomination of firms' debt. Our analysis is based on a number of simplifying assumptions and does not aim to provide quantitative policy prescriptions. Nevertheless, we highlight results that may be of relevance also in more general frameworks.

The first result is that maintaining price stability at all times is not optimal when firms' financial positions are denominated in nominal terms and debt contracts are not state-contingent. After a negative technology shock, for example, an impact

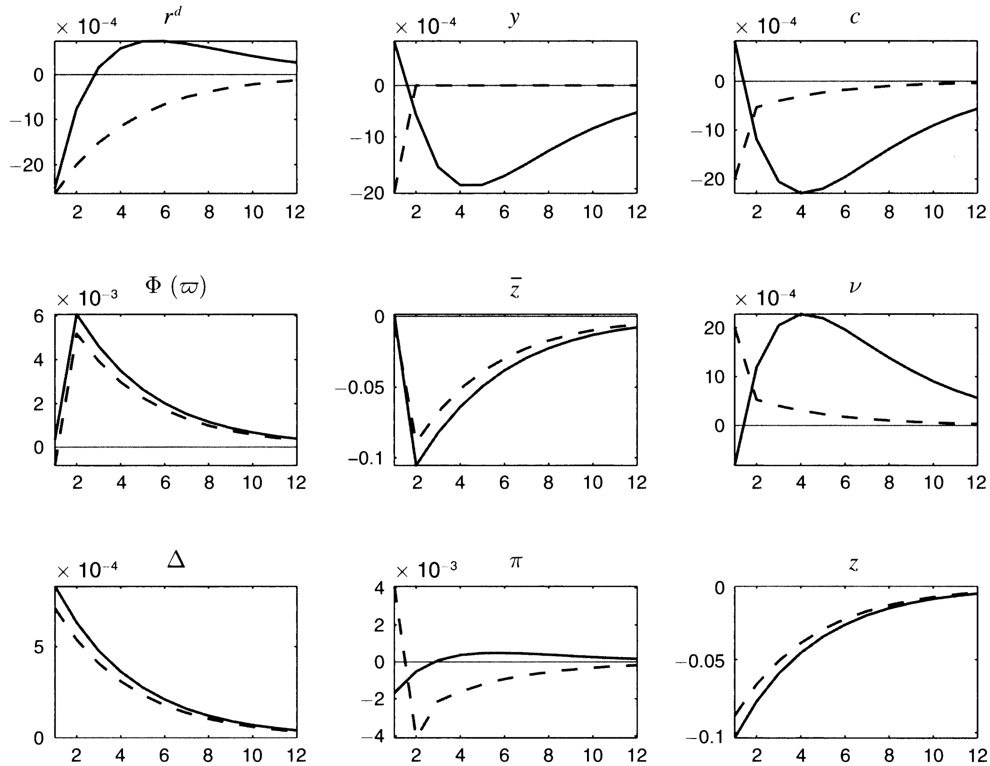

Figure 5. Impulse Responses to a Fall in the Value of Internal Assets under a Taylor Rule

Notes: Logarithmic deviations from the nonstochastic steady state. The shock is serially uncorrelated. The solid lines indicate impulse responses under the Taylor rule. The dashed lines report the impulse responses under optimal policy already shown in Figure 3.

increase in the price level stabilizes firms' leverage and allows for a more efficient economic response to the shock. This ability of monetary policy to influence the real value of firms' assets and liabilities derives from the assumption that, when shocks occur, financial contracts are predetermined. The policy response through the price level is such that, in response to technology shocks, there is no need for the central bank to adjust the nominal interest rate.

A second result is that the optimal response to an exogenous reduction in internal funds, which amounts to an increase in firms' leverage, is to reduce the nominal interest rate, if the nominal rate is not at its zero bound, and to engineer a short period of controlled inflation. Both policy responses have the advantages of mitigating the adverse consequences of the shock on bankruptcy rates and of allowing firms to quickly deleverage.

Finally, we show that a simple Taylor-type rule would produce significantly different economic outcomes from those prevailing if policy is set optimally. For example, under a Taylor rule, bankruptcy rates would increase during recessions, as it appears to be the case in the empirical evidence. Bankruptcy rates would instead be acyclical under optimal policy.

Appendix A: The Financial Contract

Consider the optimal financial contract problem that maximizes (15) subject to (16) and (17), where $f(\overline{\omega}_{i,t})$ and $g(\overline{\omega}_{i,t};\mu_t)$ are given by (9) and (10), respectively, and $\overline{\omega}_{i,t} = R^l_{i,t-1}/P_tA_t/W_t(1 - Z_{i,t-1}/X_{i,t-1})$.

