Macro-Prudential Policy under Moral Hazard and Financial Fragility

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# Macro-Prudential Policy under Moral Hazard and Financial Fragility

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**Abstract**

This paper presents a DSGE model with banks that face moral hazard in management. Banks receive demand deposits and fund investment projects. Banks are subject to potential withdrawals by depositors which may force them into early liquidation of their investments. The likelihood of this happening depends on the bank management efforts to keep the bank financially sound and the degree of bank leverage. We study the properties of this model under different monetary and macro-prudential policy arrangements. Our model is able to replicate the pro-cyclicality of leverage, and provides insights on the interplay between bank leverage and bank management incentives as a result of monetary, productivity and financial shocks. We find that a combination of pro-cyclical capital requirements and a standard monetary policy are well suited to contain the effects on output and prices of a downturn, keeping the financial system in check. Yet, in an expansionary phase (i.e. a productivity shock) this policy combination may produce desirable results for some macro-variables but at the expense of a deterioration in other macro-financial indicators.

*Key Words:* DSGE modeling; Financial frictions; Moral hazard; Macro-prudential policies

*JEL Codes: G11, 033, D86*

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# 1 Introduction

We develop a macroeconomic model to study the performance of macro-prudential policies in the context of a banking sector that deals with moral hazard in management. The model is based on the framework by Angeloni and Faia [4]. As in Angeloni and Faia [4] banks in our model are fragile due to the maturity mismatch between short term liabilities and illiquid long term assets. The bank's advantage versus other agents in the economy (households, and goods and capital producers) is the non-tradable information about investment projects it gets as a relationship lender, which allows the bank to get a better early liquidation value compared to the value the other agents would get if they fund the projects themselves.

Departing from Angeloni and Faia [4], where the bank surplus is split between bank owners, managers and depositors in a bargaining fashion, we introduce a contracting problem where the surplus, net of depositors' receipts, is divided between the bank owners and managers through an incentive compatible contract. This is accomplished with a compensation scheme the owners set up to provide managers with incentives so that they deliver the optimal level of effort and bank capital structure (leverage).

In our model, actions by managers and bank owners affect the perceived bank's fragility by depositors, who may run on their deposits and induce early liquidation of the bank assets. Banks are limited in their ability to expand their leverage because of the increasing fragility that it brings to the system. Yet, the tradeoffs between paying managers high premiums for them to assure the bank's good financial standing and putting more skin in the game via higher bank capital levels may induce bankers to over-leverage, making the system more fragile on average.

The model is related to the work by Christensen et al. [12], Meh and Moran [30] and Chen [11], which take into account the asymmetric information problems between bank managers and bank owners using the double moral hazard set up of Holmstrom and Tirole [26]. In their model bank leverage is limited because banks have to signal investors they will apply enough monitoring effort on borrowers (the bank capital channel). In our model the capital channel works through the impact bank leverage levels bring to the probability of a liquidity shock. It is also related with the work by Gertler and Karadi [21] where bankers may divert a fraction of the depositors' funds for their private consumption (e.g. large bonuses). The cost to the banker is that depositors can force the bank into bankruptcy and recover what is left over. Therefore to be able to operate, the bank would limit its leverage to the point that the benefits of diverting funds equal the potential bankruptcy costs. This resembles some features of our model given that the fragility imposed by depositors running on their funds forces the bank to limit its leverage to avoid early liquidation of its assets. Still, our model provides an alternative way for such threat to affect the bank risk taking decisions. That is, an agency problem where management effort can counteract the negative effects of high leverage on depositors' uncertainty. A similar approach is taken in Gertler and Kiyotaki [22] which is closer to our framework in that their model allows for the possibility of bank runs.

Our model is also capable of delivering pro-cyclicality of bank leverage. One of the regularities and possible causes of financial crises and severe credit cycles highlighted in the literature is the pro-cyclicality of leveraging by financial institutions (FIs). Adrian and Shin [2] for example find a strong correlation between FIs leverage and asset prices in the United States. However the pro-cyclicality of bank leverage varies significantly, depending on the structure of the financial market and the type of FIs considered. Damar et al. [13] and Adrian and Shin [2] find, for example, that it depends on how much wholesale funding is used. Also Kalemli-Ozcan et al. [28] find that leverage pro-cyclicality varies by bank size and Hamann et al. [25] find that it depends on whether banks are owned by nationals or have foreign capital.

There are different hypothesis tackling the question of pro-cyclical leverage. The literature on macro-modeling with financial frictions, but without explicit financial intermediation, stresses the idea that pro-cyclical leverage rises from the lifting of borrowing constraints as a result of the increase in asset prices (e.g., Kiyotaki and Moore [29] and Bernanke and Gilchrist [6]). The more recent work endogenizes the leverage or loan-to-value ratios in the agent's borrowing constraints (like Brunnermeier and Pedersen [9], and Geanakoplos [19]; see Brunnermeier et al. [8] for a detail review of this literature). However, only recently, these ideas have been extended to the leverage decisions by FIs. For example, Gromb and Vayanos [23] introduce financially sophisticated arbitrageurs providing unsatisfied demand for liquidity. These intermediaries face financial constraints as they can only borrow through margin accounts that have to be fully collateralized, limiting their investment capacity, and the level of market liquidity. A capital channel then operates as increases in arbitrage capital during booms increase liquidity. They show conditions under which the roll of arbitrageurs could be financially stabilizing or amplifying. In Adrian and Shin [3] investment banks adjust leveraging pro-cyclically to keep VaR constant over the cycle, shedding risk and withdrawing credit precisely when the financial system is distressed, amplifying the bust. In some of the recent DSGE models with an explicit banking sector, pro-cyclical leverage is attained by bringing bank balance-sheet constraints in a reduced-form fashion as in Gerali et al. [20], where the bank operating cost is a function of the leverage position of banks. Our model is closer to the attempts to bring micro-founded leverage constraints to the banking sector as in Meh and Moran [30] and Angeloni and Faia [4]. In our model, pro-cyclical leverage happens due to the increase in the return of the projects funded by banks, the increase in the market value of such projects and/or the decline in the cost of funding, i.e. the bank deposit interest rate, as a result of a positive technological or monetary shock. These shifts in banking decisions are driven by a fall in the risk of early liquidation of bank assets due to a liquidity shock.

Our model is in line with recent findings about the decline in lending standards in the subprime mortgage market leading to the 2007-2008 crisis (Dell'Ariccia et al. [14]). We show that facing a positive productivity shock, financial intermediaries end up taking investment projects with lower rates of return and increasing leverage with an average temporary increase in the fragility of the banking system.

Our framework also provides insights about the impact of macroeconomic shocks on bank management compensation. There is evidence from the great recession that CEOs' compensation at large US investment banks climbed while the economy was under-performing. Our results show that this indeed happens, for example, during a negative monetary shock where bank owners try to compensate for higher funding costs by providing incentives for managers to keep the bank financially sound.

The rest of the paper proceeds as follows. Section 2 presents the model and discuses the implications of introducing asymmetric information and the associated contracting issues between bank owners and managers in the banking sector. Section 3 presents the differences in the behavior of the DSGE model between the full and the asymmetric information banking regimes, and the performance of alternative monetary and macro-prudential policy arrangements under different types of macro-shocks. Finally, section 5 concludes.

# 2 Model

We follow Angeloni and Faia [4] by modeling banks as subject to runs, bringing in the fragility that is central to the financial system: the funding of illiquid assets with short term liabilities as in Diamond and Rajan [15, 16].

## 2.1 Households

We assume a continuum of identical households. They save by making demand deposits at financial institutions. In each period there is a fraction $\gamma$ of household members that are bank owners and a fraction $(1-\gamma)$ that are workers/depositors. Bank owners continue in their status in the next period with probability $\theta$. Workers work either in the production sector or in the banking sector as bank managers. Bank dividends are assumed to be passed on to the new bank owners and reinvested in the bank.

