Bank Capital Regulation and Monetary Policy

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Abstract

We introduce banks, modeled as in Diamond and Rajan (2000; 2001), in a standard DSGE macromodel and study the transmission of monetary policy and its interplay with bank capital regulation when banks are exposed to runs. A monetary expansion and a positive productivity shock increase bank leverage and risk. Risk-based capital requirements (as in Basel II) amplify the cycle and are welfare detrimental. Within a broad class of simple policy rules, the best combination includes mildly anticyclical capital ratios (as in Basel III) and a response of monetary policy to asset prices or bank leverage.

JEL: E0, E5, G01

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1 Introduction

The financial crisis is producing, among other consequences, a change in perception on the roles of financial regulation and monetary policy. The pre-crisis common wisdom sounded roughly like this. Capital requirements and other prudential instruments were supposed to ensure, at least with high probability, the solvency of individual banks, with the implicit tenet that stable banks would automatically translate into a stable financial system. On the other side, monetary policy should largely disregard financial matters and concentrate on pursuing price stability (a low and stable consumer price inflation) over some appropriate time horizon. The recent experience is changing this accepted wisdom in two ways. On the one hand, the traditional formal requirements for individual bank solvency (asset quality and adequate capital) are no longer seen as sufficient for systemic stability; regulators are increasingly called to adopt a *macro-prudential* approach[1]. On the other, some suggest that monetary policy should help control systemic risks in the financial sector. This crisis has demonstrated that such risks can have disruptive implications for output and price stability, and there is growing evidence that monetary policy influences the degree of riskiness of the financial sector[2]. These ideas suggest the possibility of interactions between the conduct of monetary policy and that of macroprudential regulation.

In this paper we study how bank regulation and monetary policy interact in a macroeconomy that includes a fragile banking system[3]. To do this we need first a model that rigorously incorporates state-of-the art banking theory in a general equilibrium macro framework and also incorporates some key elements of financial fragility experienced in the recent crisis. In our model, whose banking core is adapted from Diamond and Rajan (2000, 2001), banks have special skills in redeploying projects in case of early liquidation. Uncertainty in projects outcomes injects risk in bank balance sheets. Banks are financed with deposits and capital; bank managers optimize the bank capital structure by maximizing the combined return of depositors and capitalists. Banks are exposed to runs, with a probability that increases with their deposit ratio or leverage. The relationship between the bank and its outside financiers (depositors and capitalists) is disciplined by two incentives:

[1] Morris and Shin (2008), Lorenzoni (2008).

[2] See Borio and Zhu (2009) for arguments, and Maddaloni and Peydró Alcalde (2009) and Altunbas et al. (2009) for empirical evidence.

[3] We refer to "banks" and "deposits" for convenience, but our arguments apply equally to other leveraged entities financed through short-term revolving debt like ABSs or commercial paper.

depositors can run the bank, forcing early liquidation of the loan and depriving bank capital of its return; and the bank can withhold its special skills, forcing a costly liquidation of the loan. The desired capital ratio is determined by trading-off balance sheet risk with the ability to obtain higher returns for outside investors in "good states" (no run), which increase with the share of deposits in the bank's liability side.

Introducing these elements provides a characterization of financial sector that is, we think, more apt to interpret the recent experience than classic "financial accelerator" formulations which, although pioneering the introduction of financial frictions into macro models, focused normally on the role of firms' collateral in the transmission of shocks rather than explicitly on banks. Endogenizing the bank capital structure also provides a natural way to study banking regulation in conjunction with monetary and other macro policies. Our model allows, inter alia, to study how capital regulation, and potentially also liquidity ratios and other prudential instruments, influence economic performance, collective welfare and the optimal monetary policy.

Blum and Hellwig (1995), and Cecchetti and Li (2008) have examined optimal monetary policy design and bank regulation with specific reference to the pro-cyclicality of capital requirements. Two main elements differentiate our work. First, these studies have taken capital requirements as given and studied the optimal monetary policy response, while we consider their interaction and possible combinations. Second, in earlier studies the loan market and bank capital structure were specified exogenously or ad hoc, while we incorporate optimizing bank behavior explicitly. Gertler and Karadi (2009) and Gertler and Kiyotaki (2009) have recently proposed a model with micro-founded banks. In their work an asymmetric information problem between banks and uninformed investors is solved through the introduction of an incentive compatibility constraint, which leads to a relation between bank capital and external finance premia. Our approach to modelling the bank differs in that we allow for equilibrium bank runs. More importantly, their aim is to look at the effects of unconventional monetary policies, while we explore the interplay between (conventional) monetary policy and bank regulation. Their focus is more on crisis management, ours on crisis prevention.

Our bank's optimal deposit ratio is positively related to: 1) the bank expected return on assets; 2) the uncertainty of project outcomes; 3) the banks' skills in liquidating projects, and

negatively related to 4) the return on bank deposits. These properties echo the main building blocks of the Diamond-Rajan banking model. The intuition, roughly speaking, is that increases in 1), 2) and 3) raise the return to outside bank investors of a unitary increase in deposits, the first by increasing the expected return in good states (no run), the second by reducing its cost in bad states (run), the third by increasing the expected return relative to the cost between the two states. A higher deposit rate reduces deposits from the supply side, because it increases, *ceteris paribus*, the probability of run. Inserting this banking core into a standard DSGE framework yields a number of results. A monetary expansion or a positive productivity shock increase bank leverage and risk. The transmission from productivity changes to bank risk is stronger when the perceived riskiness of the projects financed by the bank is low. Pro-cyclical capital requirements (akin to those built in the Basel II capital accord) amplify the response of output and inflation to other shocks, thereby increasing output and inflation volatility, and reduce welfare. Conversely, anti-cyclical ratios, requiring banks to build up capital buffers in more expansionary phases of the cycle, have the opposite effect. To analyse alternative policy rules we use second order approximations, which in non-linear models allow to account for the effects of volatility on the mean of all variables, including welfare. Within a broad class of simple policy rules, the optimal combination includes mildly anti-cyclical capital requirements (i.e., that require banks to build up capital in cyclical expansions) and a monetary policy that responds rather aggressively to inflation and also reacts systematically to financial market conditions – either to asset prices or to bank leverage.

The rest of the paper is as follows. Section 2 provides a brief overview of the recent but rapidly growing literature merging banking in macro models. Section 3 describes the model, with special emphasis on the banking bloc. Section 4 characterizes the transmission mechanism and examines the sensitivity to some key parameters. Section 5 discusses the effect of introducing regulatory capital ratios. Section 6 examines the performance of alternative monetary policy rules combined with different bank capital regimes. Section 7 concludes. Proofs, further details on the model and sensitivity analyses to alternative modelling assumptions and the calibration of the Basel capital regime are contained in appendices.

2 Merging the Banking and the Macro Literatures

After the financial crisis, considerable attention has been devoted on how to embed credit frictions and financial risks into macroeconomic analyses. Attempts to take financial frictions into account pre-existed, but most of the them had focused on credit constraints faced alternatively by households and firms, without explicitly considering banks or other financial intermediaries. Models of the financial accelerator family[4] studied business cycle fluctuations generated by agency problems between firms and lenders, while models with collateral constraints along the lines of the Kiyotaki and Moore (1997) focused more on the impact of constraints on households borrowing on the macro dynamic[5]. The crisis highlighted the lack of a macro model embedding micro-founded banks. Such absence prevented both the explicit consideration of financial intermediaries as a source of shocks to the macroeconomy, and the study of the macroeconomic impact of financial regulation.

Recently, steps have been taken toward integrating banking or financial sectors in infinite horizon DSGE models, with purposes partially similar to ours. Contributions can be divided in four main categories, based on a classification pertaining to the finance literature. First, there are models that include banks facing a *single* moral hazard problem with the uninformed investors: to this category belong the papers by Gertler and Karadi (2009) and Gertler and Kiyotaki (2009), with the latter also including an interbank market. In this case the moral hazard problem is dealt with by modeling incentive compatibility constraints of a dynamic nature. The second category includes models that embed a *dual* moral hazard problem on the lines of Diamond (1984) and Holmström and Tirole (1997)[6]. The third category includes models analyzing liquidity spirals[7]. There is then a fourth category focusing on the industrial structure of the banking sector, in the Klein-Monti tradition[8]. Though some of those papers explore the impact of capital regulation and in very few cases also the interaction with monetary policy, none addresses the issue of bank runs. One of the main feature of the recent financial crisis, if not the most problematic, has been the possibility of dry up of liquidity and of funding to financial intermediaries, despite a very expansionary stance of

[4] Bernanke, Gertler and Gilchrist (1999).

[5] See Iacoviello (2005).

[6] To this category belong papers by Meh and Moran (2008) and Covas and Fujita (2009). Along the same lines Faia (2010) introduces banks and secondary markets for credit risk transfer into a DSGE model.

[7] See for instance Bunnermeier and Sannikov (2010).

[8] See among others Acharya and Naqvi (2010) and Darracq Paries et al. (2010).

monetary policy. Runs did not in general affect traditional deposits (Northern Rock and a few other cases were exceptions), but typically other more volatile forms of funding for banks and conduits, like REPOs and ABSs.

To capture these mechanisms, we build on Diamond and Rajan (2000, 2001), whose models include both moral hazard considerations and bank runs. Note that, while in this respect we connect to the literature on bank runs[9], our analysis of the interplay between bank runs and liquidity does not lead to multiplicity of equilibria. We can then study financial and macroeconomic stability issues under conventional monetary and bank regulatory policies, without making recourse to yet unexplored equilibrium-selecting instruments.

Diamond and Rajan (2006) provide a first attempt to integrate banks and bank runs in a monetary model. They do so in a two period economy model in which monetary policy is conducted by means of money supply and monetary non-neutrality is obtained via frictions on deposits. They find that monetary policy should inject money during contractionary phases. Our analysis includes banks into an infinite horizon DSGE model hence it accommodates the role of expectations and accounts for the Lucas critique. Moreover, our paper includes the study of the optimal combination of prudential regulation and monetary policy, alongside with an analysis of the monetary transmission mechanism.

3 The Baseline Model

The starting point is a conventional DSGE model with nominal rigidities. There are four type of agents in this economy: households, financial intermediaries, final good producers and capital producers. The model is completed by a monetary policy function (a Taylor rule) and a skeleton fiscal sector.

3.1 Households

There is a continuum of identical households who consume, save and work. Households save by lending funds to financial intermediaries, in the form of deposits and bank capital. To allow aggregation within a representative agent framework we follow Gertler and Karadi (2009) and assume

[9] Diamond and Dybvig (1983), Allen and Gale (2004).

that in every period a fraction γ of household members are bank capitalists and a fraction $(1-\gamma)$ are workers/depositors. Hence households also own financial intermediaries[10]. Bank capitalists remain engaged in their business activity next period with a probability θ, which is independent of history. This finite survival scheme is needed to avoid that bankers accumulate enough wealth to remove the funding constraint. A fraction $(1-\theta)$ of bank capitalists exit in every period, and a corresponding fraction of workers become bank capitalists every period, so that the share of bank capitalists, γ, remains constant over time. Workers earn wages and return them to the household[11]; similarly bank capitalists return their earnings to the households. However, bank capitalists' earnings are not used for consumption but are given to the new bank capitalists and reinvested as bank capital. Households maximize the following discounted sum of utilities:

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

where C_t denotes aggregate consumption and N_t denotes labour hours. The workers in the production sector receive at the beginning of time t a real labour income $\frac{W_t}{P_t} N_t$. Households save and invest in bank deposits and bank capital. Deposits, D_t, pay a gross nominal return R_t one period later. In fact due to the possibility of bank runs, the return on deposits is subject to a time-varying risk (see Appendix 1). However, we assume that expected losses are largely covered by government intervention and are financed with lump sum taxations: hence the loss in case of default affects the resource constraint but not the households' budget constraint[12]. Households also own the production sector, from which they receive nominal profits for an amount, Θ_t. Let T_t be net transfers to the public sector (lump sum taxes, equal to public expenditures); the budget constraint reads as follows[13]:

$$P_t C_t + T_t + D_{t+1} \leq W_t N_t + \Theta_t + R_t D_t \tag{2}$$

[10] As in Gertler and Karadi (2009) it is assumed that households hold deposits with financial intermediaries that they do not own.

