Capital regulation and monetary policy with fragile banks

Ignazio Angeloni\textsuperscript{a}, Ester Faia\textsuperscript{b,*,1}

\textsuperscript{a} ECB and Bruegel, Germany
\textsuperscript{b} Department of Money and Macro, Goethe University Frankfurt, Gruneburgplatz 1, 60323 Frankfurt am Main and CFS, Germany

Abstract

Optimizing banks subject to runs are introduced in a macro model to study the transmission of monetary policy and its interplay with bank capital regulation when banks are risky. A monetary expansion and a positive productivity shock increase bank leverage and risk. Risk-based capital requirements amplify the cycle and are welfare detrimental. Within a 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.

© 2013 Elsevier B.V. All rights reserved.

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 micro-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.\textsuperscript{2} 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.\textsuperscript{3} These ideas suggest the possibility of interactions between the conduct of monetary policy and that of prudential regulation.

Our goal in this paper is to study how bank regulation and monetary policy interact in a macroeconomy that includes a fragile banking system.\textsuperscript{4} To do this one needs 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, henceforth DR), banks have special skills in redeploying projects in case of early liquidation. Uncertainty in projects outcomes injects risk in

---

\* Corresponding author. Tel.: +49 69 79833836.
E-mail address: faia@wiwi.uni-frankfurt.de (E. Faia).

1 Kiryl Khalmetski and Marc Schöfer provided excellent research assistance. We are the sole responsible for any errors and for the opinions expressed in this paper.


3 See e.g. Maddaloni and Peydró Alcalde (2010) and Altunbas et al. (2010).

4 We refer to “banks” and “deposits” for convenience, but our arguments apply equally to other leveraged entities issuing short-term revolving debt like ABSs or commercial paper.

0304-3932/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jmoneco.2013.01.003
banks’ 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 degree of leverage. The desired capital structure 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.

Our bank's optimal leverage 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. The intuition 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.

Inserting this banking core into a macro model 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 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. Within a class of simple policy rules, the optimal combination includes mildly anti-cyclical capital requirements 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 an overview of the related literature. Section 3 describes the model, with emphasis on the banking bloc. Section 4 characterizes the quantitative properties of the model. 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, model details, other sensitivity or empirical analyses are contained in appendices.5

2. Related literature

The 2007 financial crisis highlighted the need to analyze how financial intermediaries’ behavior affects the macroeconomy and the macroeconomic impact of financial regulation.6 In this context also the endogenous diffusion of risk acquired relevance: many argued that banks’ risk-taking, arising endogenously from banks’ mis-incentives, plays an important role in bringing even a sound and stable economy towards financial instability. The recent financial crisis, as others previously, occurred after a period of stable and sustained growth, as a result of the endogenous formation of risk: the possibility of leveraging at low cost fueled indeed bank risk-taking, a fact well documented by empirical studies (see Altunbas et al., 2010; Jimenez et al., 2012). Our model below is consistent with this evidence.

A recent literature explored the importance of financial shocks (see Jermann and Quadrini, 2012) and risk shocks (see Guerron-Quintana et al., 2011 among others). Our paper is complementary to them, exploring the endogenous formation of risk resulting from bank optimizing behavior in response to shocks and policies.

Finally, our paper is connected with the literature embedding banking into macro models. The vast majority of the papers in this literature focuses on the banks’ balance sheet channels, none so far analyzed bank risk and bank runs.7 The balance sheet channel is introduced via different settings such as moral hazard problems or bank collateral constraints; some, but not all those papers, are able to replicate the pro-cyclicality of bank capital observed in the data.8 Among the papers which are closer to our also in terms of business cycle behavior of banking variables are: Acharya and Naqvi (2012), Gromb and Vayanos (2010), and Meh and Moran (2010).

3. A macro model with bank runs

The starting point is a conventional DSGE model with nominal rigidities. There are four types of agents: households, financial intermediaries, final good producers and capital producers. The model is completed by monetary policy and a skeleton fiscal sector.

---

5 The appendices to this paper can be found online at [link to EES Website for Appendices] or at www.wiwi.uni-frankfurt.de/profs-faia/.
6 Attempts to take financial frictions into account pre-existed, but most of the them focused on credit constraints on households and/or firms, without explicitly considering financial intermediaries.
7 In the recent crisis, runs did not in general occur on traditional deposits (Northern Rock and a few others were exceptions), but typically on other more volatile forms of funding for banks and conduits, like REPOS and ABSs (Gorton and Metrick, 2010).
8 Among the papers which are closer to our also in terms of business cycle behavior of banking variables are: Acharya and Naqvi (2012), Gromb and Vayanos (2010), and Meh and Moran (2010).
9 See among other Corbae and D’Erasmo (2011), but also Acharya and Naqvi (2012).
3.1. Households

There is a continuum of identical households who consume, save, work, and make portfolio decisions. Households save by lending to financial intermediaries, in the form of deposits and bank capital. To allow aggregation within a representative agent framework, in every period a fraction $\gamma$ of household members is assumed to be composed of bank capitalists, and a fraction $(1-\gamma)$ of workers/depositors; hence households also own financial intermediaries. Bank capitalists remain engaged in their business activity next period with a probability $\theta$, independent of history.\footnote{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, $\gamma$, remains constant.} Workers work either in the production sector or in the banking sector, as bank managers; both return their earnings to the household. Bank dividends, earned by bank capitalists, are assumed to be passed on to the new bank capitalists and reinvested in the bank (details below). Households maximize the following discounted sum of utilities:

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

(1)

where $C_t$ denotes aggregate consumption and $N_t$ denotes labor hours. Households save and invest in bank deposits and bank capital. Deposits, $D_t$, pay a gross nominal contractual return $R_t$. Due to the possibility of bank runs, the return on deposits is subject to a time-varying risk; the expected return on deposits is $R_t(1-\phi_t g_t)$, where $\phi_t$ is the probability of run and $g_t$, the expected loss on risky deposits, is explained in Appendix 1. Households own the production sector, from which they receive nominal profits for an amount, $\Theta_t$. Let $T_t$ be net transfers to the public sector (lump sum taxes, equal to public expenditures); the budget constraint is\footnote{Note that the return from, and the investment in, bank capital do not appear in Eq. (2), because returns on bank capital are reinvested.}:

$$P_t C_t + T_t + D_t \leq W_t N_t + \Theta_t + \varepsilon_t + R_{t-1}(1-\phi_{t-1} g_{t-1}) D_{t-1}$$

(2)

where $W_t$ is the unitary wage and $\varepsilon_t$ are total revenues earned by bank managers. Households choose the set of processes $(C_t, N_t)_{t=0}^{\infty}$ and deposits $(D_t)_{t=0}^{\infty}$, 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 the sum of discounted utilities subject to (2). The following optimality conditions hold:

$$W_t/P_t = -U_{Nt}/U_{ct}$$

(3)

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

(4)

where $\pi_{t+1} = P_{t+1}/P_t$. Eq. (3) gives the optimal choice for labor supply, while Eq. (4) gives the Euler condition with respect to deposits. Optimality also requires to satisfy the no-Ponzi condition on wealth.

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 size is normalized to unity (think of one machine) and its price is $g_1$. The bank capital structure (the deposit share $(D_t)$ and bank capital $(BK_t)$) is determined by a 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 payoff 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. The demandable nature of deposits creates a collective action problem that exposes the bank to runs (or a roll-over risk) as soon as depositors realize that the payoff from the project is non-contingent return. 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 bank capital structure (the deposit share $d_t = D_t/Q_t L_t$, equal to one minus the capital share and positively related to leverage, $1/(1-d_t)$) is determined by a 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 payoff 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. The demandable nature of deposits creates a collective action problem that exposes the bank to runs (or a roll-over risk) as soon as depositors realize that the payoff from the project is non-contingent return. 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 timing is as follows. At time $t$, the manager of the bank optimizes the capital structure, collects the funds, lends, and then 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. Each project is financed by one bank. The return of the project for the bank is equal to an expected value, $R_t^A$, plus a random shock $\chi_t$. For analytical convenience this random element is assumed to have a uniform density with dispersion $h$ (the
normal distribution case is analyzed in Appendix 2, Section 9.1; the lognormal case gives similar results). Therefore, the outcome of the project is $R^A_t + x_t$, where $x_t$ spans across the interval $[-h, h]$ with probability 1/2h.

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 early liquidation value, relative to other agents. Let the ratio of the value for the outsider (liquidation value) to the value for the bank be $0 < \lambda < 1$. The parameter $\lambda$ affects the bargaining powers of the three players (depositor, bank capitalist and bank manager) and redistributes the payoffs among them, as explained below. A run also entails a resource loss, $1 > c \geq 0$; when the run occurs, hence projects are not completed, the aggregate payoff is reduced by a factor $c$—regardless of the bank’s participation in the recovery. The parameter $c$ enriches the model’s structure and brings it closer to the data, but the basic theory is unchanged if $c=0$.

### 3.2.1. Expected return to outside financiers

Consider the ex-post realization of the project, $R^A_t + x_t$, as depicted in Fig. 1, and consider how the payoffs of the three players are distributed depending on the value of the deposit ratio $d_t$ and the deposit rate $R_t$. 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 ($R_t d_t$) are located to the right of $R^A_t + x_t$. In this case depositors run the bank and the payoff structure is determined as follows. Capitalists receive the leftover after depositors are served; hence they get zero in this case. Depositors alone (without bank) would get the fraction $\lambda (1-c)(R^A_t + x_t)$ of the project’s outcome, so they claim this amount in full. The remainder $(1-\lambda)(1-c)(R^A_t + x_t)$ is shared between depositors and the bank manager depending on their relative bargaining power. This extra payoff is assumed to be split in half (other assumptions are possible; see Appendix 2, Section 9.2). Therefore, depositors end up with $((1+\lambda)(1-c)(R^A_t + x_t))/2$ and the bank with $((1-\lambda)(1-c)(R^A_t + x_t))/2$.

**Case B: run only without the bank**: The project’s 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 are located in the intermediate segment in Fig. 1, i.e. the range where $\lambda (R^A_t + x_t) < R_t d_t \leq R^A_t + x_t$. In this case, the capitalists alone cannot avoid the run. In equilibrium the bank intervenes to avoid the run, so depositors are paid in full, $R_t d_t$, and the remainder is split in half between the bank and the capitalists, each getting $(R^A_t + x_t - R_t d_t)/2$. Total payment to outsiders is $(R^A_t + x_t + R_t d_t)/2$.