Households maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t), \tag{1}$$

where $C_t$ is aggregate consumption, $\beta$ is the rate households discount future consumption, and $N_t$ is labor hours they provide in the economy. Due to the possibility of bank runs, the return on deposits, $D_t$, is subject to a time-varying risk $R_t(1-\phi_t g_t)$. Where $R_t$ is the demand-deposit gross nominal rate offered by banks, $\phi_t$ is the probability of a bank run, which is explained in detail later on, and $g_t$ the expected loss on risky deposits in case of a bank run. Households own the production sector, earning profits $\Theta_t$, and send net transfers to the government $T_t$. Hence, their budget constraint is:

$$p_t C_t + T_t + D_t \leq w_t N_t + \Theta_t + \Xi_t + R_{t-1}(1-\phi_{t-1}g_{t-1})D_{t-1,} \tag{2}$$

where $\Xi_t$ are the expected revenues of the bank manager net of the pecuniary costs $\psi(e_t, d_t)$, the bank manager incurs to provide the level of effort $e$ and bank capital structure $d$ (deposits over bank assets). Households choose $\{C_t, N_t, D_t\}_{t=0}^{\infty}$, given the price of final goods $p_t$ and unitary wages $w_t$. For a given level of effort, the following optimality conditions hold:

$$\frac{w_t}{p_t} = \frac{U_{n,t}}{U_{c,t}} \tag{3}$$

$$U_{c,t} = \beta E_t \left[ \frac{R_t}{\pi_{t+1}} (1-\phi_t g_t) U_{c,t+1} \right], \tag{4}$$

where $\pi_{t+1} = p_{t+1}/p_t$.

## 2.2 Financial sector

As in Angeloni and Faia [4], we consider a large number of uncorrelated investment projects $L_t$. A project lasts one period and requires an initial investment. Each project size is normalized to one and its price is $Q_t$. Banks have no internal funds but are funded by two classes of agents: depositors and bank capitalists. Deposits are short term uninsured funding instruments, callable in short notice, yielding a non-contingent return $R_t$. Total bank loans are equal to the sum of deposits $D_t$ and bank capital $BK_t$. Therefore, the aggregate bank balance sheet is $Q_t L_t = D_t + BK_t$.

The bank capital structure $d_t = D_t/Q_t L_t$, is chosen by the bank owners who maximize their expected payoff subject to the bank commitment to pay depositors, as far as there are funds available on demand, and the management incentive contract signed between the bank owners and the manager. Bank leverage is equal to $1/(1 - d_t)$ and is positively related to bank capital structure. Departing from Angeloni and Faia [4], management at the bank has two types of activities: implementing the leverage level that is optimal for the bank owners $d$ and looking after the financial soundness of the bank.

Bank managers provide information to the public about bank soundness on regular basis. Such information is provided in the way of an index $i_t$ of the financial health of the bank. Depositors then make their own valuation of the bank's situation $n_t = \kappa_0 + \kappa_1 f(d_t) + i_t$ where $\kappa_1 \leq 0$. We assume that depositors follow a threshold rule where they would run if $n_t \leq 0$. The bank owners have an advantage over depositors because they know that the index values reported by bank management are a function of management effort $e$ and some management private information $x_t$, $i_t = \iota_0 + \iota_1 h(e_t) + x_t$, where $x_t$ is known to follow a uniform distribution in the range $[-h, h]$ and $\iota_1 \geq 0$. Therefore, bank owners can infer how likely depositors would run on their funds at the bank from:

$$P(no - run|e_t, d_t) = P(\kappa_0 + \iota_0 + \kappa_1 f(d_t) + \iota_1 h(e_t) \leq x_t) = P(e_t, d_t), \tag{5}$$

where $P(run|e_t, d_t) = \phi_t = 1 - P(e_t, d_t)$; both activities implying a management cost of $\psi(e_t, d_t)$. Where $\psi_e \geq 0$ and $\psi_d \geq 0$. In other words, it is costly for bank managers to apply effort to keep the bank in good financial health and also costly to engage in activities to attract depositors.

As in the relationship banking literature, the bank has a specialized non-sellable knowledge of the project. Hence, it has an advantage in extracting early liquidation value. This advantage is defined by the ratio between the market value of early liquidation by non-bankers and that of the bank, $0 < \lambda < 1$. A bank run also entails a resource loss of $0 < c < 1$ on the return of the project.

The timing is as follows. A period is divided into two sub-periods. In the first sub-period bank owners sign a contract with bank management. The contract specifies the capital structure of the bank $d$ and the contingent remuneration management would get in each of the two possible states: where $w_{0t}$ would be the payment contracted with the manager in the case of run and $w_{1t}$ would be the payment to management in case of no-run. Depositors, on the other hand, decide how much to deposit at banks. At the middle of each period the value of $x$ is realized and observed by management only, and based on that, they divulge the index $i$ and depositors decide weather they run or not on their deposits at banks.

The bank owners choose the capital structure of the banks subject to a contract they sign with bank managers to induce optimal effort. Then, the project is undertaken. If there is no-run, the project delivers $R_t^z$ at the end of the period. In this case, the bank-owners' return in period $t$ would be $R_t^z - w_{1t} - R_t d_t$ . If the run state is realized, there is only $(1-\lambda)(1-c)R_t^z$ to split between bank owners, managers and depositors, as depositors would get $\lambda(1-c)R_t^z$ at front; otherwise they would not deposit at the bank and would manage the projects themselves. We assume that, by law, there is a proportion $\gamma$ of the net yield of the project in case of run that can go to the bank owners and the managers, with $(1-\gamma)$ going to depositors. Therefore, the return for bank owners in case of run will be $\gamma(1-\lambda)(1-c)R_t^z - w_{0t}$.

**Full information and the bank manager's contract:** We assume that the bank owners observe the level of riskiness of the bank, $d$. To evaluate the wedge that asymmetric information may impose on the optimal capital structure of the bank, we shall compare two scenarios: one in which management effort is observable by bank owners and the other in which it is not (the case of asymmetric information).

In case of full information, given that the bank owners observe both the riskiness level $d$ and the effort applied by managers $e$, they can disentangle how responsible is the manager if the run state occurs vis-à-vis the owners' responsibility in having too risky capital structures (high $d$).

In the case the manager's effort is observable, the program solved by bank owners is:

$$\max_{\{e_t, d_t, w_{it}\}} P(e, d_t)\, V(R_t^z - w_{1t} - R_t d_t) + (1 - P(e, d_t))\, V(\gamma\lambda(1-c)R_t^z - w_{0t}) \tag{6}$$

Subject to the management participation constraint:

$$P(e_t, d_t)\, u(w_{1t}) + (1 - P(e_t, d_t))\, u(w_{0t}) - \varphi(d_t, e_t) \geq 0.$$

It is useful to discuss some of the features of the first order conditions of this program. Let

$$\tilde{V}_t = V\left(R_t^z - w_{1t} - R_t d_t\right) - V\left(\gamma(1 - \lambda(1-c)R_t^z - w_{0t}\right),$$

and

$$\tilde{u}_t = u(w_{1t}) - u(w_{0t})$$

be the differences in the payoffs between states for the bank owners and the manager respectively. Then, under full information, the first order condition with resect to $e_t$ is:

$$P_e(e_t, d_t)\left(\tilde{V}_t + \mu_1^F \tilde{u}_t\right) = \mu_1^F \varphi_e(d_t, e_t),$$

Where $\mu_1^F$ is the full information lagrangean multiplier. It entails that the expected marginal return to both the bank owners and bank management equals the marginal cost of providing additional effort.

The first order condition with respect to the capital structure $d$ is:

$$P_d(e_t, d_t)\left(\tilde{V}_t + \mu_1^F \tilde{u}_t\right) = \mu_1^F \varphi_d(d_t, e_t)) + P(e_t, d_t) R_t V_d(R_t^z - w_{1t} - R_t d_t).$$

Which entails that the expected marginal return to both the bank owners and bank management equals the marginal cost of providing additional leverage $d$ and the expected marginal return to the bank owners in case of no bank runs.