[11] As will be described later, the bank capital structure is determined by bank managers, who maximize the returns of both depositors and bank capitalists. Bank managers are workers in the financial sector. Hence, household members can either work in the production sector or in the financial sector. We assume that the fraction of workers in the financial sector is negligible, hence their earnings are not included in the budget constraint.

[12] To preserve the possibility of bank runs, it is sufficient that deposit risk is not covered fully.

[13] Note that the return from, and the investment in, bank capital do not appear in equation 2. The reason is that we have assumed, as explained later, that all returns on bank capital are reinvested every period.

Households choose the set of processes $\{C_t, N_t\}_{t=0}^{\infty}$ and deposits $\{D_{t+1}\}_{t=0}^{\infty}$, taking as given the set of processes $\{P_t, W_t, R_t\}_{t=0}^{\infty}$ and the initial value of deposits D_0 so as to maximize 1 subject to 2. The following optimality conditions hold:

$$\frac{W_t}{P_t} = -\frac{U_{n,t}}{U_{c,t}} \tag{3}$$

$$U_{c,t} = \beta E_t\{R_t U_{c,t+1}\} \tag{4}$$

Equation 3 gives the optimal choice for labour supply. Equation 4 gives the Euler condition with respect to deposits. Optimality requires that the first order conditions and No-Ponzi game conditions are simultaneously satisfied.

3.2 Banks

There is in the economy a large number (L_t) of uncorrelated investment projects. The project lasts two periods and requires an initial investment. Each project's size is normalized to unity (think of one machine) and its price is Q_t. The projects require funds, which are provided by the bank. Banks have no internal funds but receive finance from two classes of agents: holders of demand deposits and bank capitalists. Total bank loans (equal to the number of projects multiplied by their unit price) are equal to the sum of deposits (D_t) and bank capital, (BK_t). The aggregate bank balance sheet is $Q_t L_t = D_t + BK_t$.

The capital structure (deposit share, equal to one minus the capital share) is determined by bank manager on behalf of the external financiers (depositors and bank capitalists). The manager's task is to find the capital structure that maximizes the combined expected return of depositors and capitalists, in exchange for a fee. Individual depositors are served sequentially and fully as they come to the bank for withdrawal; bank capitalists instead are rewarded pro-quota after all depositors are served. This payoff mechanism exposes the bank to runs, that occur when the return from the project is insufficient to reimburse all depositors. As soon as they realize that the payoff is insufficient, depositors run the bank and force the liquidation of the project; in this case the bank capital holders get zero while depositors get the market value of the liquidated loan.

The timing is as follows. At time t, the manager of bank k decides the optimal capital structure, expressed by the ratio of deposits to total loans, $d_{k,t} = \frac{D_{k,t}}{Q_{k,t} L_{k,t}}$, collects the funds, lends, and then

Graph 1: Bank capital structure and the risk of bank run

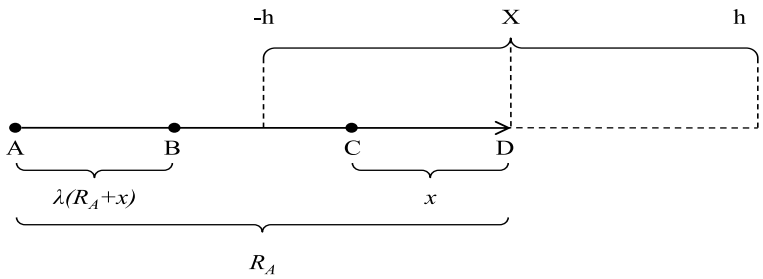


Figure 1:

the project is undertaken. At time $t+1$, the project's outcome is known and payments to depositors and bank capitalists (including the fee for the bank manager) are made, as discussed below. A new round of projects starts.

As in Diamond and Rajan (2000, 2001), we assume that the return of each project for the bank is equal to an expected value, $R_{A,t}$, plus a random shock. For simplicity we use a uniform density with dispersion h (we check the robustness of the results to other distributions; see Appendix 2). Therefore, the outcome of project j is $R_{A,t} + x_{j,t}$, where $x_{j,t}$ spans across the interval $[-h; h]$ with probability $\frac{1}{2h}$. Given our assumption of identical projects and banks, for notational convenience from now on we can omit project and bank subscripts. For the time being, we can omit time subscripts as well.

Each project is financed by one bank. Our bank is a *relationship lender*: by lending it acquires a specialized non-sellable knowledge of the characteristics of the project. This knowledge determines an advantage in extracting value from it before the project is concluded, relative to other agents. Let the ratio of the value for the outsider (liquidation value) to the value for the bank be $0 < \lambda < 1$. Even if the project is liquidated by a bank, a run is assumed to entail a value loss, $1 > c \geq 0$; when the run occurs, the recovery rate is reduced by a factor c.

Suppose the ex-post realization of x is negative, as depicted in graph 1 (point C), and consider how the payoffs of the three players are distributed depending on the ex-ante determined value of the deposit ratio d and the deposit rate R. There are three cases.

Case A: Run for sure. The outcome of the project is too low to pay depositors. This happens if gross deposits (including interest) are located to the right of C in the graph, where $R_A + x < Rd$. Payoffs are distributed as follows. Capitalists receive the leftover after depositors are served, so they get zero in this case. Depositors alone (without bank) would get the fraction $\lambda(1-c)(R_A+x)$ of the project's outcome (segment AB), so they claim this amount in full. The remainder $(1-\lambda)(1-c)(R_A+x)$ is shared between depositors and the bank manager depending on their relative bargaining power. As Diamond and Rajan (2000), we assume this extra return is split in half[14]. Therefore, depositors end up with $\frac{(1+\lambda)(1-c)(R_A+x)}{2}$ and the bank with $\frac{(1-\lambda)(1-c)(R_A+x)}{2}$.

Case B: Run only without the bank. The project outcome is high enough to allow depositors to be served if the project's value is extracted by the bank, but not otherwise. This happens if gross deposits (including interest) are located in the segment BC in the graph, i.e. the range where $\lambda(R_A+x) < Rd \leq (R_A+x)$. In this case, the capitalists alone cannot avoid the run, but with the bank they can. So depositors are paid in full, Rd, and the remainder is split in half between the bank manager and the capitalists, each getting $\frac{R_A+x-Rd}{2}$. Total payment to outsiders is $\frac{R_A+x+Rd}{2}$.

Case C: No run for sure. The project's outcome is high enough to allow all depositors to be served, with or without the bank's participation. This happens in the zone AB, where $Rd \leq \lambda(R_A+x)$. Depositors get Rd. However, unlike in the previous case, now the capitalists have a higher bargaining power because they could decide to liquidate the project alone and pay the depositors in full, getting $\lambda(R_A+x) - Rd$; this is thus a lower threshold for them. The bank manager can extract $(R_A+x) - Rd$, and again we assume that the capitalist and the manager split this extra return in half. Therefore, the manager gets:

$$\frac{[(R_A+x) - Rd] - [\lambda(R_A+x) - Rd]}{2} = \frac{(1-\lambda)(R_A+x)}{2}$$

This is less than what the capitalist gets. Total payment to outsiders is $\frac{(1+\lambda)(R_A+x)}{2}$. We can now

[14] It seems natural to assume that depositors and bank managers have equal bargaining power because neither can appropriate the extra rent without help from the other. But, as shown in Appendix 1, thi asumption is not crucial. Diamond and Rajan (2000) mention also another case in which the depositors, after appropriating the project, bargain directly with the entrepreneur running the project. If the entrepreneur retains half of the rent, the result is obviously unchanged. If not, the resulting equilibrium is more tilted towards a high level of deposits, because depositors lose less in case of bank run.

write the expected value of total payments to outsiders as follows:

$$\frac{1}{2h}\left[\int_{-h}^{Rd-R_A}\frac{(1+\lambda)(1-c)(R_A+x)}{2}dx+\int_{Rd-R_A}^{\frac{Rd}{\lambda}-R_A}\frac{(R_A+x)+Rd}{2}dx+\int_{\frac{Rd}{\lambda}-R_A}^{h}\frac{(1+\lambda)(R_A+x)}{2}dx\right] \tag{5}$$

The three terms express the payoffs to outsiders in the three cases described above, in order. The banker´s problem is to maximize expected total payments to outsiders by choosing the suitable value of d.

Proposition 1. The value of d that maximizes equation 5 is comprised in the interval $\lambda\frac{R_A+h}{R} < d < \frac{R_A+h}{R}$.

Proof. See Appendix 2.

In this interval, the third integral in the equation vanishes and the expression reduces to:

$$\frac{1}{2h}\int_{-h}^{Rd-R_A}\frac{(1+\lambda)(1-c)(R_A+x)}{2}dx+\frac{1}{2h}\int_{Rd-R_A}^{h}\frac{(R_A+x)+Rd}{2}dx \tag{6}$$

Consider equation 6 in detail. A marginal increase in the deposit ratio has three effects. First, it increases the range of x where a run occurs, by raising the upper limit of the first integral; this effect increases the overall return to outsiders by $\frac{1}{2h}\left(\frac{(1+\lambda)(1-c)}{2}Rd\right)R$. Second, it decreases the range of x where a run does not occur, by raising the lower limit of the second integral; the effect of this on the return to outsiders is negative and equal to $-\frac{1}{2h}R^2d$. Third, it increases the return to outsiders for each value of x where a run does not occurs; this effect is $\frac{1}{2h}\left(\int_{Rd-R_A}^{h}\frac{1}{2}dx\right)R=\frac{1}{2h}\left(\frac{h-Rd+R_A}{2}\right)R$. Equating to zero the sum of the three effects and solving for d yields the following solution for the level of deposits for each unit of loans:

$$d=\frac{1}{R}\frac{R_A+h}{2-\lambda+c(1+\lambda)}. \tag{7}$$

Since the second derivative is negative, this is the optimal value of d. The optimal deposit ratio depends positively on h, λ and R_A, and negatively on R and c. An increase of R (or c) reduces deposits because it increases the probability or cost of run. Moreover, an increase in R_A raises the marginal return in the no-run case (the third effect just mentioned), while it does not affect the other two effects, hence it raises d. An increase in λ reduces the cost in the run case (first

effect), while not affecting the others, so it raises d. The effect of h is more tricky. At first sight it would seem that an increase in the dispersion of the project outcomes, moving the extreme values of the distribution both upwards and downwards, should be symmetric and have no effect. But this is not the case. When h increases, the probability of each given project outcome $\frac{1}{2h}$ falls. Hence the expected loss stemming from the change in the relative probabilities (sum of the first two effects) falls, but the marginal gain in the no-run case (third term) does not, because the upper limit increases. The marginal effect is $\frac{R}{2}$, because depositors get the full return, but half is lost by the capitalist to the banker. Hence, the increase of h has on d a positive effect, as R_A.