**Case C: no run for sure**: The project’s outcome is high enough to allow all depositors to be served, with or without participation of the bank. This happens in the zone where $R_t d_t \leq \lambda (R^A_t + x_t)$. Depositors get $R_t d_t$. However, unlike in the previous case, now the capitalists have a higher bargaining power because they could decide to liquidate the project alone and still avoid the run, getting $\lambda (R^A_t + x_t) - R_t d_t$; this is thus a lower bound for them. The bank manager can extract $(R^A_t + x_t) - R_t d_t$; assuming again that the capitalist and the manager split this extra return in half, the manager gets $((1-\lambda)(R^A_t + x_t))/2$. Total payment to outsiders is $((1+\lambda)(R^A_t + x_t))/2$.

In Appendix 2 it is shown that the ex-ante optimal deposit ratio for the bank always involves some risk. But this is already clear by inspection of the last two cases. For any given realization of $x_t$, the total payoff to outsiders is constant in case C and rising in $d_t$ in case B. Moreover, the value of the payoff at the intersection point $R_t d_t = \lambda (R^A_t + x_t)$ is equal in the two cases. Hence it is never optimal, for any value of $x_t$, to be in C. The expected value of total payments to outsiders is

$$\frac{1}{2h} \int_{-h}^{h} \frac{1}{2} (R^A_t + x_t) dx_t + \frac{1}{2h} \int_{1}^{h} \frac{1}{2} (R^A_t + x_t) dx_t + \frac{1}{2h} \int_{-h}^{-1} \frac{1}{2} (R^A_t + x_t) dx_t.$$

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 $d_t$. Intuitively, this expression balances, in ex-ante expected terms, the benefits and costs to outsiders of a more leveraged capital structure for the bank. A lower leverage allows them to enjoy the benefit of a more probable no-run outcome, in which depositors are paid in full and capitalists are rewarded. A higher leverage allows them to benefit more from the intermediate case, in which they benefit from the bank manager’s relationship lender advantage.

### 3.2.2. Optimal bank capital

**Proposition 1.** The value of $d_t$ that maximizes expected value of total payments to outsiders is:

$$d_t = \frac{R^A_t + h}{R_t 2 - \lambda + c(1+\lambda)}.$$

**Proof.** See Appendix 2.

The optimal deposit ratio depends positively on $h$, $\lambda$ and $R^A_t$, and negatively on $R_t$ and $c$. Intuitively, an increase of $R_t$ (or $c$) reduces deposits because it increases the probability or cost of run. As discussed in Appendix 2, an increase
in $R^t$ raises the marginal return in the no-run case, hence it raises $d_t$. An increase in $\lambda$ reduces the cost in the run case, while not affecting the others, so it raises $d_t$. 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 project outcome $1/2h$ falls. This affects all outcomes equally and has no impact on $d_t$ at the margin. On the contrary, the change in the extreme values of the distribution has asymmetric effects: an increase in the upper extreme increases the marginal gain in the no-run case, whereas a decrease of the lower extreme has no negative effect because the depositor payoff is independent of $d_t$ in case of run. Hence the increase of $h$ has on $d_t$ a positive effect, as $R^t$.

Bank riskiness is measured by the probability of a run occurring. This is

$$\phi_t = \frac{1}{2h} \int_{-h}^{R^t} d\xi_t = \frac{1}{2} \left( 1 - \frac{R^t - R_d}{h} \right).$$

(6)

For low values of $\lambda$ and $h$, the probability would tend to fall below zero; in this case the marginal equilibrium condition (5) and the last equality of Eq. (6) cease to hold. As noted already, deposits can never fall below the level where a run is impossible. In the aggregate, investment is $Q_t = Q_t$. The total amount of deposits in the economy is

$$D_t = \frac{Q_t L_t}{R_t} = \frac{R^t + h}{2 - \lambda + c(1 + \lambda)},$$

and aggregate bank capital is

$$B_K_t = \left( 1 - \frac{R^t + h}{R_t} \right) Q_t L_t.$$

(7)

The latter expressions suggest that following an increase in $R_t$, the optimal amount of bank capital increases on impact (for given $R^t$). In general equilibrium the responses are more complex, as shown below, depending on several counterbalancing factors affecting $R^t$ and $R_t$. The expression (7) gives the level of bank capital desired by the bank manager, for any given level of investment, $Q_t L_t$, and interest rate structure ($R_t$, $R^t$). Bank capital accumulates from reinvected earnings of the bank capitalist. After remunerating depositors and paying the competitive fee to the bank manager, a payoff accrues to the bank capitalist in good states (no run), and this is reinvested in the bank as follows:

$$B_K_t = \frac{\theta}{\pi_t} [B_{K_{t-1}} + \varphi^{BK}_t Q_t].$$

(8)

The parameter $\theta$ is a decay rate, given by the bank survival rate already discussed. The expected value of the unitary payoff to the capitalist reads as follows (see Appendix 2):

$$\varphi^{BK}_t = \frac{1}{2h} \int_{R_d}^{R^t} \frac{(R^t + \xi_t - R_d)}{2} d\xi_t = \frac{(R^t + h - R_d)^2}{8h}.$$

(9)

The integral in Eq. (9) covers only the no-run state because if a run occurs the capitalist receives no return. Importantly, note that booms and busts in asset prices, $Q_t$, affect bank capital accumulation. This captures the banks’ balance sheet channel in our model.