Finally, the optimal compensation for the manager is determined by the risk sharing condition in which the ratio of the marginal costs to the bank owner in terms of utility of providing compensation between states must be equal to the ratio of the marginal benefits to the manager between states:

$$\frac{V_{w_{1t}}(R_t^z - w_{1t} - R_t d_t)}{V_{w_{0t}}(\gamma(1-\lambda)(1-c)R_t^z - w_{0t})} = \frac{(1-P(e_t,d_t))}{P(e_t,d_t)}\frac{u_{w_{1t}}(w_{1t})}{u_{w_{0t}}(w_{0t})}.$$

**Asymmetric information and the bank manager's contract:** In case of asymmetric information, we assume that bank owners can not observe the level of effort bank management exerts. Therefore, the owners can not disentangle how much responsibility management has in case of a run actually happening. Given that management effort is not observable, the owners' program is:

$$\max_{\{e_t,d_t,w_{it}\}} P(e,d_t)\,V(R_t^z - w_{1t} - R_t d_t) + (1-P(e,d_t))\,V(\gamma(1-\lambda)(1-c)e - w_{0t}). \qquad (7)$$

Subject to the incentive compatibility constraint:

$$\arg\max_{e_t} P(e,d_t)\,u(w_{1t}) + (1-P(e_t,d_t))\,u(w_{0t}) - \varphi(d_t,e_t),$$

which states that the level of effort should be such that the manager can not obtain higher expected returns with any other possible effort levels, for a given level of capital structure; and, subject to the management participation constraint with an outside offer normalized to zero:

$$P(e,d_t)\,u(w_{1t}) + (1-P(e,d_t))\,u(w_{0t}) - \varphi(d_t,e_t) \geq 0.$$

The first order conditions of the program underline the distortions faced by the banking system in this economy in the case of asymmetric information. The condition with respect to management effort $e$ is:

$$P_e(e_t,d_t)\left(\tilde{V}_t + \mu_1^A \tilde{u}_t\right) = \mu_1^A \varphi_e(d_t,e_t) + \mu_2^A(\varphi_{ee}(d_t,e_t) - \tilde{u}_t P_{ee}(e_t,d_t)),$$

were $\mu_1^A$ and $\mu_2^A$ are the Lagrangian multipliers associated with the incentive-compatible and the participation constraints respectively. Indeed, it shows that the expected return to bank owners and bank management will have to compensate not only for the marginal cost of exerting effort but also for the net second order effect that effort produces on marginal costs and the probability of run versus no-run states. A similar distortion appears in the first order condition with respect to $d$ :

$$P_d(e_t, d_t)\left(\tilde{V}_t + \mu_1^A \tilde{u}_t\right) = \mu_1^A \varphi_d(d_t, e_t) + P(e_t, d_t) R_t V_d(R_t^z - w_{1t} - R_t d_t) - \mu_2^A(\varphi_{ed}(d_t, e_t) - u_t P_{ed}(e_t, d_t))$$

The conditions related to the bank management compensation yield now:

$$\frac{V_{w_{1t}}(R_t^z - w_{1t} - R_t d_t)}{V_{w_{0t}}(\gamma(1-\lambda)(1-c)R_t^z - w_{0t})} = \frac{(1 - P(e_t, d_t))}{P(e_t, d_t)} \frac{u_{w_{1t}}(w_{1t})\left[\mu_1^A P(e_t, d_t) + \mu_2^A P_e(e_t, d_t)\right]}{u_{w_{0t}}(w_{0t})\left[\mu_1^A(1 - P(e_t, d_t)) - \mu_2^A P_e(e_t, d_t)\right]}$$

Note that the contract does not only have to take into account the marginal utilities of the bank manager between states but also the marginal effects that changes in management compensation cause on the incentive-compatible and participation constraints.

## 2.3 Production sector

There are different varieties of final goods, $Y_t(i)$, produced accordingly to a production function $Y_t(i) = A_t F((N_t(i), K(i))$. Producers have monopolistic power in their variety with a demand $y_t(i) = (p_t(i)/p_t)^{\varepsilon} Y_t$, and face quadratic price adjustment costs

$\frac{\vartheta}{2}\left[\frac{p_t(i)}{p_{t-1}(i)} - 1\right]^2$.

In symmetric equilibrium, producers maximize profits with respect to $N_t$, $K_t$ and $p_t$, which yields the expectation-augmented Phillips curve:

$$U_{c,t}(\pi_{t-1})\pi_t = \beta E_t U_{c,t+1}(\pi_{t+1} - 1)\pi_{t+1} + U_{c,t} A_t F(\cdot)\frac{\varepsilon}{\vartheta}(mc_t - (\varepsilon - 1)/\varepsilon) \qquad (8)$$

Capital accumulation is affected by adjustment costs:$K_{t+1} = (1-\delta)K_t + \xi(I_t/K_t)K_t$. In equilibrium the real return from holding a unit of capital must be equal to the real return that banks receive from their loan operations:

$$\frac{R_t^z}{\pi_{t+1}} \equiv \frac{mc_{t+1}A_{t+1}F_{k,t+1} + Q_{t+1}\left[(1-\delta) - \xi'\left(\frac{I_{t+1}}{K_{t+1}}\right)\frac{I_{t+1}}{K_{t+1}} + \xi\left(\frac{I_{t+1}}{K_{t+1}}\right)\right]}{Q_t} \tag{9}$$

Where $mc_{t+1}$ is the real marginal cost and the asset price is

$$Q_t = \frac{p_t}{\left(\xi'\left(\frac{I_t}{K_t}\right)\right)}. \tag{10}$$

### 2.4 Market clearing conditions and monetary policy

The government runs a balanced budget where $T_t = G_t$. The aggregate resource constraint would be:

$$Y_t - \Omega_t - L_t\varphi(e_t, d_t) = C_t + I_t + G_t + (\vartheta/2)(\pi_t - 1)^2$$

where $\Omega_t = (1 - P(e,d))\, R_t^z(Q_t K_t)$ represents the expected aggregate cost of a bank run.

The monetary policy follows a Taylor rule of the form:

$$\ln\left(\frac{R_t}{R_t}\right) = (1-\rho_m)\left[b_\pi \ln\left(\frac{\pi_t}{\pi}\right) + b_y \ln\left(\frac{Y_t}{Y}\right) + b_q \ln\left(\frac{Q_t}{Q}\right) + b_d \ln\Delta\left(\frac{d_t}{d}\right)\right] + \rho_m \ln\left(\frac{R_{t-1}}{R}\right) + \varepsilon_t^r$$

In this monetary policy rule, all variables without a time subscript represent target or steady state levels. Note that it contemplates in principle the possibility that a central bank may react to financial conditions such as asset prices or bank leverage positions; what we call herein macro-prudential monetary policy rules.

### 2.5 Calibration

Many parameter values follow the baseline values used in Angeloni and Faia [4] who matched the second moments of macroeconomic and financial variables with those of the US and the Euro-area macro-statistics. In particular, the model is run on a quarterly bases. The household utility function is $U(C_t, N_t) = \frac{C_t^{1-\sigma}-1}{1-\sigma} + \nu\log(1-N_t)$, and the production function is Cobb-Douglas, $F(K_t, N_t) = A_t K_t^\alpha N_t^{1-\alpha}$. Total factor productivity follows the process $A_t =$

$A_{t-1}^{\rho_A} \exp(\varepsilon_t^A)$ and government consumption is assumed to evolve as $\ln(G_t/G) = \rho_g \ln(G_t/G) + \varepsilon_t^g$, where $\varepsilon_t^A$ and $\varepsilon_t^g$ are i.i.d shocks.

Table 1, presents the model parameters borrowed from Angeloni and Faia [4]:

We assume that the probability of a bank run in (5) is:

$$\phi_t = 1 - P(e, d_t) = 1 - (\tau_1 \sqrt{e} + \tau_2 d), \tag{11}$$

where $\tau_1 \geq 0$ and $\tau_2 \leq 0$. Also, we assume that the management costs of implementing different levels of bank management effort $e$ and deliver the capital structure $d$ is:

$$\varphi(e, d) = m_1 e + m_2 d \tag{12}$$

We calibrate the parameters in (11) and (12) so that they solve a system of equations where the probability of a bank run is $\phi = 0.05$ and the bank structure is $d = 0.85$, in steady state.

