Monetary Policy and Credit Cycles: A DSGE Analysis

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bstract>
Résumé:

La crise financière récente a révélé plusieurs défaillances dans la réglementation monétaire et financière. Contrairement à ce que l'on croyait, la stabilité des prix n'est pas une condition suffisante pour assurer aussi la stabilité financière. En même temps, la réglementation micro-prudentielle s'est avérée elle aussi insuffisante pour assurer l'objectif de stabilité financière. Dans cet article, nous proposons une analyse ex-post de ce qu'une banque centrale aurait pu faire afin d'améliorer la réaction de l'économie à la bulle financière. Nous étudions à l'aide d'un modèle DSGE avec accélérateur financier la dynamique de notre économie lorsque la banque centrale a, d'abord, seulement des objectifs traditionnels, et ensuite, quand un objectif supplémentaire, celui de stabilité financière, est rajouté. Dans l'ensemble, les résultats indiquent qu'une politique monétaire plus agressive aurait eu peu de succès dans l'amélioration de la réaction de l'économie aux chocs financiers, car les actions de la banque centrale auraient été limitées par l'utilisation d'un instrument unique, le taux d'intérêt.

Mots clés: canal du capital bancaire, cycle de crédit, stabilité financière, politique monétaire.

Abstract:

The recent financial crisis revealed several flaws in both monetary and financial regulation. Contrary to what was believed, price stability is not a sufficient condition for financial stability. At the same time, micro-prudential regulation alone becomes insufficient to ensure the financial stability objective. In this paper, we propose an ex-post analysis of what a central bank could have done to improve the reaction of the economy to the financial bubble. We study by means of a financial accelerator DSGE model the dynamics of our economy when the central bank has, first, only traditional objectives, and second, when an additional financial stability objective is added. Overall, results indicate that a more aggressive monetary policy would have had little success in improving the response of the economy to the financial bubble, as the actions of the central bank would have remained limited by the use of a single instrument, the interest rate.

Keywords: bank capital channel, credit cycles, financial stability, monetary policy.

JEL classification: E58, E61, E44, D58

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1 Introduction

Before the financial crisis of $2007 - 08$, it was generally accepted that the main objective of central banks was price stability. This shared view was called into question when the crisis revealed several flaws in the existent economic policy framework. First, maintaining price stability proved to be an insufficient condition for financial stability. A new monetary transmission mechanism - the risk-taking channel - explains how monetary policy itself can influence the level of risk in the economy. Borio and Zhu (2008) define this new channel as *"the impact of changes in policy rates on either risk perceptions or risk-tolerance and hence on the degree of risk in the portfolios, on the pricing of assets, and on the price and non-price terms of the extension of funding"*. Empirical evidence for the existence of these effects was provided by several authors like Altunbas et al. (2009a, 2009b), Maddaloni and Peydro (2009), Jimenez et al. (2009) or Ioannidou et al. (2009). The main conclusion of all these studies is that keeping interest rates too low[1] for an extended period of time can determine an accumulation of systemic risk in the financial sector. The increase in risk is accompanied by an increased level of output and a development of credit activity. Once the risk materializes[2], banking problems appear and a financial crisis is almost inevitable. Based on this evidence, much of the blame for the gravity of the crisis was put on the central banks that maintained, during several years, an accommodative monetary policy stance.

Second, with the crisis, it also became clear that microprudential regulation was not enough to deal with the complex financial system and failed in maintaining financial stability. Supervisors and regulators were interested only in the risk of financial institutions taken individually, ignoring the interconnections between them. Accordingly, policy makers agree now on the need of a macroprudential authority that would monitor and react to system wide risk (Hanson et al., 2011).

A third problem in the existing policy framework was raised by De Grauwe and Gros (2009), who prove that, in the presence of bubbles, the economy can be confronted with a trade-off between price stability and financial stability. More precisely, even if inflation stays stable, the economy can experience imbalances which eventually translate into a crisis. Under these circumstances, a central bank favoring price stability will allow excessive credit creation endangering thereby the financial stability. They argue that, in the presence of such conflicts, the central bank should leave aside the price stability objective and intervene to stop the accumulation of risk.

In this paper, we study the behavior of a central bank faced with a boom-bust process. We propose two ex-post analyses. The first one allows us to see how the monetary authority could have improved the dynamics of the economy, had it chosen to lean against the wind during the asset price bubble. In the second one, we study the optimal behavior of a central bank responsible not only for price stability, but also for maintaining financial stability. The advent

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[1] Altunbas et al. (2009a) define a "too low" interest rate as either a nominal short term interest rate that stays below its Taylor rule implied level or as a real short term interest rate that is inferior to the natural interest rate.