3.3. Producers

The production sector of the model is standard and discussed only briefly here; see Appendix 3 for details. Final output producers produce different varieties, labeled $Y(i)$, according to a Cobb–Douglas production function, $Y_t(i) = A_i F(N_t(i), K_t(i))$. They have monopolistic power in the production of their own variety, whose demand is $Y(i) = (P(i)/P_i)^{-\varepsilon} Y$, with $\varepsilon$ being the demand elasticity. They face quadratic price adjustment costs

$$\beta \left[ \frac{P_t(i)}{[P_{t-1}(i)]^2} - 1 \right]^2,$$

where $\beta$ captures the degree of price stickiness. In a symmetric equilibrium, they take first-order conditions with respect to $N_t$, $K_t$, and $P_i$. The following expectation-augmented Phillips curve arises:

$$U_{t+1}(\pi_{t+1} - \pi_t) = \beta E_t[U_{t+1}(\pi_{t+1} - \pi_{t+1}) + U_{t+1}(\pi_{t+1}) - U_{t+2}(\pi_{t+2})] = \beta (mc_t - (\varepsilon - 1)/\varepsilon)$$

where $mc_t$ is the real marginal cost. In turn, the capital producing sector is competitive. Capital

---

13. $c$ and $\lambda$ are not independent as far as their effect on the capital structure is concerned, but they are distinct in that the first entails an aggregate resource loss while the second does not.

14. An alternative way of modeling sticky prices would be the Calvo–Yun approach in which firms face an exogenous probability of changing prices. Under the assumption of symmetric equilibria, a quadratic cost of adjusting prices produces an aggregate expectation-augmented Phillips curve which is observational equivalent to the one arising under the Calvo–Yun approach. Our calibration, detailed below, allows to reproduce the sensitivity of inflation to marginal cost featured within the Calvo–Yun approach.
accumulation is affected by adjustment costs: \( K_{t+1} = (1-\delta)K_t + \xi (l_t/K_t)K_t \). 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

\[
\frac{R_t^A}{\pi_t^{1+1}} = \frac{m c_{t+1} \Pi_{t+1} F_{K,t+1} + Q_{t+1}}{Q_t} \left( 1 - \delta - \zeta - \frac{X_t}{Y_t} \right) \frac{K_{t+1} - K_t}{K_t} + \frac{\zeta}{Y_t} \frac{X_t}{Y_t},
\]

where the asset price is given by \( Q_t = P_t/(Q_t^G) \). Hence, the bank return on assets \( R_t^A \) is the key transmission link from the banking sector to the production sector in the model and vice-versa.

### 3.4. Goods market clearing and monetary policy

The government runs a balanced budget: lump-sum taxation finances an exogenous government expenditure: \( T_t = G_t \). The combined resource constraints, inclusive of government budget, reads as follows:

\[
Y_t - \Omega_t = C_t + I_t + G_t + (\beta/2)(\pi_t - 1)^2
\]

where \( \Omega_t = \int_{-h}^{h} R_t^A(Q_tK_t) \frac{C_t}{2h} d\xi_t \)

represents the expected aggregate cost of run. Monetary policy follows a Taylor type rule:

\[
\ln \left( \frac{R_t}{\bar{R}} \right) = (1 - b_1) \left[ b_2 \ln \left( \frac{\pi_t}{\pi_t} \right) + b_3 \ln \left( \frac{Y_t}{Y_t} \right) + b_4 \ln \left( \frac{Q_t}{Q_t} \right) + b_5 \ln \left( \frac{d_t}{d_t} \right) \right] + b_6 \ln \left( \frac{R_t - 1}{R_t} \right) + \epsilon_t.
\]

All variables in the policy rule 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 \((d_t)\).

### 3.5. Parameter values

**Household preferences and production:** The time unit is the quarter. The utility function of households is

\[
U(C_t, N_t) = C_t^{1-\sigma} \frac{1}{1-\sigma} + \nu \log(1-N_t),
\]

with \( \sigma = 2 \). \( \nu \) is set equal to 3, generating a steady-state level of employment \( N \approx 0.3 \). The discount factor \( \beta \) is set at 0.995, so that the annual real interest rate is around 2%. A Cobb-Douglas production function is used, \( F(\cdot) = K_t^\alpha (N_t)^{1-\alpha} \), with \( \alpha = 0.3 \). The quarterly aggregate capital depreciation rate \( \delta \) is 0.025, the elasticity of substitution between six varieties. 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 \( \beta \) 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:** The average dispersion of corporate returns in the US from Bloom et al. (2012) is around 0.3; this value, multiplied by the square root of 3, which is the ratio of the maximum deviation to the standard deviation of a uniform distribution, is around 0.5. Values of \( h \) somewhat lower are used in the model analyses below, within the interval 0.35–0.45, because those values yield a more accurate estimate of the steady-state values of the bank deposit ratio and bank risk.\(^{16}\) One way to interpret \( i \) 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 short-term funding cost (a money market rate). A benchmark estimate can be obtained by taking the historical ratio between the money market rate and the loan rate. In the US over the last 20 years, based on 30-year mortgage loans, this ratio has been around 2.0–2.5%. This leads to a value of \( \lambda \) around 0.4–0.5. In the empirical analyses values somewhat lower were used, within the interval 0.35–0.45. The survival rate of banks, \( \theta \), is set 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% up to 80 or 90% for some assets. A conservative 80% is used here, which implies \( c = 0.2 \).