A natural measure of bank riskiness is the probability of a run occurring. This can be written as:

$$z = \frac{1}{2h} \int_{-h}^{Rd-R_A} dx = \frac{1}{2}\left(1 - \frac{R_A - Rd}{h}\right) \tag{8}$$

Note that for low values of λ and h, the probability would tend to fall below zero; in this case the marginal equilibrium condition 7 and the last equality of 8 cease to hold. Deposits can never fall below the level where a run becomes impossible. Some degree of bank risk is always optimal in this model.

In the aggregate, the amount invested in every period (time subscripts are nor reinserted) is $Q_t L_t = Q_t K_t$. The total amount of deposits in the economy is $D_t = \frac{Q_t L_t}{R_t} \frac{R_{A,t}+h}{2-\lambda+c(1+\lambda)}$, and aggregate bank capital is

$$BK_t = (1 - \frac{1}{R_t} \frac{R_{A,t} + h}{2 - \lambda + c(1+\lambda)})Q_t L_t \tag{9}$$

The latter expressions suggest that following an increase in R_t the optimal amount of bank capital increases on impact (for given R_A). In general equilibrium the responses are more complex, depending on several counterbalancing factors affecting R_A and R, as the later results will show.

Equation 9 is the level of bank capital desired by the bank manager, for any given level of investment, $Q_t L_t$ and interest rate structure (R_t, $R_{A,t}$). We assume that bank capital comes from reinvested earnings of the bank capitalist. After remunerating depositors and paying the competitive fee to the bank manager, a return accrues to the bank capitalist, and this is reinvested in the bank as follows:

$$BK_t = \frac{\theta}{\pi_t}[BK_{t-1} + RTK_t Q_t K_t] \tag{10}$$

where RTK_t is the unitary return to the capitalist. The parameter θ is a decay rate, given by the bank survival rate already discussed. RTK_t can be derived from equation 6 as follows:

$$RTK_t = \frac{1}{2h} \int_{R_t d_t - R_{A,t}}^{h} \frac{(R_{A,t} + x_t) - R_t d_t}{2} dx_t = \frac{(R_{A,t} + h - R_t d_t)^2}{8h} \tag{11}$$

Note that this expression considers only the no-run state because if a run occurs the capitalist receives no return. The accumulation of bank capital is obtained substituting 11 into 10:

$$BK_t = \frac{\theta}{\pi_t}[BK_{t-1} + \frac{(R_{A,t} + h - R_t d_t)^2}{8h} Q_t K_t] \tag{12}$$

Importantly, notice that booms and busts in asset prices, Q_t, also affect bank capital. This captures the balance sheet channel in our model.

3.3 Producers

The production sector of the model is standard; see Appendix 3 and the longer version of this paper (reference) for details. Final output producers produce different varieties according with a Cobb-Douglas production function, $Y_t(i) = A_t F(N_t(i), K_t(i))$. They have monopolistic power in the production of their own variety, whose demand is given by $Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t$, with ε being the demand elasticity. Additionally they face quadratic price adjustment costs, $\frac{\vartheta}{2}\left[\frac{P_t(i)}{P_{t-1}(i)} - 1\right]^2 P_t$, where ϑ captures the degree of price stickiness. Their first order conditions equate, as usual, the real wage, $\frac{W_t}{P_t}$, and the real rental rate of capital, Z_t, to the marginal products of labor and capital, $F_{n,t}, F_{k,t}$ and give rise to a non-linear forward looking New-Keynesian Phillips curve in which deviations of the real marginal cost, mc_t, from its desired steady state value are the driving force of inflation,π_t:

$$U_{c,t}(\pi_t - 1)\pi_t = \beta E_t\{U_{c,t+1}(\pi_{t+1} - 1)\pi_{t+1}\} + U_{c,t} A_t F_t(\bullet)\frac{\varepsilon}{\vartheta}(mc_t - \frac{\varepsilon - 1}{\varepsilon})$$

In turn, the capital producing sector is competitive. Capital accumulation is affected by adjustment costs: $K_{t+1} = (1-\delta)K_t + \phi(\frac{I_t}{K_t})K_t$. In equilibrium, the gross (real) return from holding a unit of capital is equalized to the gross (real) return that the banks receive for their loan services.

$$\frac{R_{A,t+1}}{\pi_{t+1}} \equiv \frac{Z_{t+1} + Q_{t+1}((1-\delta) - \phi\prime(\frac{I_{t+1}}{K_{t+1}})\frac{I_{t+1}}{K_{t+1}} + \phi(\frac{I_{t+1}}{K_{t+1}}))}{Q_t} \tag{13}$$

where the asset price is given by $Q_t = \frac{P_t}{\phi'(\frac{I_t}{K_t})}$.Hence, the bank return on assets $R_{A,t}$ is the key transmission link from the banking sector to the production sector in the model. Hence shocks affecting investment and asset price would also affect the average return to outside investors.

3.4 Goods Market Clearing and Monetary Policy

The government runs a balance budget and uses lump sum taxation to finance exogenous government expenditure and to cover the average losses to households in case bank runs occur:

$$T_t = G_t + \Delta_t$$

where Δ_t is the aggregate expected loss on deposits (see Appendix 1 for the derivation). Equilibrium in the final good market requires that the production of the final good equals the sum of private consumption by households and entrepreneurs, investment, public spending, and the resource costs that originate from the adjustment of prices. The combined resource constraints, inclusive of government budget, reads as follows:

$$Y_t - \Omega_t - \Delta_t = C_t + I_t + G_t + \frac{\vartheta}{2}(\pi_t - 1)^2 \tag{14}$$

In the above equation, $\Omega_t = \int_{-h}^{R_t - R_{A,t}} R_{A,t}(Q_{t-1}K_t)\frac{c}{2h}dx_t$ represents the expected cost of run while G_t is exogenous government consumption of the final good.

We assume that monetary policy is conducted by means of an interest rate reaction function of this form:

$$\begin{aligned} \ln\left(\frac{R_t}{R}\right) &= (1-\phi_r)\left[\phi_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \phi_y \ln\left(\frac{Y_t}{Y}\right) + \phi_q \ln\left(\frac{Q_t}{Q}\right) + \phi_d \ln\Delta\left(\frac{d_t}{d}\right)\right] \\ &\quad + \phi_r \ln\left(\frac{R_{t-1}}{R}\right) \end{aligned} \tag{15}$$

All variables are deviations from the target or steady state (symbols without time subscript). Note that the reaction function includes two alternative terms that express a systematic reaction to financial market conditions, in the form of a response to asset prices (Q_t) or to the change of the deposit ratio (d_t). We will compare policy rules of this form, characterized by different parameter sets $\{\phi_\pi, \phi_y, \phi_q, \phi_d, \phi_r\}$.

3.5 Parameter values

Household preferences and production. The time unit is the quarter. The utility function of households is $U(C_t, N_t) = \frac{C_t^{1-\sigma}-1}{1-\sigma} + \nu \log(1 - N_t)$, with $\sigma = 2$, as in most real business cycle literature. We set ν set equal to 3, chosen in such a way to generate a steady-state level of employment $N \approx 0.3$. We set the discount factor $\beta = 0.995$, so that the annual real interest rate is around 2%. We assume a Cobb-Douglas production function $F(\bullet) = K_t^{\alpha}(N_t)^{1-\alpha}$, with $\alpha = 0.3$. The quarterly aggregate capital depreciation rate δ is 0.025, the elasticity of substitution between varieties 6. The adjustment cost parameter is set so that the volatility of investment is larger than the volatility of output, consistently with empirical evidence: this implies an elasticity of asset prices to investment of 2. The price stickiness parameter ϑ is set equal to 30, a value that matches, in the Rotemberg framework, the empirical evidence on the frequency of price adjustments obtained using the Calvo-Yun approach[15].

Banks. To calibrate h we have calculated the average dispersion of corporate returns from the data constructed by Bloom et al. (2009), which is around 0.3, and multiplied this by the square root of 3, the ratio of the maximum deviation to the standard deviation of a uniform distribution. The result is 0.5. We set the value of h slightly lower, at 0.45, a number that yields a more accurate estimates of the steady state values of the bank deposit ratio[16], and then run sensitivity analyses above and below this value[17]. One way to interpret λ is to see it as the ratio of two present values of the project, the first at the interest rate applied to firms' external finance, the second discounted at the bank internal finance rate (the money market rate). A benchmark estimate can be obtained by taking the historical ratio between the money market rate and the lending rate. In the US over the last 20 years, based on 30-year mortgage loans, this ratio has been around 3

[15] The New Keynesian literature has usually considered a frequency of price adjustment of four quarters as realistic. Recently, Bils and Klenow (2004) have argued that the observed frequency of price adjustment in the US is higher, in the order of two quarters.

[16] The bank capital accumulation equation 12, once we substitute in the optimal deposit ratio 7, yields a quadratic equation in R_A. Solving the quadratic equation for given values of the parameters, one obtains a root for R_A equal to 1.03 (3 percent on a quarterly basis). The corresponding value of d is 80 percent, and bk is 20 percent. Notice that the bank capital accumulation equation includes the money that households transfer in every period to new bankers, given by a fraction of the value of the project: $\phi Q_t K_t$. The steady state value that helps to pin down the return on asset, R_A, is 0.075. Since such term is negligible we have omitted that in the dynamic.

[17] In principle, h could be endogenous to the state of the economy; Bloom (2009) shows that the dispersion of corporate returns is anticyclical. A link between h and the cycle could be added into our framework. In this paper we have used a fixed h and done sensitivity analysis.

percent. This leads to a value of λ around 0.6. In the empirical analyses we have chosen 0.45 and then run sensitivity analyses above and below this value. Finally we parametrize the survival rate of banks, θ, at 0.97, a value compatible with an average horizon of 10 years. Notice that the parameter $(1-\theta)$ is meant to capture only the exogenous exit rates, as the failure rate is linked to the distribution of idiosyncratic shocks to corporate returns. The parameter c can be set looking at statistics on recovery rates, available from Moody's. These rates tend to vary considerably, from below 50 percent up to 80 or 90 percent for some assets. We used a conservative 80 percent, which implies $c = 0.2$.

Shocks. Total factor productivity is assumed to evolve according to an AR(1) process, $A_t = A_{t-1}^{\rho_\alpha} \exp(\varepsilon_t^\alpha)$, where ε_t^α is an i.i.d. shock with standard deviation σ_α. In line with the real business cycle literature, we set $\rho_\alpha = 0.95$ and $\sigma_\alpha = 0.056$. Log-government consumption is assumed to evolve according to the process $\ln(\frac{G_t}{G}) = \rho_g \ln(\frac{G_{t-1}}{G}) + \varepsilon_t^g$, where G is the steady-state share of government consumption (set in such a way that $\frac{G}{Y} = 0.25$) and ε_t^g is an i.i.d. shock with standard deviation σ_g. We follow the empirical evidence for the U.S. in Perotti (2004) and set $\sigma_g = 0.0074$ and $\rho_g = 0.9$.We introduce a monetary policy shock as an additive disturbance to the interest rate set through the monetary policy rule. The monetary policy shock is assumed to be moderately persistent (coefficient 0.2), as argued by Rudebusch (2002). Based on the evidence of Angeloni, Faia and Lo Duca (2010), and consistently with other empirical results for US and Europe, the standard deviations of the shocks is set to 0.006.