[2] Generally, when the monetary authority decides to increase interest rates.

of the crisis determined many authors to analyze directly the interplay between monetary policy and macroprudential regulation[3] excluding the case where the monetary authority is itself responsible for financial stability. Our analysis seeks to fill a gap in the existing literature by proposing a theoretical model that provides arguments for the inadequacy of monetary policy in maintaining financial stability when only using the interest rate as instrument. To conduct our analysis, we start from the standard financial accelerator model of Bernanke et al. (1999). The financial accelerator mechanism is compulsory because it allows for rapid risk accumulation during good times and it amplifies the downturn once the situation reverses. However, in order to study financial stability, several elements are added to this framework. As banks are the major actors of financial stability, the financial accelerator is modeled not only through the firm balance sheet channel (Bernanke et al., 1999), but also through the bank capital channel as in Badarau and Levieuge (2011). Next, to obtain a complete business cycle, we introduce a boom-bust process inspired by the one of Bernanke and Gertler (1999). The positive bubble triggers the risk and favors its accumulation, whereas the burst of the bubble induces the crisis as risk materializes, which is exactly how recent crises developed[4]. Finally, to be closer to reality, we allow for speculative behavior when investment decisions are made.

Giving a macroprudential objective to the central bank is, however, not straightforward. In opposition to price stability, financial stability is difficult to define and measure because of its wide range of application[5]. For the purpose of the present paper, we restrict the concept of financial stability to limiting credit variability. To account for financial risk, we integrate the credit-to-GDP ratio in the monetary policy rule and/or in the loss function of the central bank. The choice of the financial indicator is determined by the latest Basel agreement (BIS, 2011) on financial stability which establishes credit growth with respect to GDP as a reference measure capturing excessive risk accumulation. Moreover, the ratio of loans to GDP was proposed before in the economic literature, together with asset prices, as an early warning indicator of banking crisis[6].

In the analysis, two specifications of the interest rate rule are used: a standard Taylor rule and an augmented Taylor rule that includes the reaction to the credit-to-GDP ratio. For the second part of our study, optimizations are made for different loss functions of the central bank, considering this time that the financial stability objective plays a more or less important role for the monetary authority.

The paper is organized as follows. Section 2 describes the DSGE model and the key mechanism through which shocks are transmitted. In the same section, we also explain the boom-bust process. Section 3 presents and discusses the main results. Impulse response functions, obtained following a financial shock, are compared according to the different monetary policy rules used.

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[3] See, for example, Angelini et al. (2011), Lambertini et al. (2011).

[4] More precisely, we refer to the Internet bubble and the housing bubble. Moreover, these crises made clear the existence of the financial accelerator, as booms that preceded them were more intense and busts more drastic.

[5] Usually, authors prefer defining financial instability instead of financial stability. Some definitions can be found in Ferguson (2002), Borio and Lowe (2002) and Kindleberger (2000). The ECB gives a definition for financial stability, but it remains too vague to come to a conclusion on its appropriate measure: "financial stability is a condition in which the financial system (...) is capable of withstanding shocks and unraveling of financial imbalances" (ECB, 2008, p. 117).

[6] See for example, Borio and Lowe (2002), Borio (2003), De Grauwe and Gros (2009).

Optimization results are also presented together with a comparison of variances issued from this optimal behavior. The fourth section concludes and gives directions for future research.

2   The Model

This section provides a description of the theoretical model used in the analysis of macroeconomic policies. The starting point is a standard New Keynesian framework for a closed economy in which we introduce a banking sector and financial frictions. Besides the standard financial accelerator mechanism of Bernanke et al. (1999), we model financial frictions between banks and households by introducing the bank capital channel as in Badarau and Levieuge (2011). Moreover, in order to reproduce a complete business cycle, we consider a boom-bust process that lets asset prices first increase over and then decrease beyond their fundamental value.

We consider an economy populated by households, entrepreneurs and capital producers, banks, a government and a monetary authority. In order to facilitate aggregation and to introduce nominal price rigidities and monopolistic competition, we also add retailers, but their role remains secondary in the model. Households save money in the form of bank deposits, work for entrepreneurs and consume retail goods. Entrepreneurs produce homogenous wholesale goods using a constant returns to scale production function. In the production process, they use capital bought from capital producers and labor supplied by households and by entrepreneurs themselves. To finance investments in capital, entrepreneurs use their net worth, but this is never fully sufficient, so, they are always obliged to resort to external finance. Banks have the role of supplying credits to entrepreneurs. Likewise, banks have two sources of funding, bank capital and deposits collected from households. Debt contracts are renewed at the end of each period (Bernanke et al., 1999, Carlstrom and Fuerst, 1997). We suppose that banks don't have a fully diversified portfolio so they have a non null probability of default. The same goes for entrepreneurs, who may fail on their investments project. In the default case, of either the entrepreneur, or the bank, a costly state verification procedure is started.