**Shocks:** Total factor productivity evolves as \( A_t = A_{t-1}^\rho \exp(\epsilon_t^\rho) \), where \( \epsilon_t^\rho \) is an i.i.d. shock with \( \sigma_\rho = 0.056 \) and \( \rho_\rho = 0.95 \) as in RBC studies. Log-government consumption is assumed to evolve according to the process \( \ln(G_t/G) = \rho_\gamma \ln(G_{t-1}/G) + \epsilon_{t+1}^\gamma \), where \( G \) is the steady-state share of government consumption (set so that \( G/Y = 0.25 \)) and \( \epsilon_{t+1}^\gamma \) is an i.i.d. shock with \( \sigma_\gamma = 0.0074 \), \( \rho_\gamma = 0.9 \) (both values set according to empirical studies for industrialized countries). Finally, the interest rate rule is subject to a moderately persistent shock.\(^{17}\)

---

\(^{15}\) The New Keynesian literature has usually considered a frequency of price adjustment of four quarters as realistic.

\(^{16}\) The bank capital accumulation Eq. (8), once we substitute in the optimal deposit ratio (5), both in steady-state form, yield a quadratic equation in \( R_t \). One root, around 1.035, is our steady-state value of \( R_t \).

\(^{17}\) Autoregressive coefficient of 0.2: this is consistent with Rudebusch (2002). Based on the evidence of Angeloni et al. (2011), and consistently with other empirical results for US and Europe, the standard deviations of the shocks is set to 0.006.
4. Transmission channels

Fig. 2 shows the response to a monetary restriction under two alternative values of \( h \): 0.35 (the benchmark) and 0.45 (higher uncertainty on the project outcome). It also compares these impulse responses with those obtained from a model without banks, in which monetary policy is transmitted directly via the real money market rate.

Inflation and output drop on impact, with a corresponding protracted fall in investment and capital formation. The increase in interest rate activates the risk taking channel: bank leverage and risk decline. Two things are noteworthy. First, the transmission to bank risk is stronger if the uncertainty of project is low: in “euphoric” states, when investment riskiness is perceived to be low, a monetary expansion has a strong effect on bank risk. In the model, this effect follows directly from Eq. (6), as a higher concentration of the probability distribution (low \( h \) in the denominator) produces a higher change of risk, for any given change in the interest rates and leverage appearing in the numerator. Second, the model without bank displays a stronger impact of monetary policy; our banking sector “shelters” the real sector to some extent, a result reminiscent of empirical analyses showing that relationship lending protects borrowers from monetary shocks (e.g. Petersen and Rajan, 1994). Seeing it with the reverse sign, a monetary accommodation in our model comes along with the endogenous build up of risk: large risks indeed usually emerge after periods of expansionary money, stable and sustained growth and rising leverage. Another way of seeing this is that bank risk is, all other things equal, contractionary; consistently, the transmission to output and investment of a monetary contraction is milder in the short run when \( h \) is smaller, because bank risk declines more. The lower rate of investment causes a lower demand for bank loans; since bank capital accumulation is slow one observes, in the short run, a higher bank leverage because banks need to collect deposits in order to finance their loans (the leverage increase is not sufficiently strong, however, to offset the reduction of bank risk).

A positive productivity shock (Fig. 3, again with two variants, with \( h \) equal to 0.35 or 0.45 and by comparing with the model without banks) reduces inflation and increases output, investment and capital. The policy-driven interest rate \( R \), falls, as the monetary authority reacts to inflation. 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 of this shock. Entrepreneurial risk differs 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 lower the effect on the probability of run of any given change in bank leverage (denominator effect in Eq. (6)). At the same time, the effect of any given change of interest rate on bank leverage is higher, as one can see by inspecting Eq. (5). The fact that the response of bank risk to a productivity shock is stronger when the entrepreneurial risk is lower again highlights a self-reinforcing mechanism operating in “exuberant” states: productivity increases generate more bank risk when initially the perceived uncertainty of investment projects is low, the more so if the reaction of the central bank is to lower interest rates in response to lower inflation. Lastly, notice that contrary to the monetary policy shock, in this case the model with banks displays an amplified output response on impact. This results from the bank balance sheet channel: in the short run, the increase in the asset price induced by the positive productivity shock expands bank lending and aggregate investment. In the longer run, however, the risk taking channel dominates, and the output performance of the model with banks is again more attenuated than that of the model without banks.

4.1. Alternative policy regimes

In this context, it is of interest to explore possible responses of the central bank to financial conditions. Fig. 4 compares the benchmark monetary policy rule with an alternative where the central bank reacts also to asset prices, with a response coefficient equal to 1, under a positive asset price shock. As one can see, the rule reacting to the asset price is rather successful in stabilizing inflation and output. The interpretation is as follows: when following a standard Taylor rule, the central bank maintains a more accommodative stance because inflation declines; hence the effect of the asset price boom on the real economy is stronger. If the central bank instead reacts to the rise in the asset price, it dampens the effect on investment and output. In this case, the central bank lets bank risk vary somewhat more, but this is instrumental, given the nature of the shock, to stabilizing the macroeconomy. While this result speaks in favor of some response of monetary policy to asset prices, it is not conclusive because it is obtained under a single shock only. This comparison will be extended later using a set of calibrated shocks.