The solution for $Z_{i,t-1}/X_{i,t-1}$, $R^l_{i,t-1}$, and $\overline{\omega}_{i,t}$ is the same across firms. Let $z_{t-1} \equiv Z_{i,t-1}/X_{i,t-1}$ and $v_t \equiv P_tA_t/W_t$. We can define the function $\overline{\omega}_{i,t} \equiv \overline{\omega}_t = \overline{\omega}(R^l_{t-1}, z_{t-1}; v_t)$ as

$$\overline{\omega}_t = \frac{R^l_{t-1}(1 - z_{t-1})}{v_t}. \tag{46}$$

We can rewrite the problem as

$$\max E_{t-1}\left[v_t \frac{1}{z_{t-1}} f\left(\overline{\omega}(R^l_{t-1}, z_{t-1}; v_t)\right)\right],$$

subject to

$$E_{t-1}\left[v_t g\left(\overline{\omega}(R^l_{t-1}, z_{t-1}; v_t); \mu_t\right)\right] \geq R^d_{t-1}(1 - z_{t-1}) \tag{47}$$

$$E_{t-1} v_t f\left(\overline{\omega}(R^l_{t-1}, z_{t-1}; v_t)\right) \geq R^d_{t-1} z_{t-1}, \tag{48}$$

where the functions $f(\overline{\omega}_{i,t})$ and $g(\overline{\omega}_{i,t};\mu_t)$ are given by (9) and (10), respectively.

Define as $\lambda_{1,t-1}$ and $\lambda_{2,t-1}$ the Lagrangean multipliers of (47) and (48), respectively. Conjecturing that $\lambda_{2,t-1} = 0$, the first-order conditions are

$$0 = E_{t-1}\left[-\frac{v_t}{z^2_{t-1}} f\left(\overline{\omega}\left(R^l_{t-1}, z_{t-1}; v_t\right)\right) + \frac{v_t}{z_{t-1}} f_2\left(R^l_{t-1}, z_{t-1}; v_t\right)\right]$$

$$+ \lambda_{1t-1} E_{t-1}\left[v_t g_2\left(R^l_{t-1}, z_{t-1}; v_t, \mu_t\right) + R^d_{t-1}\right]$$

$$E_{t-1}\left[\frac{v_t}{z_{t-1}} f_1\left(R^l_{t-1}, z_{t-1}; v_t\right)\right] + \lambda_{1t-1} E_{t-1}\left[g_1\left(R^l_{t-1}, z_{t-1}; v_t, \mu_t\right) v_t\right] = 0$$

$$E_{t-1}\, g\left(\overline{\omega}\left(R^l_{t-1}, z_{t-1}; v_t\right); \mu_t\right) v_t = R^d_{t-1}(1 - z_{t-1}),$$

where f_j and g_j, with $j = 1, 2$, are the derivatives of f and g with respect to the first and second argument of the function $\overline{\omega}(R^l_{t-1}, z_{t-1}; v_t)$.

We can rewrite these conditions as

$$\lambda_{1t-1} R^d_{t-1} z_{t-1} = E_{t-1}\left[\frac{v_t}{z_{t-1}} f\left(\overline{\omega}\left(R^l_{t-1}, z_{t-1}; v_t\right)\right)\right],$$

$$R^l_{t-1}(1 - z_{t-1})\lambda_{1t-1} E_{t-1}\left[\frac{\mu_t}{v_t}\phi\left(\frac{R^l_{t-1}(1 - z_{t-1})}{v_t}\right)\right]$$

$$+ \left(\frac{1}{z_{t-1}} - \lambda_{1t-1}\right) E_{t-1}\left[1 - \Phi\left(\frac{R^l_{t-1}(1 - z_{t-1})}{v_t}\right)\right] = 0,$$

$$E_{t-1}\left[g\left(\overline{\omega}\left(R^l_{t-1}, z_{t-1}; v_t\right); \mu_t\right) v_t\right] = R^d_{t-1}(1 - z_{t-1}).$$

From the second condition, since $z_{t-1} < 1$ and $\lambda_{1t-1} > 0$, $R^l_{t-1}(1 - z_{t-1}) \times \lambda_{1t-1} E_{t-1}[(\mu_t/v_t)\phi(R^l_{t-1}(1 - z_{t-1})/v_t)] > 0$. Moreover, $1 > \Phi(R^l_{t-1}(1 - z_{t-1})/v_t)$, so that $\lambda_{1t-1} - (1/z_{t-1}) > 0$ and $\lambda_{1t-1} z_{t-1} > 1$. It follows that $R^d_{t-1} z_{t-1} < E_{t-1}[v_t f(\overline{\omega}(R^l_{t-1}, z_{t-1}; v_t))]$, which verifies the conjecture that $\lambda_{2t-1} = 0$.