Finally, we assume that bank owners are risk averse with $V(\cdot) = \ln(\cdot)$ and bank management is risk neural, as in the resent partial equilibrium theoretical literature dealing with bank management incentives and risk taking (e.g. Chaigneau [10]).

# 3 Results

## 3.1 Bank riskiness and leverage under full and asymmetric information

We study the implications of moral hazard, bank fragility and the early project liquidation channels on the transmission of monetary policy by analyzing impulse-responses of macroeconomic and financial variables to monetary, productivity and financial shocks. These responses will be analyzed with and without macro-prudential bank capital requirements.[1]

[1] We use the software Dynare to solve the model numerically and calculate the impulse-response functions presented in this section. Our codes extend those developed by Angeloni et al. [5]. We thank them for their kind gesture of sharing their codes with us.

Table 1: Model parameters (taken from [4]

| Description | Parameter | Values | Source |
|---|---|---|---|
| Discount rate | $\beta$ | 0.995 | Match annual real interest rate of 2% |
| Real interest rate | $R_t$ | 2% | Accordingly with the discount rate |
| Labor elasticity in the utility function | $\nu$ | 3 | To match a 0.3 steady-state unemployment level |
| Bank survival rate | $\theta$ | 0.97 | Data at 10 years horizon |
| Capital share in production | $\alpha$ | 1/3 | US National accounts |
| Calvo price stickiness | $\vartheta$ | 30 | Rotemberg framework and Calvo-Yun to data |
| Early liquidation bank advantage | $\lambda$ | 0.4 | Ratio of money market interest rate to the loan rate |
| Depreciation rate | $\delta$ | 0.025 | Quarterly aggregate depreciation |
| Expected return on projects | $R^z$ | 0.21 | Calibrated to mach bank capital at the steady state |
| Cost of a bank default | $c$ | 0.2 | Based on recovery rate figures from Moodyťs |
| S.D. of productivity shock | $\sigma(\varepsilon^A)$ | 0.056 | RBC studies |
| S.D. of government shock | $\sigma(\varepsilon^g)$ | 0.0074 | Empirical studies industrialized economies |
| S.D. of monetary shock | $\sigma$ | 0.006 | Empirical studies for US and Europe |
| Productivity Autoregressive process | $\rho^A$ | 0.95 | RBC studies industrialized economies |
| Gov. autoregressive process | $\rho^g$ | 0.90 | RBC studies industrialized economies |
| Taylor rule Autoregressive process | $\rho^m$ | 0.2 | RBC studies industrialized economies |
| Elasticity asset prices to investment eq. (9) | | 2 | Based on ratio volatility of investment to output |

### 3.1.1 Monetary shock

Figure 1 presents the effect of a one-standard deviation negative monetary policy shock on the full and the asymmetric information economies. On the onset, aggregate product and inflation falls in both economies. In the full information case, aggregate output initially falls more compared with the fall in the asymmetric economy. Yet, after that, the full information economy does better. The prices of final goods, in contrast, fall more and the fall is less persistent in the asymmetric case. This is explained by the behavior of investment and capital accumulation. The full and asymmetric economies have opposite dynamics in asset prices and capital accumulation. In addition, these aggregates have smaller deviations from the steady state in the asymmetric information case compared with the pronounce effects in the full information case. As a result, the monetary shock has opposite effects on the level of investment project returns managed by banks: increasing in the full information case and slightly decreasing in the asymmetric case.[2]

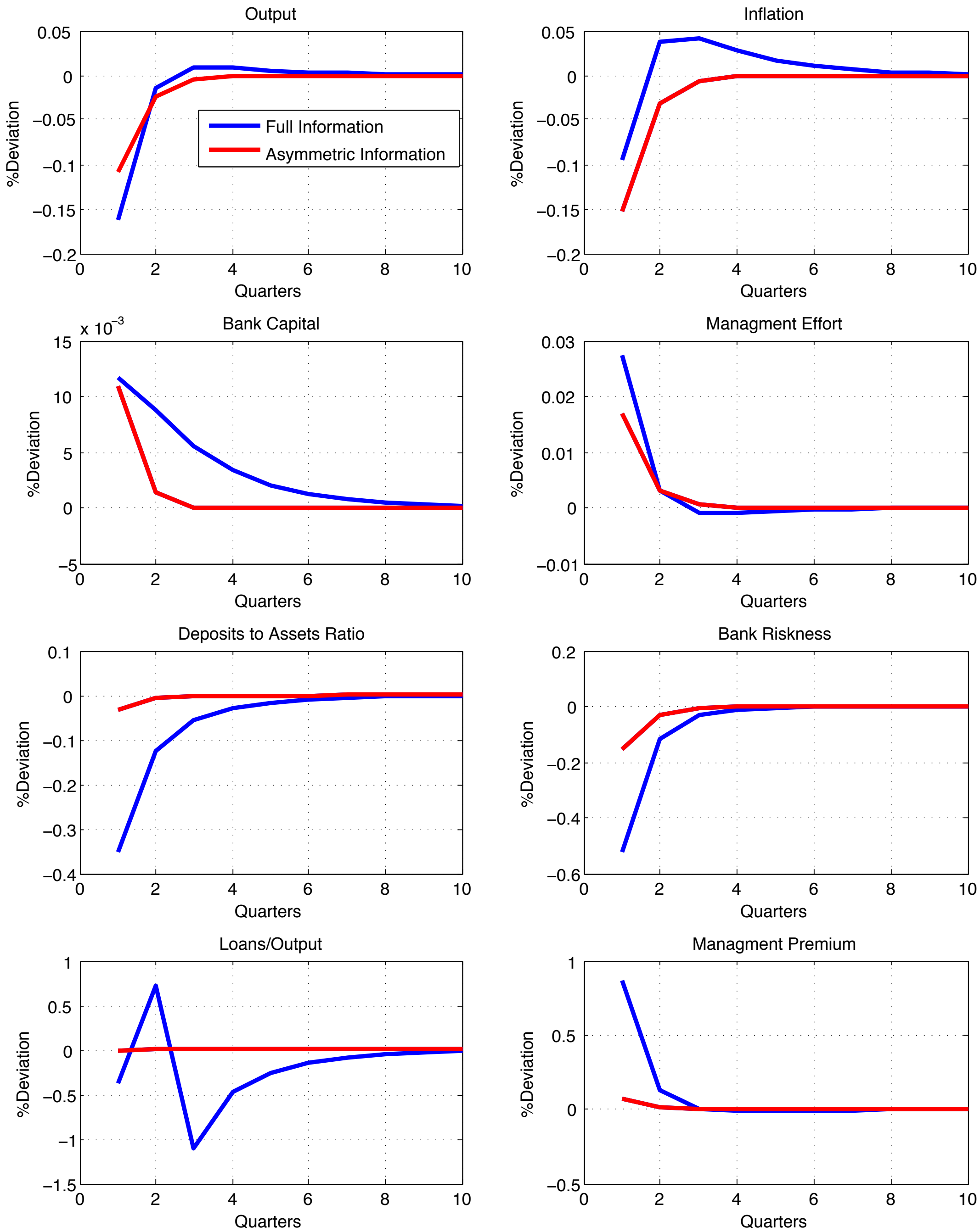
These differences are explained by the incentive problems faced by banks in the two worlds. The monetary shock increases the funding cost of the bank, reducing in both cases the leverage level and bank riskiness. In this sense, negative monetary shocks make the economy less fragile. Indeed, to compensate for the yield losses, banks attempt to be more conservative in their decisions by increasing effort and bringing down the likelihood of having to incur in losses due to early project liquidation. In the full information case, this shift is more pronounced given that the owners do not have the incentive restrictions faced in the asymmetric case. This is reflected in the bigger increases in management compensation with full information.