Table 1 shows model-based unconditional standard deviations (taken as a ratio to that of output) and first-order autocorrelations of selected variables and compares them with US and euro area data estimates. The model broadly

---

18 Parameters for this table are \( h = 0.35 \); \( \lambda = 0.45 \). For the euro area, data are weighted averages of national data (EA-12). National account data are from Eurostat and national sources, in some cases reconstructed backward using a multiplicative backcasting method; employment data (number of persons) are from OECD, in some cases reconstructed using the same method; CPI are from OECD; bank deposit and lending rates (respectively, long-term deposits and household loans) are from the ECB. Bank risk are bank expected default frequencies from Moody’s KMV. US data are from the St. Louis Fed website. Bank deposit and lending rates are, respectively, average rates of deposits in M2, lending rates refer to household loans. Bank expected default frequencies are from Moody’s KMV. All data were detrended using a Hodrick Prescott filter (smoothing factor: 1600). Estimation samples vary according to data availability.
reproduces the main features of the data, but some qualifications should be made. First, the model underestimates the persistence of investment and employment, probably due to the lack of extensive frictions in our model, that was kept deliberately simple to facilitate comparison with the existing literature. Second, importantly given our focus on bank risk, the model overestimates somewhat the volatility (not the persistence) of bank risk relative to our comparators, especially the euro area. Here we think the model is right, or at least not inconsistent with a proper reading of the data. The data are average bank expected default frequencies (EDF) calculated by Moody’s KMV feeding observed asset prices and volatilities into a modified Black–Sholes–Merton formula (see Crosbie and Bohn, 2003 for details). Again, the sample period is likely to be very atypical, considering the extremely low asset price volatility that prevailed during the “great moderation”. It should be noted that the model tends to overestimate not only the second moment of bank risk but also its first moment: for the parameter ranges considered, the steady-state value of $\phi_t$ ranges between 5% and 9% in the free capital model and between 1% and 6% in the version with capital requirements (see Section 5 below for the introduction of capital requirements in our model), whereas the data indicate an EDF of around 0.5% before 2007, rising to 3% (US) and 1% (euro area) at the end of the sample. Even these end-period observations are likely to be underestimates, especially for the euro area, considering that not all (not most, probably) bank distress cases end up in actual default: many result in acquisitions (see Corbae and D’Erasmo, 2011), or official intervention of some sort, the number of which has risen dramatically after 2007. This contributes to bias the market-based data further down, relative to a fair and realistic estimate of system-wide bank distress probabilities.

5. Introducing bank capital requirements

In examining the role of bank capital regulation, our goal is positive, not normative; the goal is to explore the implication of existing or realistic capital regulation regimes, not attempt to design a new “optimal” regime. Our regulator

\[ h \text{ between } 0.35 \text{ and } 0.45 \text{ and } \lambda \text{ between } 0.35 \text{ and } 0.45. \]
sets minimum capital ratios to reduce bank risk, perceived to be undesirably high under a “free capital” regime,\textsuperscript{20} and enforces the requirement by imposing a penalty for non-compliance.\textsuperscript{21} In case of non-compliance, the regulator is assumed to apply a levy on the bank capitalist. To simplify the analysis while maintaining realism, this levy is set so that bank outside investors receive a payoff cut as they would under a bank run. Intuitively, the regulator “punishes” the capitalist of a non-compliant bank with a penalty equal to that occurring in a bank failure, mimicking such outcome with a tax. The expected tax revenue, positive by construction, is returned to the capitalist as a non-contingent transfer.\textsuperscript{22}

**Proposition 2.** The following can be shown:

(a) the actual deposit rate $d_{t}^{\text{ACT}}$ chosen by the manager is

$$d_{t}^{\text{ACT}} = d_{t} - \frac{1}{R_{c}} \frac{2 - (1 + \lambda)(1 - o_{c})}{3 - (1 + \lambda)(1 - o)} b_{t}^{\text{MIN}},$$

where $b_{t}^{\text{MIN}}$ is the minimum capital ratio (defined below) and $d_{t}$ is the deposit ratio in absence of any capital requirement.

(b) For plausible parameter values, the actual bank capital is higher than the minimum, i.e. banks maintain a capital buffer above the minimum (as in Elizalde and Repullo, 2007).

(c) a (non-zero) capital requirement lowers bank risk.

\textsuperscript{20} This is compatible with the notion of (second best) optimal capital regulation. Since frictions are present in the model, it is entirely possible that the “free capital” outcome and its associated bank risk are sub-optimal from a welfare perspective. We will show examples in which capital regulation is welfare improving.

\textsuperscript{21} Real-life international regulators, within the Basel Committee on banking Supervision, do not set penalties directly but let the national supervisors use the enforcing instruments they see fit in each national context. National practices vary 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.

\textsuperscript{22} It should be noted that in case of non-compliance a run does not necessarily occur: the project can still generate enough returns to pay depositors even if it is insufficient ex-post to comply with the regulatory capital. In this case the depositor is paid in full. A run actually occurs only if the project outcome is insufficient to pay depositors.
Proof. See Appendix 4.

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

$$b_{Kt}^{MIN} = \frac{BK_{t}^{MIN}}{Q_tK_t} = const + b_0^c\left(\frac{Y_t}{Y_{SS}}\right)^{b_1^c}.$$  \hspace{1cm} (12)

Appendix 5 shows that Eq. (12) 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 5 for estimates), one can calibrate $b_1^c$ so that the equation for $b_{Kt}^{MIN}$ 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 \( b^*_0 = 0 \), the equation for \( b^*_{MIN} \) reproduces the Basel I regime, in which the capital ratio is fixed.\(^{23}\) Setting positive value of \( b^*_0 \) 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.