Using the definition of the threshold, (46), the first-order conditions can be written as (20) and (21).

Appendix B: Equilibria

The equilibrium conditions restricting the variables $\{c_t, N_t, v_t, P_t, R^d_t, \overline{\omega}_t, z_t, R^l_t, X_t, Z_t\}$, given z_{-1}, X_{-1}, $Z_{-1} = z_{-1}X_{-1}$, and R^l_{-1}, can be summarized by

$$\frac{u_c(t)}{\alpha} = \frac{v_t}{A_t}, \; t \geq 0 \tag{49}$$

$$\frac{u_c(t-1)}{P_{t-1}} = R^d_{t-1}\beta E_{t-1}\frac{u_c(t)}{P_t}, \; t \geq 1 \tag{50}$$

$$E_{t-1}\left[v_t f(\overline{\omega}_t)\right] = \frac{R^d_{t-1}}{1 - \dfrac{E_{t-1}\left[\mu_t \overline{\omega}_t \phi(\overline{\omega}_t)\right]}{E_{t-1}\left[1 - \Phi(\overline{\omega}_t)\right]}} z_{t-1}, \; t \geq 1 \tag{51}$$

$$E_{t-1}\left[v_t g(\overline{\omega}_t; \mu_t)\right] = R^d_{t-1}(1 - z_{t-1}), \; t \geq 1 \tag{52}$$

$$\overline{\omega}_t = \frac{R^l_{t-1}(1 - z_{t-1})}{v_t}, \; t \geq 0 \tag{53}$$

$$N_t = \frac{v_t X_{t-1}}{A_t P_t}, \; t \geq 0 \tag{54}$$

$$Z_{t-1} = z_{t-1} X_{t-1}, t \geq 0 \tag{55}$$

$$Z_{t-1} = (1 - \gamma_{t-1}) f(\overline{\omega}_{t-1}) \frac{v_{t-1}}{z_{t-2}} Z_{t-2}, \; t \geq 1 \tag{56}$$

$$(1 - g)A_t N_t\left[1 - \mu_t G(\overline{\omega}_t)\right] = c_t, \; t \geq 0. \tag{57}$$

The other equilibrium conditions determine the remaining variables.

Given the path for the price level, there is a unique equilibrium for the other variables. To see this, notice that at $t = 0$, given the values of z_{-1}, X_{-1} and R^l_{-1}, the equilibrium for c_0, N_0, v_0, and $\overline{\omega}_0$ can be determined using (49), (53), (54), and (57), for $t = 0$. Given these variables, $Z_{-1} = z_{-1}X_{-1}$, and the path for the price level, P_t,

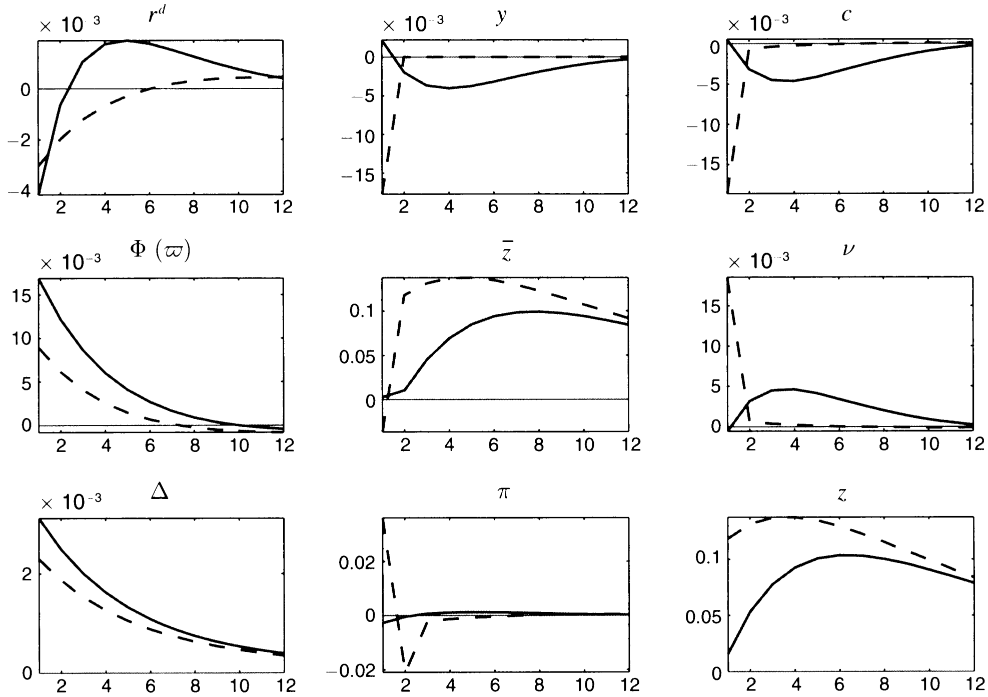

FIGURE A1. IMPULSE RESPONSES TO AN INCREASE IN σ_{ω_t}

Notes: Logarithmic deviations from the nonstochastic steady state. Correlation of the shock: 0.9. The solid lines indicate impulse responses under the Taylor rule. The dashed lines report the impulse responses under optimal policy (in the $g > 0$ case).