4 Transmission Channels

We first look at the response to a monetary restriction (figure 1), shown under two alternative values of h: 0.45 (the benchmark) and 0.65 (higher uncertainty on the project outcome). Both inflation and output drop on impact, as standard in most models, with a corresponding fall in investment. The increase in interest rate activates the risk taking channel: bank leverage and bank risk decline. The spread between $R_{A,t}$ and R_t ("bank lending premium") rises; other things equal, in the model an increase in this premium tends to accompany a decline in bank risk (see equation 8), while the relation with output and investment depends on the nature of the shock[18]. Note that

[18] Unlike in the financial accelerator model, where the external finance premium tends to be anticyclical. For a comparison of these two models see Angeloni, Faia and Lo Duca (2011).

the transmission of the monetary shock to bank leverage and risk is stronger if the uncertainty of project is low. This suggests the idea that in "euphoric" states, when investment riskiness is perceived to be low, a monetary expansion may have a particularly strong effect on bank risk. The lending premium rises more if h is high, and the contraction of output is more pronounced.

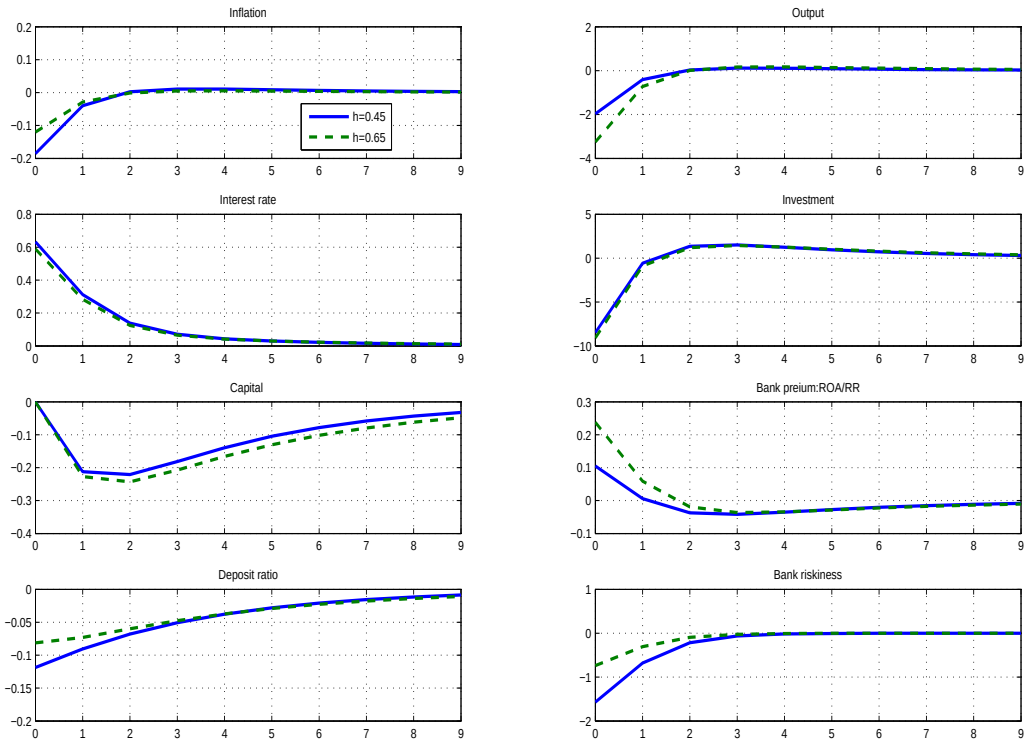


Fig 1: Positive interest rate shock; h=0.45 (solid line) or 0.65 (dashed line)

A positive productivity shock (figure 2, again with two variants, with h equal to 0.45 or 0.65) reduces inflation and increases output. The increase in productivity also brings about an increase in capital and investment. The bank lending premium declines, enhancing the expansionary effect of the shock. The policy-driven short term interest rate, R_t, falls, as the monetary authority reacts to the fall in inflation by means of a Taylor rule. Lower interest rates raise deposits and tilt the composition of the bank balance sheet towards higher leverage and risk; the risk taking channel operates under a productivity shock via the effect on interest rates. The two lines in the figure highlight the role played by entrepreneurial risk in the transmission. Note that entrepreneurial

risk is distinct from bank risk: the first is measured by the parameter h, while the second depends endogenously on the bank capital structure. The two are linked, however: a higher h tends to increase the bank leverage and the probability of run on the bank , as one can see in equation 8. Moreover, h also affects the response of bank risk to all other shocks. Note that the short run response of bank risk is stronger if the entrepreneurial risk is lower. This again highlights a self-reinforcing mechanism that may operate in "exuberant" phases: positive productivity shocks generate more bank risk if the perceived uncertainly of investment projects is low.

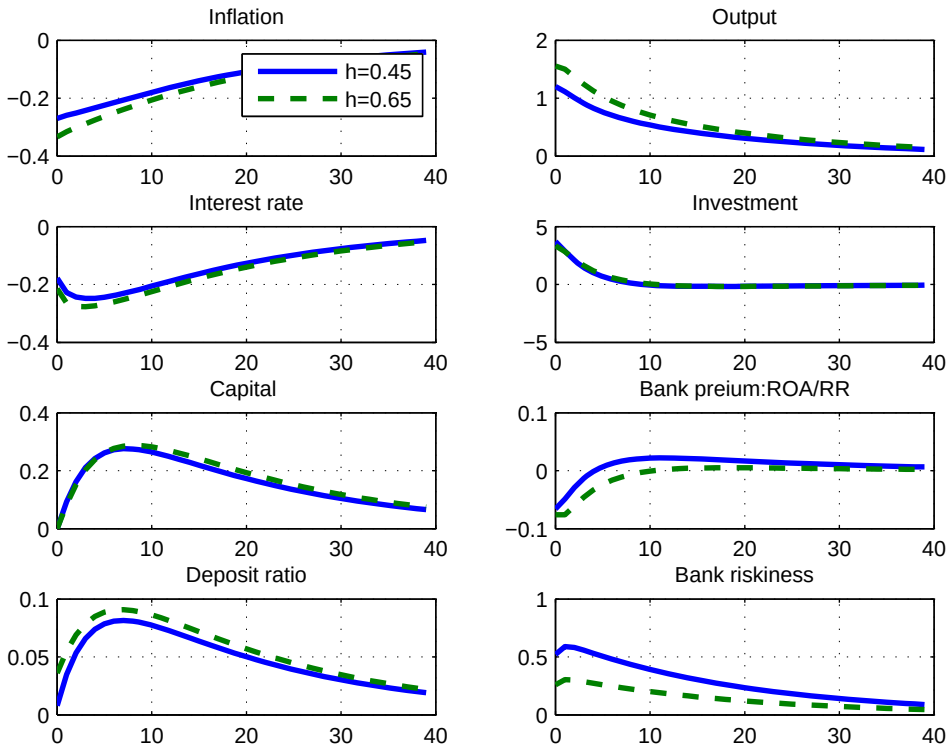


Fig. 2: Positive productivity shock; h=0.45 (solid line) or 0.65 (dashed line)

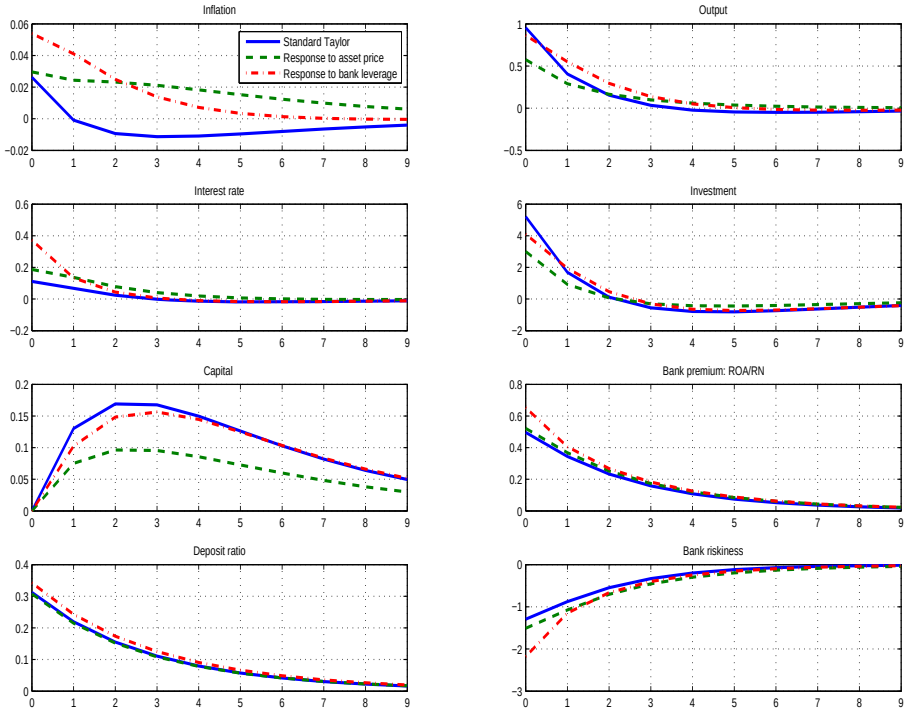


Fig. 3: Positive asset price shock; alternative monetary policy responses

Figure 3 compares the benchmark monetary policy rule with two strategies in which the interest rate reacts also to asset prices (Tobin's Q) or alternatively to bank leverage (with coefficient equal to 1). We regard these as alternative options of using monetary policy (also) to control risks in the financial sector. Comparing these alternatives can contribute new elements to the old debate on whether monetary policy should react to expected inflation only (see Bernanke and Gertler (1999)) or to asset prices as well (Cecchetti, Genberg, Lipsky and Whadwani (2000)). Since one argument in that debate was that responding to asset prices would inject volatility in the economy, it is interesting to look at an alternative measure based on bank balance sheets, that should be empirically more stable.

The figure is constructed assuming an asset price shock. As one can see, the two strategies give mixed results. The rule that reacts to Tobin Q (dashed line) is successful in stabilizing inflation and output, but on bank risk and the deposit ratio the result is less clear. Reacting to leverage (dashed-dotted line) instead does not seem to improve the performance relative to a standard Taylor rule,

and in some cases (on output and inflation for example) the performance is actually worse. All in all, the results speak in favor of some response to asset prices. But this result is obtained under a single shock only. We will extend the comparison later using a set of calibrated shocks.

In earlier versions of this paper we also tested the quantitative properties of the model in terms of its ability to generate empirically plausible volatilities and autocorrelations. We verified that the model captures well the volatilities and autocorrelations of investment and the main banking variables (deposit ratio, return on assets and bank risk) in both the euro area and the US[19].

5 Introducing Bank Capital Requirements

In this section we introduce bank capital regulation. Our goal is not normative (deriving optimal bank capital requirements given the model's frictions) but positive (exploring the implication of the existing capital regulation, as well as of alternatives currently discussed by international regulatory bodies). The regulator sets minimum capital requirements on banks in order to reduce their risk, perceived to be undesirably high under an unregulated regime. The regulator enforces the capital requirement by imposing a penalty on non-compliance. The Basel Committee does not set penalties, but leaves it to national supervisors to use the enforcing instruments they see fit in each national context. National practices vary both with regard to the nature of the penalties (explicit, implicit or both) and to the degree to which they are set ex-ante and publicly disclosed.