The fall in bank leverage induces a fall in aggregate funding with full information, reducing investment and asset prices and, by the no-arbitrage condition (9), increasing the funding of projects with higher returns $R^z$. In contrast, in the asymmetric case, the fall in leverage and bank riskiness is substantially less pronounced. Hence, investment is only slightly affected by bank capital structure decisions. Most of the general equilibrium adjustment is therefore taken by the prices of final goods and the cost of bank funding $R$. The asymmetric information friction in some sense acts as a buffer for the real sector. However, the agency friction leaves the banking sector more fragile and less profitable than under full information.[3]

[2]All figures in section 3 present only some of the impulse-responses. The others can be provided upon request.

[3]The result that the financial sector acts as a buffer has been documented in other papers that model banks explicitly in a DSGE model such as Angeloni and Faia [4] and Hafstead and Smith [24].

Figure 1: Full versus asymetric information: Monetary shock



### 3.1.2 Productivity shock

Figure 2 presents the effects of a one-standard deviation positive technology shock on the full information and the asymmetric information economies. A productivity boom brings both economies to higher levels of product and lower prices of final goods, with impulse-response functions in consumption and investment more pronounced under full information. However, there are substantial differences in the behavior of final goods and asset prices and that of the banking system, all of which have more moderated fluctuations in the asymmetric information case. In particular, in the full information case sharper falling of prices of final goods induce a stronger response in monetary policy, causing lower deposit rates and higher bank leverage and riskiness levels than in the asymmetric case. As a result, investment and consumption response functions are higher in the full information regime. Interestingly, even though bank riskiness in the asymmetric case increases after a productivity shock, the short term effects could go the other way, reducing bank riskiness, as is shown at the onset of the shock. This may be due to the fact that in this case bank capital increases as a result of the lower costs in case of early liquidation whereas, with full information, bank capital actually falls.

Note the asymmetric riskiness position of the banking sector under a boom (productivity shock) and a contraction (monetary shock). During booms, riskiness seems to be attenuated by the agency friction in the model, whereas, during contractions the banking system remains more fragile under asymmetric information.

### 3.1.3 Financial shock

Figure 3 shows the effects of a one-standard deviation negative shock of bank capital on the full information and the asymmetric information economies. Drops in bank capital bring bank leverage up, reducing lending and production in the economy. Prices however tend to be higher in the asymmetric case, whereas they drop under the full information due to a decrease in marginal costs. As would be expected, both economies tend to become more financially fragile, though in the asymmetric case, aggregate lending has a stronger drop on the onset of the shock. Interestingly, as bank capital falls and leverage increases, bank management compensation and effort declines. In sum, a fall in bank capital weakens the financial and management profile of the banking sector.

Figure 2: Full versus asymetric information: Productivity shock

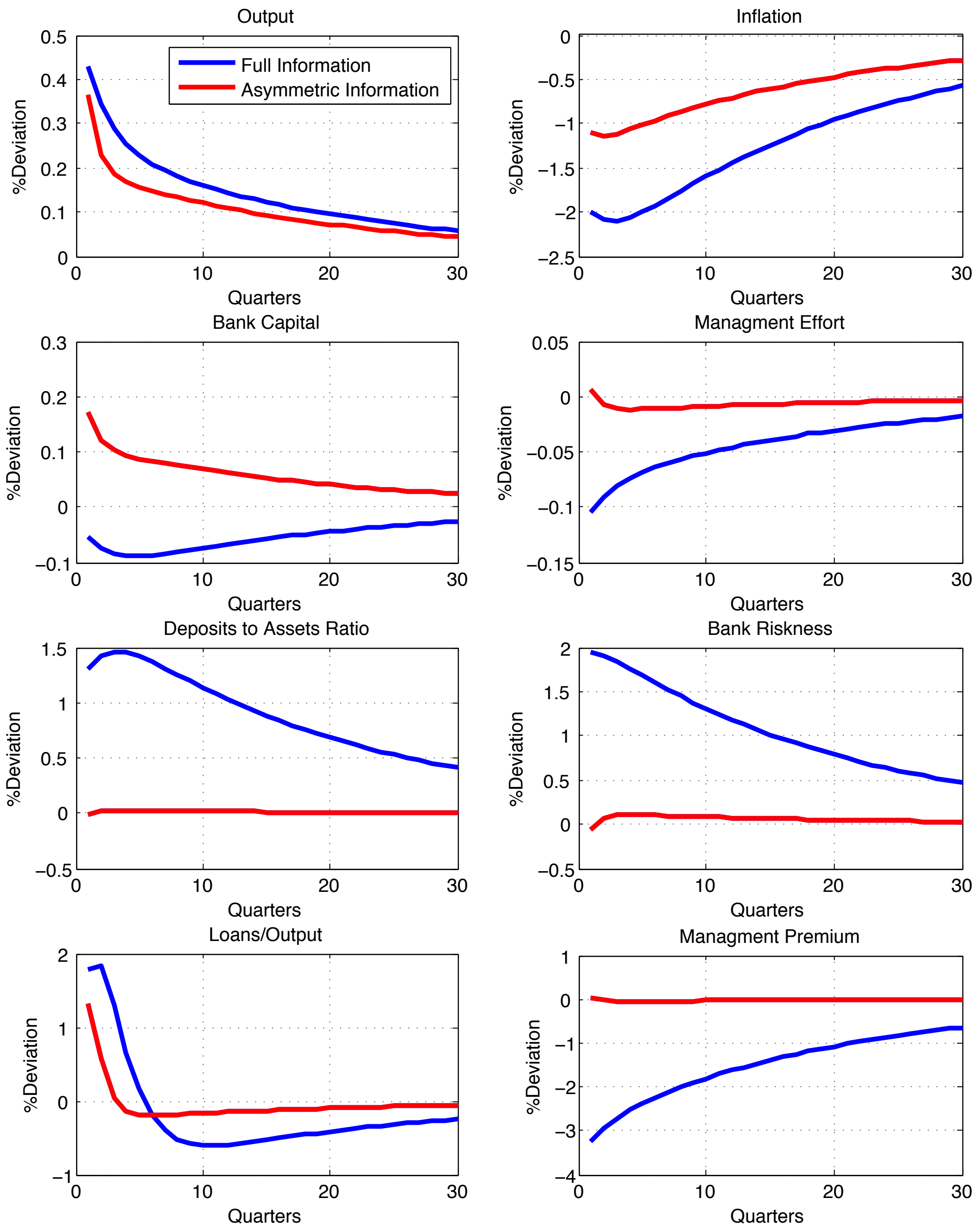
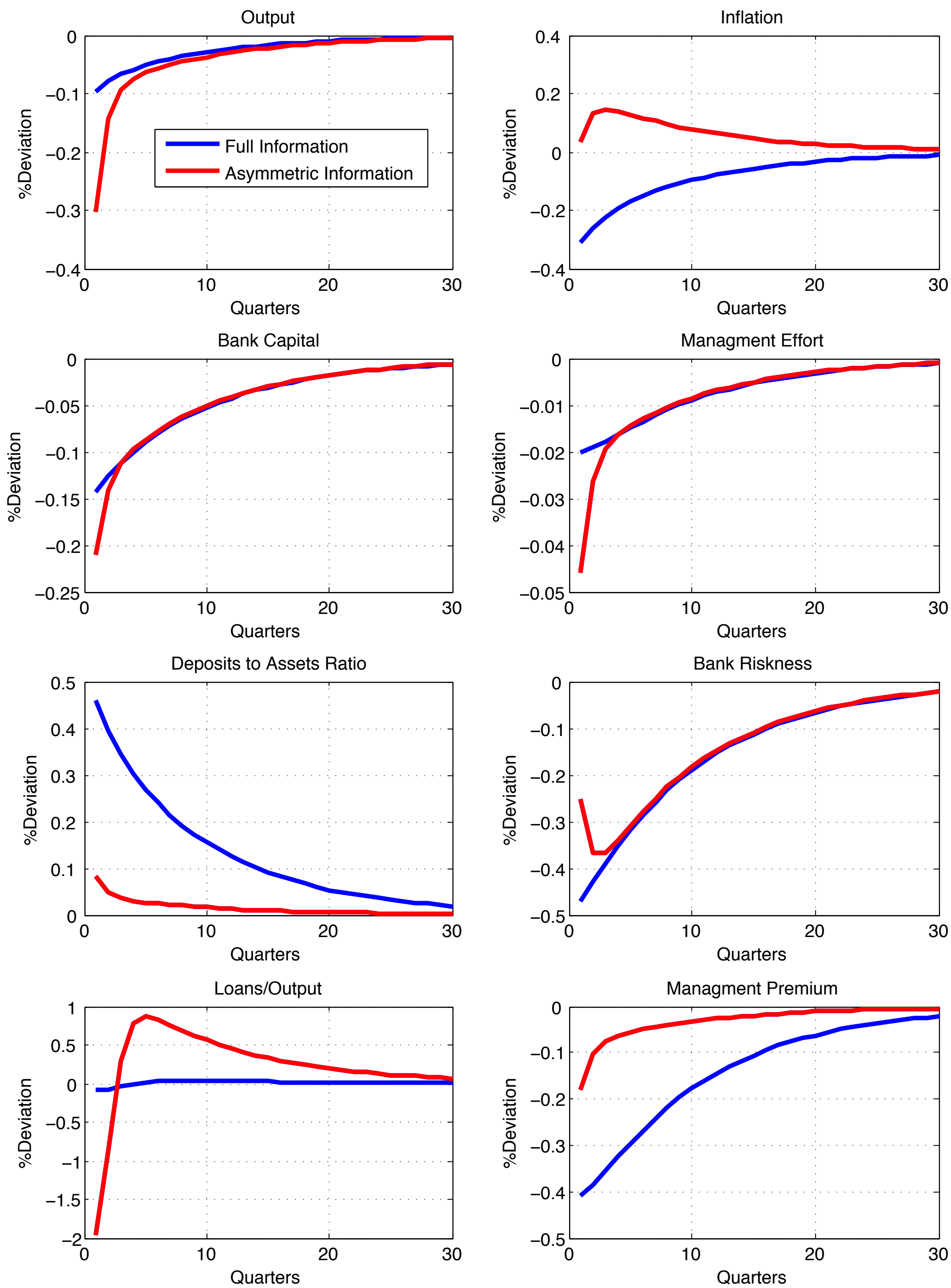