5.1. Impulse responses under capital requirements

Fig. 5 shows, under our usual productivity shock, the responses of the model when minimum capital requirements are imposed. The parameters mimic three alternative regimes: in the first the required capital ratio is fixed (as in Basel I); in the second it is moved anticyclically (decreasing when output is above potential, hence producing pro-cyclical macroeconomic effects), as in Basel II\(^{24}\); the third is 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 \( b^*_0 \); this regime is referred to as “Basel III”.\(^{25}\) The figure shows that the Basel II regime results in a strong amplification of the short run effect of the shock on all variables in the model. The effect is rather extreme, due to the absence of non-bank capital markets and other smoothing factors, but is illustrative of the potential destabilizing property of pro-cyclical capital requirements. The amplification is evident on all variables, from output and investment to bank leverage and risk. 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.

6. Comparing policy regimes

Alternative policy combinations are compared using four criteria: household welfare and the volatility of three macro variables: output, inflation and bank risk. Household welfare is, of course, the only theoretically founded criterion; it relies, however, on highly speculative assumptions on the utility function. Volatilities are ad hoc, but frequently used, measures of policy performance. Our welfare computations do not rely on first-order approximations, because in an economy with time-varying distortions stochastic volatility affects both first and second moments.\(^{26}\) Welfare comparison are made using as metric the fraction of household’s consumption that would be needed to equate conditional welfare \( W_0 \) under a generic rule to the level of welfare \( W_0 \) implied by the “best” rule. Such fraction, \( \iota \), is defined by: \( W_{0,\iota} = \mathbb{E}_0(\sum_{t=0}^{\infty} \beta^t U((1+\gamma)C_t)) = W_0 \). Welfare and volatilities are computed under productivity, government expenditure and monetary policy shocks, calibrated as in Section 3.5.

6.1. Alternative monetary policy regimes

Our attention is focused on simple and operational Taylor type rules as the one described in Section 3.4. Two groups of six rules are considered. The first includes 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 at 0.4.\(^{27}\) 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 response to inflation, interest rate smoothing and response to financial markets—either to the asset price or to bank leverage.

To start with, Table 2 shows the sensitivity of the performance of the monetary policy rules to alternative banking parameters, in a model with free capital, for some parameter values within our ranges. Intuitively, high \( h \) and a low \( \lambda \) should prevail under stressed market conditions, when uncertainty is high and liquidation values low.

The table is constructed so as to compare, for each parameter combination, each policy with the best one; the latter is marked by a 0, while the other cells show losses (welfare loss, or volatility increase) relative to the best rule within each column. Hence by construction the numbers in this table are comparable only within, not across columns. Two main messages emerge. First, an aggressive response to inflation is preferable, not only, as one would expect, if the criterion shown is inflation volatility (\( \pi \)), but also if the criterion is welfare (\( J \)), output (\( Y \)) or bank risk (\( \phi \)). There is no trade-off between output and inflation stabilization, or macro stability and banking stability in this case. Second, all best rules

\(^{23}\) In fact, capital regulation was slightly procyclical also under Basel I, due to accounting and other factors. We disregard this.

\(^{24}\) See Appendix 5 for numerical details, 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.

\(^{25}\) This terminology is used here for convenience only. In fact, the new capital accord agreed by the Basel committee, 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.

\(^{26}\) See for instance Schmitt-Grohe and Uribe (2007). We focus on the conditional expected discounted utility of the representative agent. This allows us to take into account the transitional effects from the deterministic to the different stochastic steady states respectively implied by each policy rule.

\(^{27}\) For higher values, numerical convergence problems were occasionally encountered, especially under the Basel II specification.
within the class examined incorporate some reaction to financial conditions. Which rule wins depends on the criterion used. Most often, it is best to react to asset prices without smoothing when welfare or output stabilization are the criteria. On the contrary, to stabilize inflation or bank risk some smoothing appears to be useful, and it also helps to react to bank leverage. Interest rate smoothing has two effects: it dampens interest rate changes and it generates expectations of further changes in the same direction. The second may help in controlling inflation, while the first is often mentioned as a way to

Table 2
Comparing welfare, \( U \), output, \( Y \), inflation, \( \pi \), and bank riskiness, \( \phi \), volatilities under alternative monetary policy rules and banking parameters.

<table>
<thead>
<tr>
<th>h, ( \lambda ) values</th>
<th>Benchmark: 0.35; 0.45</th>
<th>( h=0.35; \lambda = 0.35 )</th>
<th>( h=0.45; \lambda = 0.35 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h ) ( \lambda )</td>
<td>( r )</td>
<td>( Y )</td>
<td>( \pi )</td>
</tr>
<tr>
<td>Taylor</td>
<td>0.08</td>
<td>0.16</td>
<td>0.28</td>
</tr>
<tr>
<td>React Q</td>
<td>0.06</td>
<td>0.02</td>
<td>0.25</td>
</tr>
<tr>
<td>React D</td>
<td>0.07</td>
<td>0.13</td>
<td>0.27</td>
</tr>
<tr>
<td>Smoothing</td>
<td>0.08</td>
<td>0.50</td>
<td>0.23</td>
</tr>
<tr>
<td>React Q</td>
<td>0.12</td>
<td>0.16</td>
<td>0.40</td>
</tr>
<tr>
<td>React D</td>
<td>0.08</td>
<td>0.44</td>
<td>0.23</td>
</tr>
<tr>
<td>Aggressive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>0.00</td>
<td>0.08</td>
<td>0.01</td>
</tr>
<tr>
<td>React Q</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>React D</td>
<td>0.00</td>
<td>0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>Smoothing</td>
<td>0.02</td>
<td>0.41</td>
<td>0.00</td>
</tr>
<tr>
<td>React Q</td>
<td>0.04</td>
<td>0.15</td>
<td>0.13</td>
</tr>
<tr>
<td>React D</td>
<td>0.01</td>
<td>0.36</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 5. Impulse response to a 1% productivity increase. Alternative Basel regimes.
take financial stability into account (see e.g. Rudebusch, 1995). Note that the differences in welfare are in all cases rather small (within one quarter of 1% in consumption terms) as already noted in the literature on the welfare cost of cyclical fluctuations. The differences in volatility of output and risk (as well as inflation) are, instead, economically quite significant.