To simplify the analysis while maintaining realism, we assume that, in case of non-compliance, the regulator adjusts the return to bank capitalists downward, to replicate the return to outside investors (depositor and capitalist) that, in an unregulated regime, would prevail under a bank run. In case of non-compliance a run does not necessarily occur, because the project outcome may be sufficient to pay depositors though it is insufficient to comply with the minimum capital ex-post. In this case, the levy generates a cash inflow whose ex-ante expected value is returned to capitalists in form of a transfer. We also assume that the regulator maintains "orderly conditions" in financial markets, by ensuring that the bank run, if it occurs, does not entail social costs (value of $c = 0$). As a result, banks are always capable of recovering the full value of the project.

The adjusted return to the capitalist net of the lump-sum transfer, in case of non-compliance

[19] Results are available on request.

without run, is the difference between the returns he gets with and without bank run[20]:

$$-\frac{(R_A+x)-Rd}{2}+\left[\frac{(R_A+x)(1+\lambda)}{2}-Rd\right]=\frac{\lambda(R_A+x)+Rd}{2}$$

The lump-sum transfer is equal to the expected value, $\frac{1}{2h}\int_{Rd-R_A}^{Rd+bk^{MIN}-R_A}\frac{\lambda(R_A+x)+Rd}{2}dx$, where bk^{MIN} is the minimum capital ratio set by the regulator.

The minimum capital requirement in the model takes the form of a time-contingent ratio between the required banking capital, BK_t, and the total bank loan exposure, Q_tK_t, and is set equal to a simple exponential function:

$$bk_t^{MIN}\equiv\frac{BK_t^{MIN}}{Q_tK_t}=const+b_0^c\left(\frac{Y_t}{Y_{SS}}\right)^{b_1^c} \tag{16}$$

In Appendix 4 we show that equation 16 mimics very well the minimum capital requirement implied by the internal ratings based (IRB) approach of Basel II, for appropriate values of the constant, b_0^c and b_1^c. Specifically, a negative value of b_1^c implies that the minimum capital ratio decreases with the output gap; since the average riskiness of bank loans tends to be negatively correlated with the cycle (see Appendix 4 for estimates), one can calibrate b_1^c so that equation 16 reproduces, for each value of the output gap, the capital requirement under the IRB approach, in which the minimum capital ratio increases with the riskiness of the bank's loan portfolio. For $b_1^c=0$, equation 16 reproduces the Basel I regime, in which the capital ratio is fixed [21]. Setting positive value of b_1^c one can study the implications of a hypothetical regime that, following the current discussions about reforming Basel II, requires banks to accumulate extra capital buffers when the economy is booming.

Banks set their actual capital optimally given the incentives set by the regulator. The actual bank capital ratio will differ from both the one that would result in absence of regulation, and the regulatory minimum; in fact, it is generally be optimal for banks to maintain a safety buffer above

[20] Note that the first term on the LHS is the capitalist return without run (for sufficiently low values of R_A+x, in the zone where the bank's intervention is necessary), while the second is equal to the difference betwen the deposit return with and without run. Implicitly, we are therefore assuming that the capitalist is charged also the imputed cost of run for the depositor.

[21] In fact, it has been noted that capital regulation is slightly procyclical also under Basel I, due to a number of accounting and other factors. We disregard this.

the minimum, to reduce the risk of incurring in the penalty[22]. The actual capital is determined extending equation 5 as follows

$$\frac{1}{2h}\int_{-h}^{R_t d_t + bk_t^{MIN} - R_{A,t}} \frac{(1+\lambda)(R_{A,t}+x_{j,t})}{2} dx_{j,t} + \frac{1}{2h}\int_{R_t d_t + bk_t^{MIN} - R_{A,t}}^{\frac{R_t d_t + bk_t^{MIN}}{\lambda} - R_{A,t}} \frac{(R_{A,t}+x_{j,t}) + R_t d_t}{2} dx_{j,t} + \tag{17}$$

$$+\frac{1}{2h}\int_{\frac{R_t d_t + bk_t^{MIN}}{\lambda} - R_{A,t}}^{h} \frac{(1+\lambda)(R_{A,t}+x_{j,t})}{2} dx_{j,t}$$

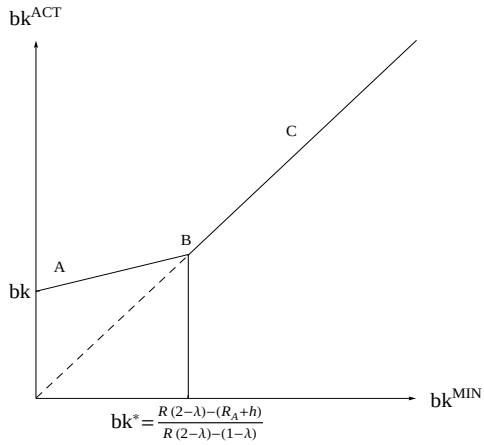
Solving the integrals as seen earlier, it is straightforward to show that the internal optimum is given by

$$bk_t^{ACT} = bk_t + \frac{1}{R_t}\frac{1-\lambda}{2-\lambda} bk_t^{MIN} \tag{18}$$

where bk_t is the economic capital. Note that for intermediate values of λ (close to 0.5) the coefficient of bk_t^{MIN} on the r.h.s. is close to one third; hence $bk_t^{ACT} > bk_t^{MIN}$ unless bk_t^{MIN} is much higher than bk_t. In other words, if the capital constraint is not too tight, banks will normally maintain extra capital above the minimum required, a point stressed by Elizaldea and Repullo (2007). The actual deposit ratio in this case is given by $d_t^{ACT} = d_t - \frac{1}{R_t}\frac{1-\lambda}{2-\lambda} bk_t^{MIN} = \frac{1}{R_t}\frac{R_{A,t}+h}{2-\lambda} - \frac{1}{R_t}\frac{1-\lambda}{2-\lambda} bk_t^{MIN}$, a lower value than in the absence of constraint as one would expect. This range, where the capital constraint is not binding (though it does affect the bank's capital) is represented by the segment AB in graph 2[23].

[22] Our treatment of actual and regulatory capital is close in spirit to that proposed by Elizaldea and Repullo (2007) in the context of a partial equilibrium banking model.

[23] When the capital requirement is sufficiently high (segment BC in the graph), the ex-ante desired capital ratio tends to fall below the regulatory minimum. In this case the capital requirement may become strictly binding, i.e. the ex-ante ratio coincides with the regulatory minimum. This case normally regards a small number of distressed, caoital constrained banks.



Graph 2

In addition to replacing bk_t with 18, we need to modify the bank capital accumulation equation 12. Solving 17 for the return of the capitalist and substituting in the accumulation equation we get:

$$BK_t = \theta[BK_{t-1} + \frac{(R_{A,t} + h - R_t d_t^{ACT})^2 - (bk_t^{MIN})^2}{8h} Q_t K_t] \tag{19}$$

which, we one can easily see, reduces to the standard accumulation equation for $bk_t^{MIN} = 0$[24].

Figure 4 shows, under our usual productivity shock, the responses of the model when minimum capital requirements are imposed. The parameters are calibrated so as to mimic three alternative regimes (see Appendix 4 for numerical details); in the first the required capital ratio is fixed (as in Basel I); in the second it is moves anticyclically (decreasing when output is above potential, hence producing pro-cyclical macroeconomic effects), as in Basel II[25]; as our third case, we consider the performance of a hypothetical regime where the cyclical property of the capital requirement is opposite to that under Basel II, as determined by inverting the sign of the exponent b_1^c; we refer to this regime as "Basel III"[26]. In the figure we see that the Basel II regime results in a strong

[24] The return to the capitalist should include also the lump-sum transfer from the regulator, not shown in equation 19 for notational simplicity.

[25] Kashyap and Stein (2004) report very different estimates of the degree of procyclicality of Basel II, depending on methodologies, data, etc. What seems to be very robust is the *sign* – Basel II is clearly procyclical in the sense that the capital requirements on a given loan pool increase more, when the economy decelerates, relative to what they did under Basel I.

[26] This terminology is used here for convenience only. In fact, the new capital accord agreed by the Basel committee,

amplification of the short run effect of the shock on all variables in the model. The amplification is particularly evident on output and investment, but also bank leverage and risk react more under this shock in a Basel II environment. Conversely, the Basel III regime implies a more moderate response of the macro and banking variables, relatively to Basel I. Basel III is quite effective in insulating the effects of the shock on the balance sheet and on the riskiness of the banking system.

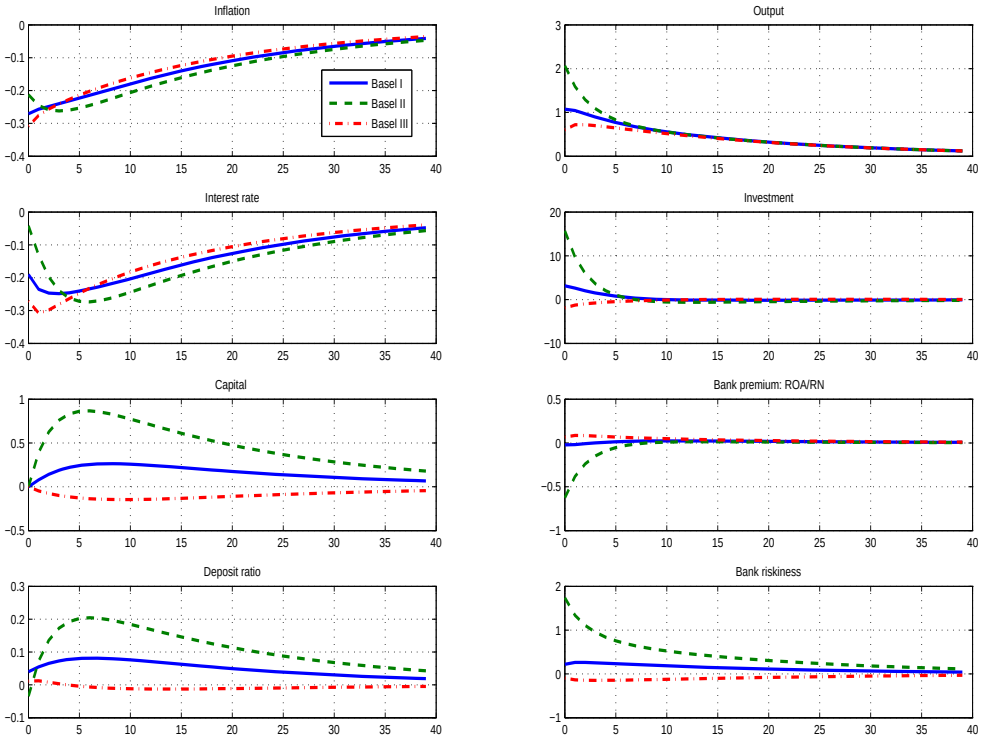


Fig 4: Positive productivity shock under alternative Basel regimes

6 Optimal Monetary Policy and Bank Capital Regulation

We compare the performance of alternative policy combinations using three criteria: household welfare, output volatility and inflation volatility. Household welfare, calculated from the utility function, is clearly the most internally consistent criterion. Output and inflation volatilities are alternative, ad hoc but frequently used, measures of policy performance.

commonly referred to as Basel III, includes, in addition to an anticyclical capital surcharge, also a significant increase in the average capital requirements as well as other provisions. We neglect this element here.