Figure 3: Full versus asymmetric information: Financial shock



## 3.2 Interaction between monetary and macro-prudential policies

We start by comparing how a central bank that is active in its responses to financial conditions fairs compare with one that follows a traditional Taylor rule.[4] As shown in Figure 4, under a negative monetary shock, a standard Taylor rule performs similarly to a Taylor rule that is responsive to asset prices. Yet, under an expansionary productivity shock (Figure 5) a taylor rule that reacts to asset prices better succeeds in keeping prices, aggregate lending and bank riskiness in check. Similarly, under a negative bank capital shock (Figure 6), an extended Taylor rule sensitive to asset prices is able to better contain the increase in bank leverage, being able to dominate the standard Taylor rule by actually further reducing the level of bank riskiness in the economy. However, its good performance in terms of financial conditions seem to be at the expense of its weakness in keeping the price level stable, as prices drop quite more than under a standard Taylor rule.

### 3.2.1 Monetary policy and bank capital requirements

Macro-prudential policy is based on a time-contingent minimum-capital-requirement ratio between the required banking capital, $BK_t$ and the total bank loan exposure $Q_tK_t$ following the rule:

$$bk_t^m = a_0 + a_1^c \left(\frac{Y_t}{Y}\right)^{a_2^c}.$$

Assuming $a_2^c < 0$ would imply a pro-cyclical capital requirement as in Basel III. In this case, banks would need to raise capital and/or reduce lending during the expansion phase and have a more relaxed leverage requirement during contractions.

Bank requirements in our banking sector are imposed as an additional constraint in the asymmetric information program (7) solved by the bank owners:

$$(1 - d_t) \geq bk_t^m.$$

[4]We also compare these two versions of the Taylor rule with one in which the monetary authority is sensitive to bank leverage. As the Taylor rule reacting to asset prices performs better in terms of macro volatility and output we do not present the results of the extended Taylor rule reacting to bank leverage.