the remaining variables c_t, N_t, v_t, $\overline{\omega}_t$, Z_{t-1}, R^d_{t-1}, z_{t-1}, R^l_{t-1}, and X_{t-1} for $t \geq 1$, are determined using (49)–(57), for $t \geq 1$. These are four contemporaneous variables and five predetermined variables, restricted by four contemporaneous conditions and five predetermined conditions. If P_t are set exogenously, all the other variables have a single solution. Alternatively, we could set exogenously R^d_{t-1}, plus P_t, in as many states as $\#S^t - \#S^{t-1}$, and again there would be a unique equilibrium.

Appendix C: Impulse Responses to Financial Shocks

We present additional impulse responses to financial shocks in the baseline model, where the Friedman rule is not optimal. Shocks are serially correlated with a 0.9 correlation coefficient and standardized to generate approximately a 10 percent maximum change in internal funds. In both cases, we compare the impulse responses under the optimal policy to those arising under the Taylor rule.

Figure A1 shows the impulse responses to a persistent increase in the riskiness of the economy, i.e., to an increase in the standard deviation of the idiosyncratic shocks σ_{ω_t}. The impulse responses to this shock are qualitatively similar to a shock in the value of firms' internal assets. The main exception is the response of leverage, which falls after a σ_{ω_t} shock and increases after a γ_t shock. Figure A2 plots the responses to an exogenous increase in the proportion of total funds lost in monitoring activities, μ_t.

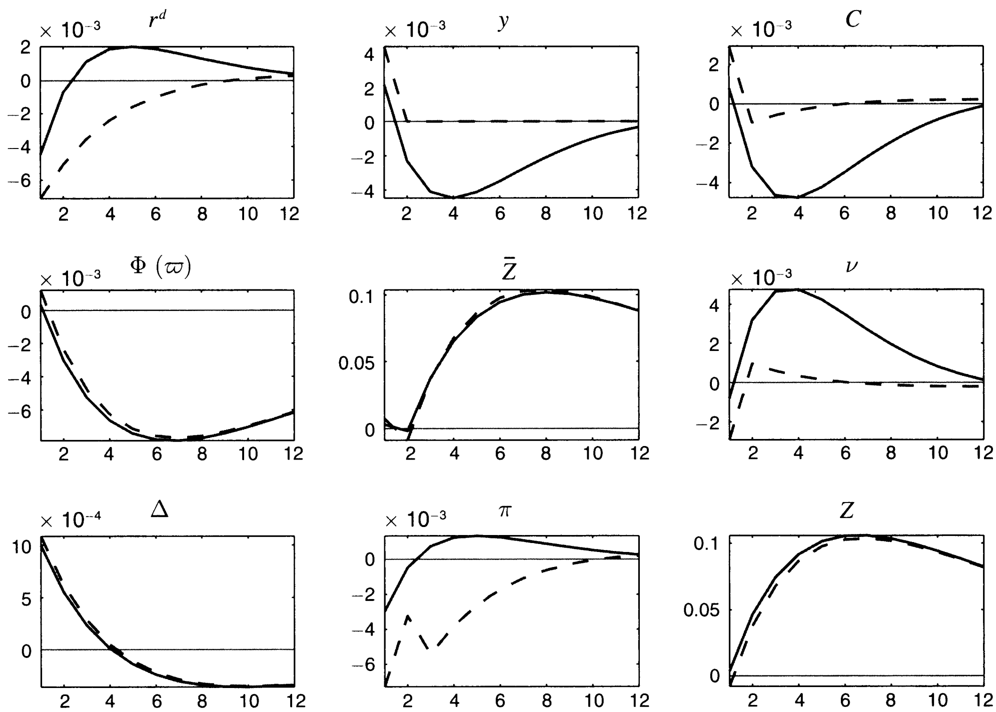

FIGURE A2. IMPULSE RESPONSES TO AN INCREASE IN μ_t

Notes: Logarithmic deviations from the nonstochastic steady state. Correlation of the shock: 0.9. The solid lines indicate impulse responses under the Taylor rule. The dashed lines report the impulse responses under optimal policy (in the $g > 0$ case).

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