Some observations on the computation of welfare are in order. First, we cannot safely rely on first order approximations to compare the welfare associated to monetary policy rules, because in an economy with time-varying distortions stochastic volatility affects both first and second moments[27]. Since in a first order approximation of the model solution the expected value of a variable coincides with its non-stochastic steady state, the effects of volatility on the variables' mean values is by construction neglected. Policy alternatives can be correctly ranked only by resorting to a higher order approximation of the policy functions[28]. Additionally one needs to focus on the *conditional* expected discounted utility of the representative agent. This allows to account for the transitional effects from the deterministic to the different stochastic steady states respectively implied by each alternative policy rule.

Our metric for comparing welfare for alternative policies is the fraction of household's consumption that would be needed to equate conditional welfare $\mathcal{W}_0$ under a generic policy to the level of welfare $\widetilde{\mathcal{W}}_0$ implied by the optimal rule. Such fraction, Ω, should then satisfy: $\mathcal{W}_{0,\Omega} = E_0\left\{\sum_{t=0}^{\infty}\beta^t U((1+\Omega)C_t)\right\} = \widetilde{\mathcal{W}}_0$Under a given specification of utility one can solve for Ω and obtain $\Omega = \exp\left\{\left(\widetilde{\mathcal{W}}_0 - \mathcal{W}_0\right)(1-\beta)\right\} - 1$.We compare the performance of alternative monetary policy combinations when the model is hit by three shocks, productivity, government expenditure and monetary policy, calibrated as indicated earlier.

The monetary policy rules we consider belong to the class represented by (15). We limit our attention to simple and realistic monetary policy functions, among the ones most frequently discussed in the literature. We consider two groups of six rules each. The first group is a standard Taylor rule with an inflation response coefficient of 1.5 and an output response coefficient of 0.5, plus variants with interest rate smoothing (coefficient 0.6) and a reaction alternatively to the asset price or to the (change of) the deposit ratio. The coefficient on the latter terms is set to 0.4 – for higher values, numerical convergence problems were occasionally encountered, especially under the Basel II specification. Our second group of rules is identical to the first except that it embodies a more aggressive response to inflation, with a coefficient of 2.0. Our choice of policy rules allows to examine deviations from the standard Taylor formulation in three directions: a more aggressive

[27] See for instance Kim and Kim (2003), Schmitt-Grohe and Uribe (2003) and Faia (2009).

[28] See Kim and Kim (2003) for an analysis of the inaccuracy of welfare calculations based on log-linear approximations in dynamic open economies.

response to inflation, interest rate smoothing and response to financial markets – either to the asset price or to bank leverage.

Before turning to policy combinations, in table 1 we show the sensitivity of the choice of the monetary policy rules to alternative parameters of the banking model. We consider different combinations of entrepreneurial risk, h, and liquidation value, λ; the first moves between 0.45 (our benchmark) and 0.55, the second between 0.35 and 0.45 (benchmark). Intuitively, high h and a low λ should prevail under stressed market conditions, when uncertainty is high and liquidation values low.

The table shows three metrics: the first is our expected conditional welfare, namely the percentage of consumption costs, as detailed before, relatively to the optimal rule (the one with the highest welfare); the second is the volatility of output of each policy relatively to the one featured by the optimal rule (the one with lower output volatility); the third is the volatility of inflation relatively to the one featured by the optimal rule (the one with lower inflation volatility). By construction, hence the best policy in each column shows an entry equal to zero. To illustrate, the three entries at the top left side of the table say that, under the first set of parameter values, the first rule (standard Taylor) entails a welfare loss relative to the welfare maximizing one (aggressive Taylor with reaction to Q) equivalent to 0.3351 percent of household consumption, or an increase in output volatility relative to the output volatility minimizing one (standard Taylor with reaction to Q) equal to 0.1830 percent of output, or a higher inflation volatility relative to the inflation volatility minimizing one (aggressive Taylor with smoothing and reaction to bank leverage) equal to 0.4244. Evidently, the numbers in the table are comparable only within, not across columns.

Under all parameters, an aggressive response to inflation turns out to be optimal if the criterion is inflation minimization, as one would expect, but also if the criterion is welfare (defined over consumption and leisure). A more moderate response is needed, instead, to stabilise output. Moreover, all optimal rules incorporate some reaction to financial conditions. Which rule wins the contest depends on the criterion used. Based on welfare and inflation stabilization, an aggressive response to inflation with a reaction to the asset price performs best. A rule with smoothing and reaction to bank leverage is appropriate when the criterion chosen is inflation stabilization. In most cases the differences in performance under the welfare criterion are rather small, as already

noted in the literature on the welfare cost of cyclical fluctuations. The differences in volatility of output and inflation are, instead, economically quite significant. The rankings are robust to the four different parameter sets.

Table 2 shows the performance of the same rules under four bank capital regimes: free capital (no regulation), Basel I, II and III. This time the entries are calculated relative to the optimal combination of monetary rule and bank capital regime in the whole table, not within each column (comparisons within each column are still possible, however). Regardless of the criterion, the best policy combination includes an aggressive monetary policy rule with some reaction to financial market conditions and Basel III. Again, under the welfare and output criteria the best rule reacts to Q, while under the inflation criterion it reacts to leverage and includes interest rate smoothing. Note that the results in the table are consistent with the claim of Bernanke and Gertler (1999) that reacting to asset prices is not effective in stabilizing inflation; bank leverage is found to be better in this case.

7 Conclusions

Since the crisis started, views on how to conduct macro policies have changed. Though a new consensus has not emerged, some old well established paradigms are put into question. One concerns the interaction between bank regulation and monetary policy. The old consensus, according to which the two policies should be conducted in isolation, each pursuing its own goal using separate sets of instruments, is increasingly challenged. After years of glimpsing at each other from the distance, monetary policy and prudential regulation – though still unmarried – are moving in together. This opens up new research horizons, highly relevant at a time in which central banks on both sides of the Atlantic are acquiring new responsibilities in the area of financial stability.

In this paper we tried to move a step forward by constructing a new macro-model that integrates banks in a meaningful way and using it to analyze the role of banks in transmitting shocks to the economy, the effect of monetary policy when banks are fragile, and the way monetary policy and bank capital regulation can be conducted as a coherent whole. Our conclusions at this stage are summarized in the introduction, and need not repeating here.

While our model brings into the picture a key source of risk in modern financial system, namely

leverage, there are also others that we have left out from our highly abstract construct. Of special importance is the interconnection within the banking system. As some have noted (see e.g. Morris (2008), Brunnermeier et al. (2009)), a system where leveraged financial institutions are exposed against each other and can suddenly liquidate positions under stress is, other things equal, more unstable than one in which banks lend only to entrepreneurs, as in our model. Introducing bank inter-linkages and heterogeneity in macro models is, we believe, an important goal in this line of research.

8 Appendix 1. Expected Loss on Risky Deposits

We want to calculate is the expected return on deposits, taking into account the fact that given the possibility of run, the expected return is below the riskless return.

Consider the return on deposits in the three possible events: run for sure, run only without bank, and no run for sure. Time subscripts are omitted in this appendix for notational simplicity.

In the **first case** (run for sure), the payoff to the depositor is $\frac{(1+\lambda)(1-c)(R_A+x)}{2}$. This holds in the interval of x comprised between $[-h; (Rd - R_A)]$. The expected value of this component of payoff is $\frac{1}{2h} \int_{-h}^{Rd-R_A} \frac{(1+\lambda)(1-c)(R_A+x)}{2} dx$. The expected payoff on deposits **conditional** on a run is $\frac{(1+\lambda)(1-c)}{2} [R_A + \frac{(Rd-R_A)-h}{2}]$. This can be obtained alternatively in two ways; either by dividing $\frac{1}{2h} \int_{-h}^{Rd-R_A} \frac{(1+\lambda)(1-c)(R_A+x)}{2} dx$ by the probability of run $\frac{1}{2h} \int_{-h}^{Rd-R_A} dx$ and solving, or more intuitively by replacing x in $\frac{(1+\lambda)(1-c)(R_A+x)}{2}$ with its expected value in case of a run, $\frac{(Rd-R_A)-h}{2}$. Note that the latter expression is simply the midpoint between $-h$ and $(Rd - R_A)$, two negative numbers in our calibration. Intuitively, the mean is equal to the midpoint because the distribution is uniform.

In the **second case** (run only without bank) as well as in the **third case** (never run) the conditional return to the depositor is the same and equal to the riskless return Rd, independent of x. The total probability of this event is $\frac{1}{2h} \int_{Rd-R_A}^{h} dx$.

The expected payoff on deposits per unit of investment (ρ_I), is given by sum of the conditional returns in the two events multiplied by their probability:

$$\rho_I = \rho_I \mid_{run} z + Rd(1 - z)$$

where $z = \frac{1}{2h} \int_{-h}^{Rd-R_A} dx$ and $\rho_I \mid_{run} = \frac{(1+\lambda)(1-c)}{2} [R_A + \frac{(Rd-R_A)-h}{2}]$.

This can also be written as

$$\rho_I = Rd - z(Rd - \rho_I \mid_{run}) = Rd \left[1 - z \left(\frac{Rd - \rho_I \mid_{run}}{Rd}\right)\right]$$

The expected loss on deposits per unit of investment is $Rd - \rho_I = z \left(\frac{Rd-\rho_I|_{run}}{Rd}\right)$. To obtain

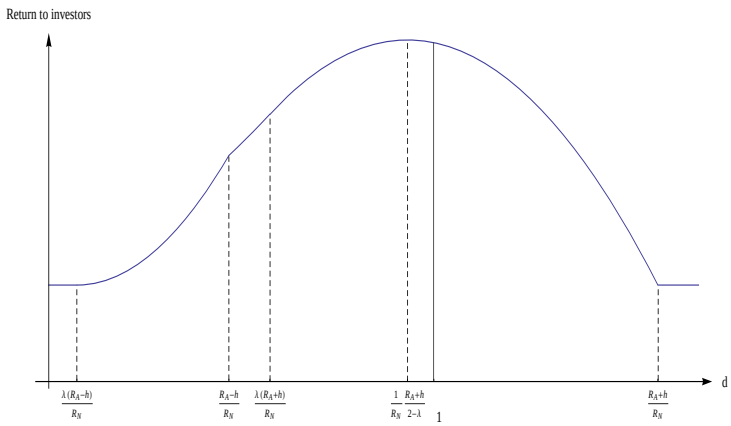
the aggregate loss, the unitary loss has to be multiplied by aggregate investment.

9 Appendix 2: Bank Capital Structure

Proof of Proposition 1. For notational simplicity, we set in this appendix $c = 0$ (no cost of run). The proof can easily be generalised to any value comprised between 0 and 1.

We want to show that the value of d that maximizes equation 5 is within the interval $\left(\lambda\frac{R_A+h}{R}; \frac{R_A+h}{R}\right)$. To do this we show first that the optimum is not below $\frac{R_A-h}{R}$; than that it is not above $\frac{R_A+h}{R}$; and finally that it cannot be in the interval $\left(\frac{R_A-h}{R}; \lambda\frac{R_A+h}{R}\right)$.

1. Consider first very low values of Rd, below $\lambda(R_A - h)$. In this case a run is impossible ex-ante, with or without the bank. The return to outsiders is given by $\frac{1}{2h}\int_{-h}^{h}\frac{(1+\lambda)(R_A+x)}{2}dx = \frac{1}{2}(1+\lambda)R_A$, which does not depend on d. Hence the value of equation 5 in this interval is constant.