Figure 4: Macro-prudential monetary policy: Monetary shock

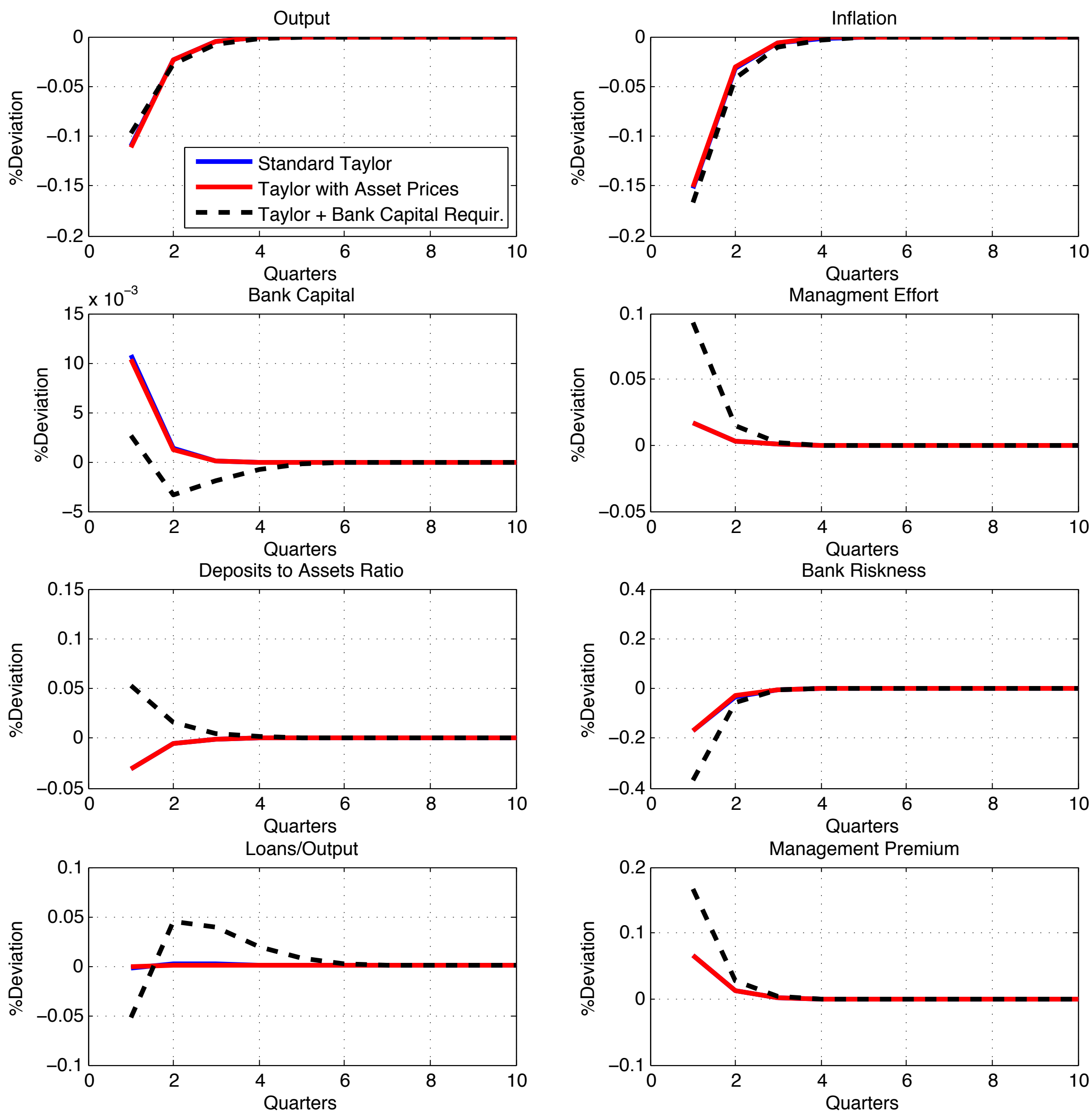


Figure 5: Macro-prudential monetary policy: Productivity shock

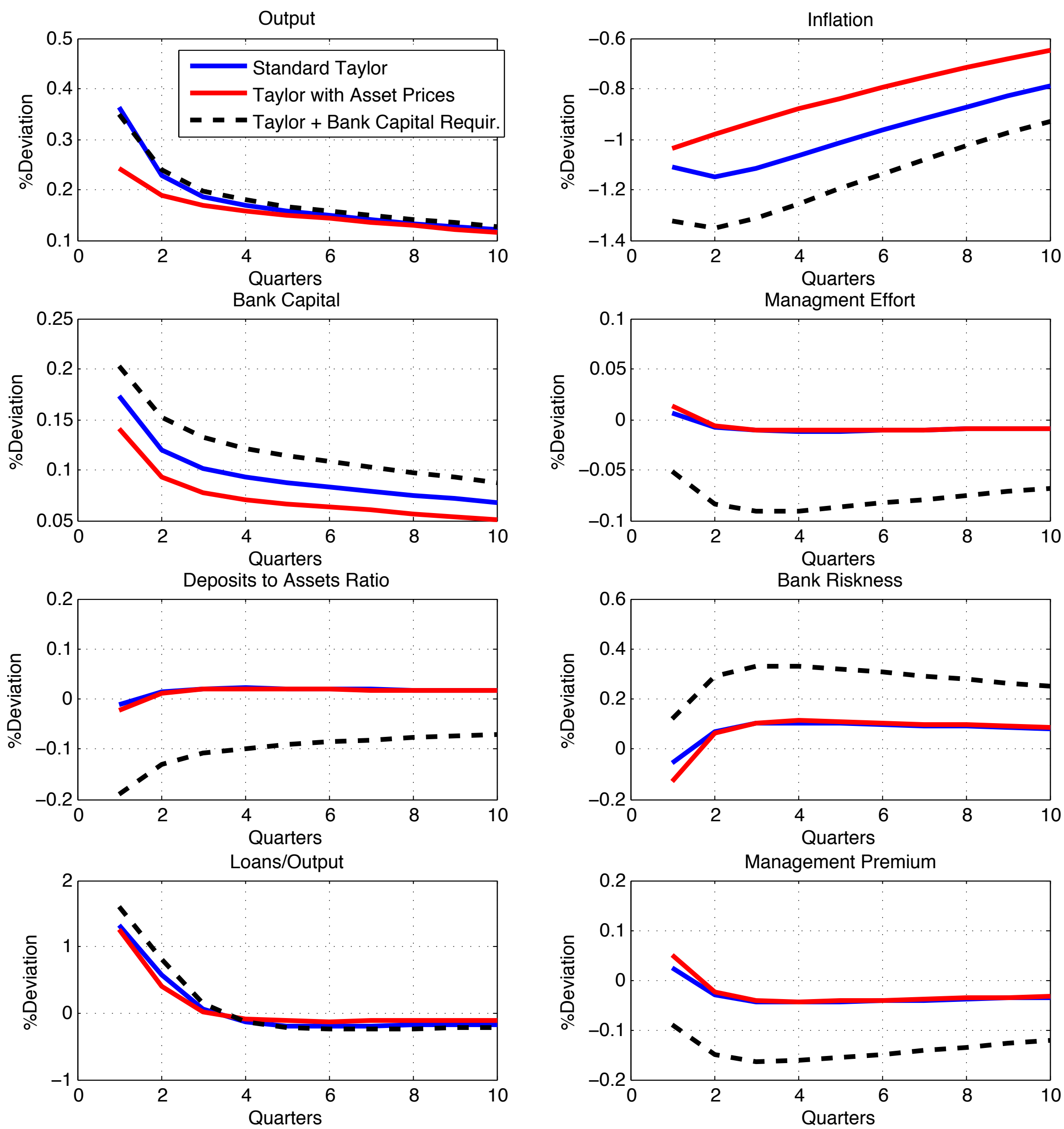
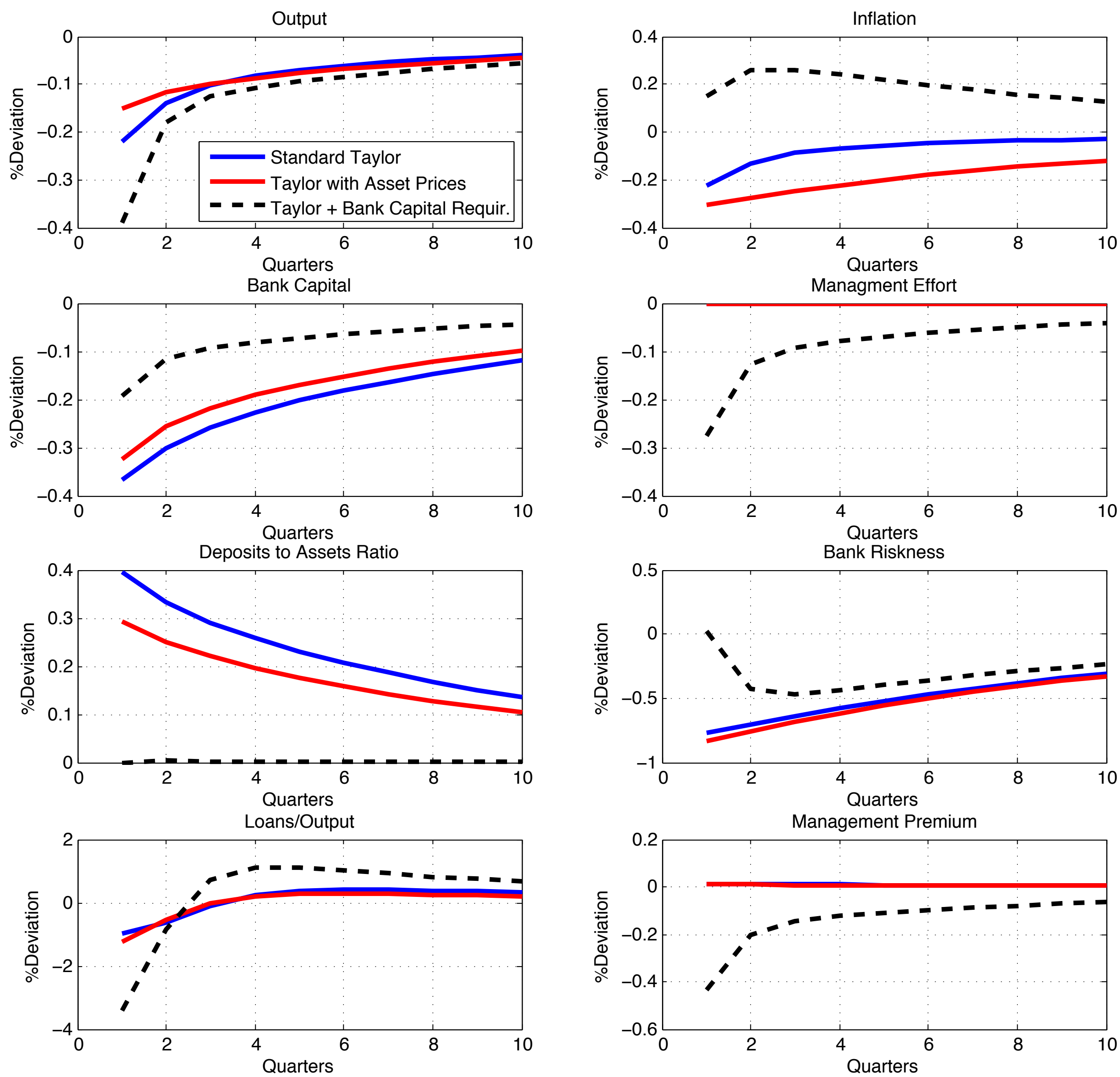


Figure 6: Macro-prudential monetary policy: Financial shock



Again, Figures 4-6 can be used to compare a regime with macro-prudential capital requirements and a standard Taylor rule (the black dotted impulse-responses) with that where only the monetary authority reacts to financial conditions (the red impulse-responses). During a monetary contraction, a pro-cyclical capital requirement in place supporting standard monetary policies seems to better manage the financial soundness of the banking system without having significant differences with the other policy regimes in terms of aggregate output and price stability. Indeed, the relaxation in capital requirements during a monetary downturn allows the banking system to increase its leverage and aggregate lending, while providing conditions for the banks to give higher premiums to managers, inducing higher management effort, than under the other policy regimes.