To gain a feel of how the welfare surface is shaped, Fig. 6 plots the surface against two parameters of the monetary policy rule, under free capital: the coefficient on inflation and that on the asset price.28 Welfare levels tend to increase with the coefficient values, although at a lower pace while approaching the extreme. Although this figure is somehow less informative than the table above, as the search can only be conducted for given values of $h$ and $l$, it nevertheless reinforces the message that relatively aggressive monetary policy rules perform comparatively well.29

6.2. Monetary and bank capital regimes combinations

Table 3 brings in capital regulation. It shows the performance of the rules under four banking regimes30: free capital, Basel II and III—the latter being the two regimes at the center of recent policy discussions. This time the entries are calculated relative to the optimal combination of monetary-bank capital regime in the whole table, not within each column (comparisons within each column are still possible, however). The best policy combination always includes Basel III. An aggressive monetary rule is always chosen except when output stabilization is the overriding criterion; note, however, that the output volatility losses when shifting to an aggressive rule are minimal, while the losses in terms of other criteria of making the reverse change are rather large. From this perspective, an aggressive inflation response comes out as clear winner. Note, finally, that some response to bank leverage helps in this case, performing slightly better than a response to asset prices. While the choice between these two variables is not clear-cut, the message that some response to financial conditions helps increasing welfare and reducing volatility in the economy emerges rather unambiguously from our results.

7. Conclusions

Views on how to conduct macro policies are changing rapidly, and well-established paradigms are being questioned. One concerns the interaction between prudential regulation and monetary policy. The earlier consensus according to which the two policies should be conducted in isolation, each pursuing its goal using separate instruments and

---

28 The search grid, $b_n = (0.9 : 2.9)$, $b_q = (−0.5 : 0.6)$, $b_r = (0,0.6)$, was chosen to account for all possible values that would deliver determinacy and by ruling out singularities for most of the regimes considered in the simulations. The search has been repeated alternatively for $b_r = 0$ and $b_r = 0.5/4$ and delivered similar results.

29 The highest level of welfare is reached in the graph for $b_n = 2.7$, $b_q = 0.5$, $b_r = 0$, although welfare levels remain similar in the range $b_n = (2 : 2.7)$, $b_q = (0.4 : 0.6)$.

30 The parametrization in this case is $h = 0.35$, $\lambda = 0.45$. The table has been re-computed also for the alternative $h = 0.35$, $\lambda = 0.35$ and results were largely unchanged.
information sets, 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, and this opens up new exciting 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.

This paper moves a step forward by constructing a macro-model that integrates risky banks and using it to analyze 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 support the introduction of anti-cyclical capital requirements and an active use of monetary policy reacting also to financial conditions.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jmoneco.2013.01.003.

Table 3

Comparing welfare, $U$, output, $Y$, inflation, $\pi$, and bank riskiness, $\phi$, volatilities under alternative monetary policy rules and Basel regimes.

<table>
<thead>
<tr>
<th>Regime</th>
<th>Free capital</th>
<th>Basel II</th>
<th>Basel III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\gamma$</td>
<td>Y</td>
<td>$\pi$</td>
</tr>
<tr>
<td>Taylor</td>
<td>0.10</td>
<td>1.13</td>
<td>0.33</td>
</tr>
<tr>
<td>React Q</td>
<td>0.09</td>
<td>0.99</td>
<td>0.30</td>
</tr>
<tr>
<td>React D</td>
<td>0.10</td>
<td>1.10</td>
<td>0.33</td>
</tr>
<tr>
<td>Smoothing</td>
<td>0.10</td>
<td>1.47</td>
<td>0.29</td>
</tr>
<tr>
<td>React Q</td>
<td>0.15</td>
<td>1.13</td>
<td>0.46</td>
</tr>
<tr>
<td>React D</td>
<td>0.10</td>
<td>1.41</td>
<td>0.29</td>
</tr>
<tr>
<td>Aggressive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>0.03</td>
<td>1.05</td>
<td>0.07</td>
</tr>
<tr>
<td>React Q</td>
<td>0.02</td>
<td>0.97</td>
<td>0.06</td>
</tr>
<tr>
<td>React D</td>
<td>0.02</td>
<td>1.03</td>
<td>0.07</td>
</tr>
<tr>
<td>Smoothing</td>
<td>0.04</td>
<td>1.38</td>
<td>0.06</td>
</tr>
<tr>
<td>React Q</td>
<td>0.06</td>
<td>1.12</td>
<td>0.19</td>
</tr>
<tr>
<td>React D</td>
<td>0.04</td>
<td>1.33</td>
<td>0.06</td>
</tr>
</tbody>
</table>

References