Graph 3

Graph 3 shows the shape of the piece-wise function for the following parameter values: $R_A = 1.03$; $R = 1.01$; $\lambda = 0.5$; $h = 0.55$. As Rd grows above $\lambda(R_A - h)$, but below $R_A - h$, the relevant expression becomes

$$\frac{1}{2h}\int_{-h}^{\frac{Rd}{\lambda}-R_A}\frac{(R_A+x)+Rd}{2}dx + \frac{1}{2h}\int_{\frac{Rd}{\lambda}-R_A}^{h}\frac{(1+\lambda)(R_A+x)}{2}dx$$

The derivative with respect to d is $\frac{R}{4h}\left[\frac{Rd}{\lambda}-(R_A-h)\right]$, which is positive and increasing in d_t in the interval we consider. Intuitively, in this region, depending on the realization of $x_{j,t}$, one may fall either in the case where the run is impossible ex-post, or in the case where it is possible without the bank. The return to outside claimants is higher in the second case (because the banker´s fee is smaller), so as d_t increases the overall expected return to outsiders increases. Hence we conclude that the value of $d_t=\frac{R_{A,t}-h}{R_t}$ dominates all values to the left-hand side of it.

2. Consider now the opposite case, $R_t d_t > (R_{A,t}+h)$. In this case the expression reduces to a constant, equal to the value already found for the case $R_t d_t < \lambda(R_{A,t}-h)$ (graph 3, right-hand side). In this case the run is certain ex-ante, and depositors get always the same, namely the expected liquidation value of the loan $R_{A,t}$ minus the banker´s fee $\frac{1}{2}(1-\lambda)R_{A,t}$.

3. We are now at the case where $\left(\frac{R_{A,t}-h}{R_t}<d_t<\lambda\frac{R_{A,t}+h}{R_t}\right)$. The derivative of equation 5 with respect to d_t is $\frac{2Rd}{8h\lambda}(\lambda-1)^2>0$. This portion of the curve is upward sloping and convex. If the function is continuous at $d=\lambda\frac{R_A+h}{R_t}$[29], we conclude that the value $d=\lambda\frac{R_A+h}{R}$ dominates all points to the left and that the value $d=\lambda\frac{R_A+h}{R}$ dominates all points to the right, QED.

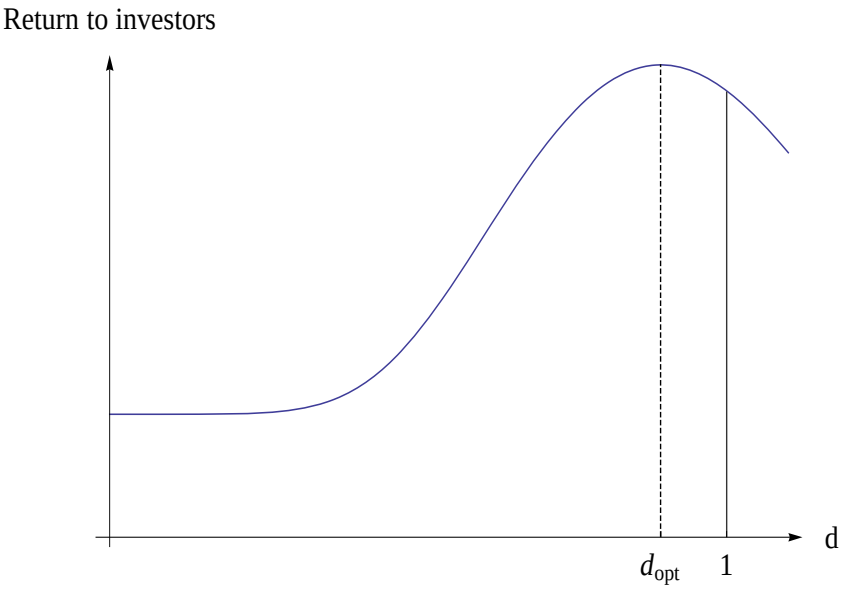
9.1 Sensitivity to the density function: the case of normal distribution

Let us assume that x follows a zero-mean normal distribution. The expected value of returns to outside investors is

$$\left(\frac{1}{\sqrt{2\pi\sigma^2}}\right)\left\{\begin{array}{c}\int_{-\infty}^{Rd-R_A}\exp\left[-\frac{x^2}{2\sigma^2}\right]\frac{(1+\lambda)(R_A+x)}{2}dx+\int_{Rd-R_A}^{\frac{Rd}{\lambda}-R_A}\exp\left[-\frac{x^2}{2\sigma^2}\right]\frac{(R_A+x)+Rd}{2}dx+\\ \int_{\frac{Rd}{\lambda}-R_A}^{\infty}\exp\left[-\frac{x^2}{2\sigma^2}\right]\frac{(1+\lambda)(R_A+x)}{2}dx\end{array}\right\}$$

Graph 4 shows the expected value of returns to outside investors for d ranging between 0 and 1 under the following parameter set: $R_{A,t}=1.03$; $R_t=1.01$; $\lambda=0.5$, when the distribution of returns follows a standard normal ($\sigma=0.3$). Sensitivity analysis shows that, as with the uniform distribution, the optimal value of d is positively related to R_A, λ and σ, and negatively related to R.

[29] The function is continuous and well behaved for all but very low values of h and λ. More specifically, when $R_A(1-\lambda)-(1+h)\lambda\geq 0$, the function exhibits a discontinuity at $d=\lambda\frac{R_A+h}{R_t}$, which can give rise to a new global maximum at this point for sufficiently low parameter values (e.g. $h=\lambda<0.35$).



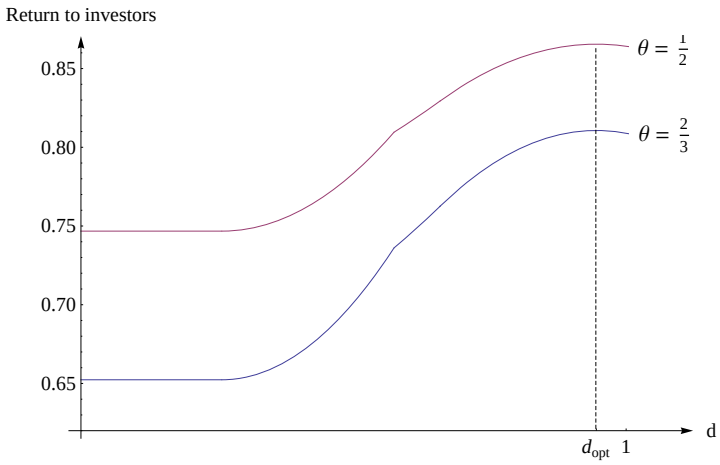
Graph 4

9.2 Sensitivity to bargaining power assumption

Alternatively to what assumed earlier, we depart from the assumption that all players have equal bargaining power and show that the solution to the bankers ' problem is unchanged. Let θ be the bargaining power of the banker in his game with the depositor (in case of run) or with the capitalist (in case of no run or possible run). The bargaining power of the depositor (or capitalist) in their respective games is $1-\theta$. The payoff function of the depositor and capitalist combined, homologue to 5, is

$$\frac{1}{2h}\int_{-h}^{Rd-R_{A,t}}(R_A+x)[1-\theta(1-\lambda)]dx+\frac{1}{2h}\int_{Rd-R_A}^{\frac{Rd}{\lambda}-R_A}[(R_{A,t}+x)(1-\theta)+\theta Rd]dx+\frac{1}{2h}\int_{\frac{Rd}{\lambda}-R_A}^{h}[1-\theta(1-\lambda)](R_A+x)dx$$

The function is shown in the Graph 5 below for two value of θ, $\frac{1}{2}$ and $\frac{2}{3}$. As the graph suggests, the maximum is unchanged.



Graph 5

10 Appendix 3. Final Output and Capital Producers

Each firm i has monopolistic power in the production of its own variety and therefore has leverage in setting the price. In changing prices it faces a quadratic cost equal to $\frac{\vartheta}{2}(\frac{P_t(i)}{P_{t-1}(i)} - 1)^2$, where the parameter ϑ measures the degree of nominal price rigidity[30]. The higher ϑ, the more sluggish is the adjustment of nominal prices. In the particular case of $\vartheta = 0$, prices are flexible. Each firm assembles labour and (finished) entrepreneurial capital to operate a constant return to scale production of the variety i of the intermediate good:

$$Y_t(i) = A_t F(N_t(i), K_t(i)) \tag{20}$$

Each monopolistic firm chooses a sequence $\{K_t(i), L_t(i), P_t(i)\}$, taking nominal wage rates W_t and the rental rate of capital Z_t, as given, in order to maximize expected discounted nominal profits:

$$E_0\{\sum_{t=0}^{\infty} \Lambda_{0,t}[P_t(i)Y_t(i) - (W_t N_t(i) + Z_t K_t(i)) - \frac{\vartheta}{2}\left[\frac{P_t(i)}{P_{t-1}(i)} - 1\right]^2 P_t]\} \tag{21}$$

subject to the constraint $A_t F_t(\bullet) \leq Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t$, where $\Lambda_{0,t}$ is the households' stochastic discount factor and ε is the demand elasticity.

[30] Alternative assumptions, such as adjustment costs on deposits, would yield similar results.

Let's denote by $\{mc_t\}_{t=0}^{\infty}$ the sequence of Lagrange multipliers on the above demand constraint, and by $\tilde{p}_t \equiv \frac{P_t(i)}{P_t}$ the relative price of variety i. The first order conditions of the above problem read:

$$\frac{W_t}{P_t(i)} = mc_t A_t F_{n,t} \tag{22}$$

$$\frac{Z_t}{P_t(i)} = mc_t A_t F_{k,t} \tag{23}$$

$$\begin{aligned} 0 &= U_{c,t} Y_t \tilde{p}_t^{-\varepsilon}((1-\varepsilon) + \varepsilon mc_t) - U_{c,t}\vartheta \left[\pi_t \frac{\tilde{p}_t}{\tilde{p}_{t-1}} - 1\right] \frac{\pi_t}{\tilde{p}_{t-1}} + \\ &\quad + \vartheta E_t\{U_{c,t}\left[\pi_{t+1}\frac{p_{t+1}}{p_t} - 1\right]\pi_{t+1}\frac{\tilde{p}_{t+1}}{\tilde{p}_t^2}\} \end{aligned} \tag{24}$$

where $F_{n,t}$ is the marginal product of labour, $F_{k,t}$ the marginal product of capital and $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross aggregate inflation rate (its steady state value, π, is equal to 1). Notice that all firms employ an identical capital/labour ratio in equilibrium, so individual prices are all equal in equilibrium. The Lagrange multiplier mc_t plays the role of the real marginal cost of production. In a symmetric equilibrium $\tilde{p}_t = 1$. This allows to rewrite equation 24 in the following form:

$$\begin{aligned} U_{c,t}(\pi_t - 1)\pi_t &= \beta E_t\{U_{c,t+1}(\pi_{t+1} - 1)\pi_{t+1}\} + \\ &\quad + U_{c,t} A_t F_t(\bullet)\frac{\varepsilon}{\vartheta}(mc_t - \frac{\varepsilon - 1}{\varepsilon}) \end{aligned} \tag{25}$$

The above equation is a non-linear forward looking New-Keynesian Phillips curve, in which deviations of the real marginal cost from its desired steady state value are the driving force of inflation.