However, the introduction of a pro-cyclical capital requirement instrument in an otherwise standard Taylor rule regime seems to exacerbate the impact that a positive productivity shock has on macroeconomic conditions (Figure 5). This is because we are constraining the banks to be under a binding condition regarding their leverage position during the expansion. In this sense, our results are not conclusive and further work would be fruitful in understanding how this requirements would work under occasionally binding constraints.

Finally, figure 6 presents the results when there is a negative shock in bank capital. Surprisingly, under such scenario the macro-prudential policy seem to exercise a tighter constraint on banks than when they are free to choose their bank capital structure (red and blue lines). Interestingly, the economy under macro-prudential capital requirements manage to increase aggregate lending as capital drops to a lesser extend than in the other policy regimes, yet keeping bank leverage tightly under control. In addition, it tends to generate inflation during the downturn; but with lower levels of output and slightly higher levels of bank riskiness than those reached in those regimes without bank capital requirements. These results merit further scrutiny as they suggest the need for fine tuning of macro-prudential capital requirements and a better understanding of the tradeoffs that a combination of monetary and macro-prudential policies may bring between the real and the financial sectors.

# 4 Conclusion

We build a DSGE model with a banking sector fragile to runs on demand deposits. In this model depositors take decisions of wether to withdraw or not on demand based on the bank leverage levels and news announced by bank managers about the financial health of banks. We find that, during downturns the combination of macro-prudential tools such as pro-cyclical capital requirements (as proposed in Basel III) and standard monetary policy dominates regimes in which only the central bank attempts to react to financial conditions. However, this result can not be generalized as it depends on the type of shock (with different results in the case of a financial shock) and it does not follow through in a symmetric fashion when considering expansionary shocks where capital requirements may actually induce more macro-instability. Finally, it is worth mentioning that because the agency frictions in the model, management premiums may rise during downturns. Also, lower bank capital requirements during a financial contraction may induce inflationary pressures which may serve well when the economy is facing deflationary headwinds.[5]

Our model could be extended to explore different incentive environments. For example, it could bring in incentive schemes that remunerate loan officers based on the volume of loans as in Acharya and Naqvi [1]. Future research could include in a micro funded fashion the shifts in incentives to take on risks, for both managers and bank owners, as a result of government guarantees. Our model provides a suitable set up to incorporate deposit insurance by modifying the problem faced by households in their deposit/saving decisions under partial deposit insurance; and by incorporating insurance premiums and the consequent reduction in the liability of bank owners in case of run. This would allow the study of risk shifting due to the moral hazard induced by government rescue programs (see Eufinger and Gill [18] and Chaigneau [10]). Bringing these ideas into a DSGE model should provide insights about the regulation of compensation arrangements in the financial system as complementary macro-prudential tools. Indeed, this agenda should allow the study of the general equilibrium implications of linking bank management compensation schemes to the asset value of banks or the debt levels as in Edmans et al. [17], as well as the impact of linking capital requirements or deposit insurance premiums to bank management compensation as in Eufinger and Gill [18] and John and John [27]. Likewise, the model could be extended to study risk taking by bank managers in an asymmetric information environment where depositors have other asset vehicles such as money, treasuries or bonds besides demand deposits at banks (see Bolton et al. [7]).

[5] See among other press articles that may be related to this finding: "Fury over Lehman's Executive Pay," Al Jazeera (October 7, 2008) and "CEO Pay Climbs Higher Despite Slow Economy," NBC News (June 15, 2008).

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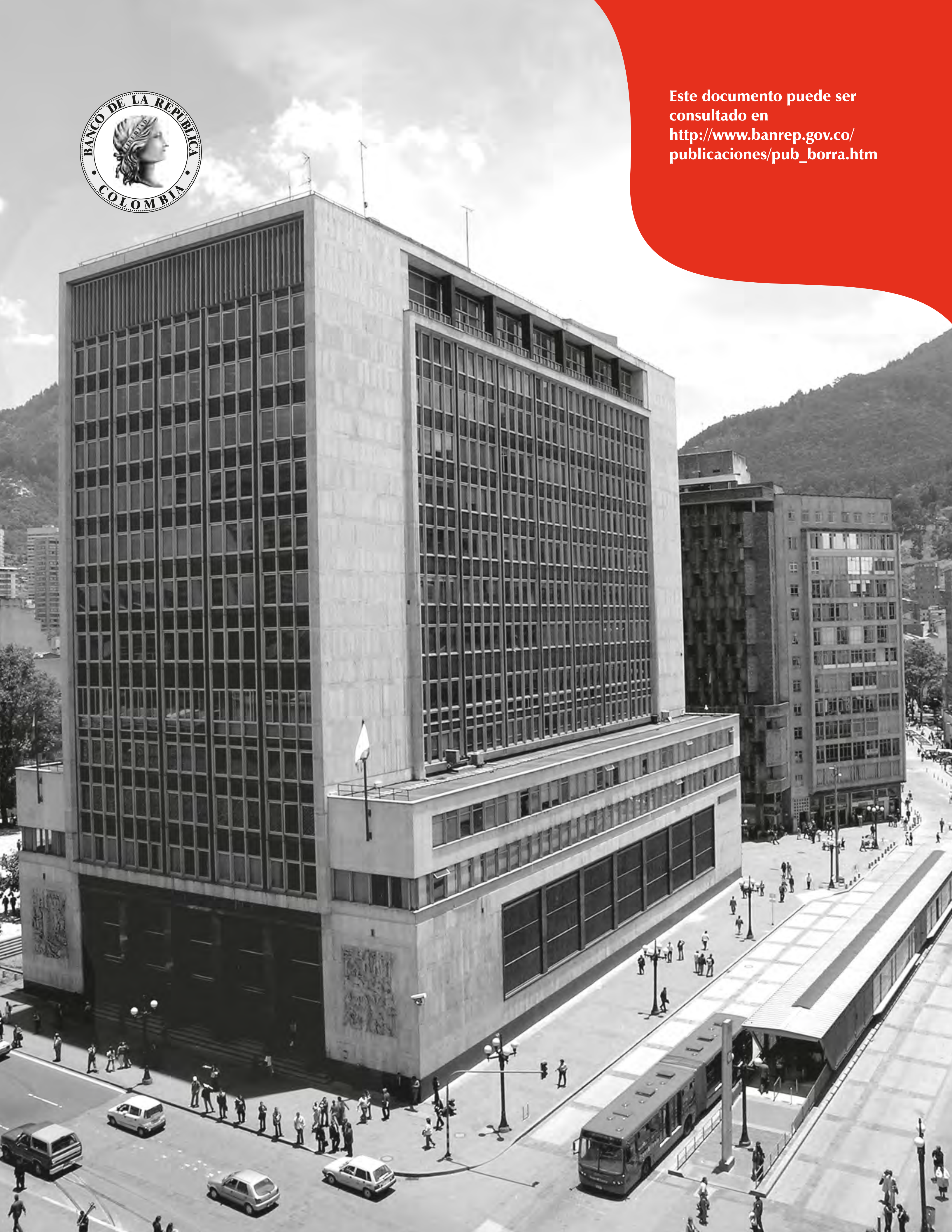

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