10.1 Capital Producers

A competitive sector of capital producers combines investment (expressed in the same composite as the final good, hence with price P_t) and existing capital stock to produce new capital goods. This activity entails physical adjustment costs. The corresponding CRS production function is $\phi(\frac{I_t}{K_t})K_t$, so that capital accumulation obeys:

$$K_{t+1} = (1-\delta)K_t + \phi(\frac{I_t}{K_t})K_t \tag{26}$$

where $\phi(\bullet)$ is increasing and convex.

Define Q_t as the re-sell price of the capital good. Capital producers maximize profits $Q_t\phi(\frac{I_t}{K_t})K_t - P_tI_t$, implying the following first order condition:

$$Q_t\phi'(\frac{I_t}{K_t}) = P_t \tag{27}$$

The gross (nominal) return from holding one unit of capital between t and $t+1$ is composed of the rental rate plus the re-sell price of capital (net of depreciation and physical adjustment costs):

$$Y_t^k \equiv Z_t + Q_t((1-\delta) - \phi\prime(\frac{I_t}{K_t})\frac{I_t}{K_t} + \phi(\frac{I_t}{K_t})) \tag{28}$$

The gross (real) return from holding a unit of capital between t and $t+1$ is equalized in equilibrium to the gross (real) return that the banks receive for their loan services, $R_{A,t+1}$:

$$\frac{R_{A,t+1}}{\pi_{t+1}} \equiv \frac{Y_{t+1}^k}{Q_t} \tag{29}$$

11 Appendix 4. Calibrating the Basel II regime

In equation 16, the dependence of the minimum capital ratio on the deviation of output from its steady state is intended to mimic the cyclical sensitivity of the risk weights that affect the capital requirements under the Basel II Internal Ratings Based approach. The parameters b_0^c and b_1^c can be calibrated so as to ensure that the resulting required capital ratio is, at each point in the cycle, close to that resulting from the application of the actual Basel II IRB rules.

The IRB risk-weighted approach requires banks to hold capital to cover unexpected losses, for a given confidence level, given the distribution of potential losses. Potential loan losses are determined by the probability of default (PDs) of borrowers, which differ across rating classes, and by their losses conditional on default (losses given default, or LGDs). This methodology, based on Merton (1974), implies that the capital requirement for a unit of exposure is given by (for details see Basel Committee on Banking Supervision (2005))

$$CR = LGD\left\{\Phi\left[\frac{1}{\sqrt{1-\rho}}\Phi^{-1}(PD) + \sqrt{\frac{\rho}{1-\rho}}\right]\Phi^{-1}(.999) - PD\right\}MA$$

where ρ is an estimate of the cross-borrower correlation and MA is an adjustment for average loan maturity. The correlation is approximated by the Basel Committee by means of the following

function of PD:

$$\rho = 0.12 \left[\frac{1 - \exp(-50PD)}{1 - \exp(-50)} \right] + 0.24 \left[1 - \frac{1 - \exp(-50PD)}{1 - \exp(-50)} \right]$$

The maturity adjustment formula is given by

$$MA = \frac{1 + (M - 2.5)b(PD)}{1 - 1.5b(PD)}$$

where M is the average maturity of loans, that we assume fixed and equal to 3 years.

We follow Darracq Paries et al. (2010) in assuming that LGD is constant over the cycle and equal to 0.45. On the contrary, PDs are typically found to be anticyclical – the stronger the cyclical position, the lower the average PD of non-financial corporations. We modelled the link between the aggregate PD and the cycle, for the euro area, with the following regression equation:

$$PD_t = con + \alpha PD_{t-1} - \beta \Delta(y - y^{ss}) + errorAR(1)$$

The equation has been estimated using quarterly euro area data; see table A2. PD is a quarterly average of the median default probability of euro area non financial firms (source: Moody's KMV). PD depends on its own lagged value and the (change of) the ratio of output to its trend; $\Delta(y - y^{ss})$ is the change deviation of euro area (12) output, seasonally adjusted, from its HP filter, with a $\lambda = 1600$. The coefficient of the output variable is negative and significant, with a mean lag of about 6 quarters. On impact, a one percentage increase in output decreases PD by 0.13 percent (the sample average of PD is .58 percent). The residual of this equation is AR(1) with a persistence parameter of 0.58 and a standard error of 0.1 percent.

Table A2. Link between GDP and corporate default probabilities in euro area

Dependent variable: PD. Method: Least squares.

Sample adjusted: 1995 Q3 - 2009 Q4. Convergence achieved after 6 iterations.

Newey-West HAC standard errors and covariance (lag truncation = 3)

Variable	Coefficient	Standard errors	t-statistics	Prob.
Constant	0.097466	0.060223	1.618405	0.1114
PD_{t-1}	0.829403	0.130329	6.363929	0.0000
$\Delta(y - y^{ss})$	−0.125905	0.043360	−2.903730	0.0053
$AR(1)$	0.568747	0.171038	3.325274	0.0016

R-squared	0.944649	Mean dependent var.	0.579157
Adjusted R-squared	0.941574	S.D. dependent var.	0.448131
S.E. of regression	0.108320	Akaike info criterion	−1.540980
Sum squared residuals	0.633595	Schwarz criterion	−1.398881
Log likelihood	46.68842	F-statistic	307.1967
Durbin Watson	1.838241	Prob (F-statistic)	0.00000

The anticyclical relation of PD to output implies a similar response of the capital requirement: when the cyclical position is strong, CR declines because PD declines. This is the "pro-cyclicality" property of Basel II: in a recession, for a given capital, the supply of loans declines because regulatory capital increases. To calibrate our parameters we have proceeded as follows: we used the output gap estimates used elsewhere in the paper to calculate the average amplitude and frequency of the cycle, and given these we calculated the average CRs under Basel II and according to equation 16, then we found the values of b_0^c and b_1^c that minimize the distance from the Basel II CRs. Such values are $b_0^c = 1.02$ and $b_1^c = -0.5$. To simulate the impact of the capital ratio under a strictly binding Basel regime, we have scaled down b_1^c to -0.1, to take into account that only a fraction of banks are strictly capital constrained in any given period (between 10 and 30 percent according to sporadic supervisory information). Conversely, a value of $b_1^c = 0$ expresses a capital requirement regime that is insensitive to risk; we have used this assumption to mimic the effect of Basel I, whereas to simulate the Basel III regime we have simply inverted the value of b_1^c.

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TABLE 1: COMPARING MONETARY POLICY RULES UNDER ALTERNATIVE BANKING PARAMETERS

Policy rules:		h=0.45; λ=0.45			h=0.45; λ=0.35			h=0.55; λ=0.45			h=0.55; λ=0.35		
		Welfare	Output	Inflation	Welfare	Output	Inflation	Welfare	Output	Inflation	Welfare	Output	Inflation
Taylor	Standard	0.3351	0.1830	0.4244	0.3417	0.1776	0.4274	0.3043	0.1898	0.4031	0.3142	0.1846	0.4100
	React to Q	0.2604	**0**	0.3652	0.2653	**0**	0.3655	0.2372	**0**	0.3520	0.2447	**0**	0.3557
	React to D	0.3203	0.1459	0.4127	0.3262	0.1344	0.4152	0.2906	0.1564	0.3922	0.2996	0.1453	0.3984
	Smoothing	0.2368	0.6469	0.3244	0.2267	0.5610	0.3263	0.2584	0.9145	0.3110	0.2450	0.7944	0.3155
	Sm. and react to Q	0.2806	0.0783	0.5738	0.2893	0.0570	0.5717	0.2348	0.0924	0.5515	0.2426	0.0664	0.5563
	Sm. and react to D	0.2270	0.5905	0.3187	0.2184	0.5042	0.3211	0.2452	0.8467	0.3047	0.2329	0.7258	0.3093
Aggressive Taylor	Standard	0.0150	0.1951	0.0267	0.0146	0.1682	0.0253	0.0179	0.3451	0.0323	0.0174	0.3025	0.0315
	React to Q	**0**	0.1195	0.0152	**0**	0.0975	0.0131	**0**	0.2529	0.0203	**0**	0.2166	0.0188
	React to D	0.0102	0.1834	0.0219	0.0098	0.1549	0.0204	0.0124	0.3323	0.0274	0.0119	0.2881	0.0265
	Smoothing	0.0347	0.6917	0.0024	0.0232	0.5984	0.0019	0.0613	1.0451	0.0030	0.0460	0.9105	0.0027
	Sm. and react to Q	0.1496	0.2564	0.1969	0.1441	0.2203	0.1917	0.1590	0.3725	0.2091	0.1546	0.3257	0.2059
	Sm. and react to D	0.0279	0.6444	**0**	0.0174	0.5522	**0**	0.0518	0.9857	**0**	0.0374	0.8517	**0**

The table compares the performance of monetary policy rules under alternative values of the banking parameters. The entries labelled "welfare" show the welfare loss, expressed in percent of steady state consumption, of departing from the optimal combination (that whose entry is zero). The entries labelled "output" (or "inflation") show the difference in the conditional volatility of output (or inflation) relative to the optimal combination (that whose entry is zero).

TABLE 2: COMPARING MONETARY POLICY RULES UNDER ALTERNATIVE BASEL REGIMES

Policy rules:		Free capital			Basel I			Basel II			Basel III		
		Welfare	Output	Inflation	Welfare	Output	Inflation	Welfare	Output	Inflation	Welfare	Output	Inflation
Taylor	Standard	0.1001	0.3123	0.4487	0.1122	0.3663	0.4531	0.1408	0.7929	0.5504	0.0975	0.0802	0.3913
	React to Q	0.0807	0.1293	0.3896	0.0928	0.1906	0.3978	0.0967	0.4227	0.4321	0.0906	0.0072	0.3710
	React to D	0.0963	0.2752	0.4370	0.1081	0.3370	0.4412	0.1318	0.7200	0.5274	0.0953	0.0732	0.3847
	Smoothing	0.0746	0.7762	0.3488	0.0957	0.8807	0.3516	0.1148	1.0623	0.4222	0.0782	0.6985	0.2993
	Sm. and react to Q	0.0860	0.2077	0.5981	0.1473	0.3782	0.6716	0.1189	0.4893	0.7211	0.1639	0.2770	0.6276
	Sm. and react to D	0.0721	0.7198	0.3430	0.0921	0.8253	0.3445	0.1084	0.9862	0.4097	0.0765	0.6580	0.2958
Aggressive Taylor	Standard	0.0170	0.3244	0.0510	0.0130	0.2326	0.0370	0.0337	0.5418	0.0675	0.0008	0.0136	0.0214
	React to Q	0.0131	0.2488	0.0395	0.0103	0.1635	0.0286	0.0237	0.3666	0.0396	0.0006	**0**	0.0209
	React to D	0.0157	0.3127	0.0462	0.0118	0.2189	0.0320	0.0311	0.5042	0.0592	**0**	0.0145	0.0175
	Smoothing	0.0221	0.8211	0.0267	0.0269	0.7895	0.0192	0.0483	0.9672	0.0466	0.0094	0.6150	0.0021
	Sm. and react to Q	0.0519	0.3857	0.2212	0.0584	0.4037	0.2257	0.0672	0.5266	0.2531	0.0495	0.2928	0.2021
	Sm. and react to D	0.0203	0.7737	0.0243	0.0248	0.7411	0.0159	0.0446	0.9023	0.0414	0.0084	0.5783	**0**

The table compares the performance of monetary policy rules under alternative bank capital regimes. The entries labelled "welfare" show the welfare loss, expressed in percent of steady state consumption, of departing from the optimal combination (that whose entry is zero). The entries labelled "output" (or "inflation") show the difference in the volatility of output (or inflation) relative to the optimal combination (that whose entry is zero).