Financial frictions due to asymmetric information and agency problems appear at two levels. On the one hand, entrepreneurs face an external finance premium on the money borrowed from the bank. On the other hand, financial frictions appear between banks and households, as the former also have to pay a finance premium when rising funds from households. These external finance premiums depend inversely on the financial condition of the borrowers. For example, a borrowing firm with a high financial leverage - calculated as the amount of assets over internal capital - will face a higher external finance premium. This premium influences the cost of capital, it has, thus, a negative impact on investment decisions which in turn influence the output in the economy. This mechanism corresponds to the financial accelerator mechanism of Bernanke et al. (1999). Moreover, the same reasoning applies to banks with the difference that banks pass on their premium to entrepreneurs. This will induce a supplementary impact on aggregate investment and output. Retailers differentiate wholesale goods produced by entrepreneurs and distribute them to the economy.

For the development of the model, we use a simplified framework including representative

agents. In the remainder of this section we will present the building blocks of the model with an accent on the banking sector and on the boom-bust process.

2.1 The Banking Sector:

In the production process entrepreneurs need capital. At the end of each period, t, the representative firm will buy K_{t+1} units of physical capital at price Q_t. To finance this purchase, the firm uses its own net worth, N_{t+1}^f. We suppose that internal funds are never enough to entirely finance new capital, so the firm has to obtain a credit from the bank to cover the remainder of the sum, B_{t+1}[7]:

$$B_{t+1} = Q_t K_{t+1} - N_{t+1}^f. \tag{1}$$

In order to supply credit to firms, banks finance themselves not only with their own net worth (bank capital), N_{t+1}^b, but also with external funds. They collect deposits from households amounting to A_{t+1}:

$$A_{t+1} = B_{t+1} - N_{t+1}^b = Q_t K_{t+1} - N_{t+1}^f - N_{t+1}^b. \tag{2}$$

Interest rates for credits (R^B) and deposits (R^A) are determined from two constrained optimization programs, one for the firm and another one for the bank. The optimization program for the entrepreneur consists in the maximization of its expected profit subject to the participation of the bank to the credit contract. However, the bank will agree to the loan only if it is able to raise funds from households, thus, a second participation constraint appears in the entrepreneur's optimization program. Similarly, the representative bank maximizes the expected profit subject to the participation of the household to the funding contract.

2.1.1 Firm's Maximization Program

The return on capital is affected by both aggregate and idiosyncratic risk. Aggregate risk, R^K, affects all firms in the economy in the same way and its value is revealed to everyone in period $t+1$, whereas the idiosyncratic risk[8], ω, is firm specific and is known only by the entrepreneur. Thus, the ex post gross return on capital is $\omega_{t+1} R_{t+1}^K Q_t K_{t+1}$. Moreover, there exists a threshold value, $\overline{\omega}^f$, below which the result of the firm is not enough to repay bank debt, case in which the entrepreneur declares default. This threshold is obtained in a situation where the ex post gross return of the entrepreneur is only enough to repay the credit from the bank:

$$\overline{\omega}_{t+1}^f R_{t+1}^K Q_t K_{t+1} = R_{t+1}^B B_{t+1}. \tag{3}$$

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[7] As investment decisions take place at the end of period t, going into period $t+1$, the entrepreneur is capable of estimating in t the capital needed in the production process for the following period, K_{t+1}, as well as the resources necessary to finance this capital, N_{t+1}^f and B_{t+1}. Therefore, all these variables are predetermined in the model.

[8] ω is a random variable issued from a log-normal distribution, with mean $-\frac{\sigma^2}{2}$ and variance equal to σ^2, *i.i.d.* over firms and over time.

The presence of idiosyncratic risk gives rise to asymmetric information between the borrower and the bank regarding the outcome of the investment project. The bank proceeds to a costly state verification (Townsend, 1979) only if the entrepreneur fails, that is, when $\omega < \overline{\omega}^f$. Monitoring costs, μ^b, are proportional to the gross expected return, $\mu^b \omega_{t+1} R_{t+1}^K Q_t K_{t+1}$. The following table summarizes gross revenues[9] of the entrepreneur and of the bank in each state of nature - default or success - of the investment project.

Table 1. Gross revenues from the investment project and the lending operation

	Default $(\omega < \overline{\omega}^f)$	Success $(\omega \geq \overline{\omega}^f)$
Entrepreneur	0	$\omega_{t+1} R_{t+1}^K Q_t K_{t+1}$
Bank	$(1 - \mu^b)\omega_{t+1} R_{t+1}^K Q_t K_{t+1}$	$R_{t+1}^B B_{t+1}$

Note: Under the default hypothesis, the entrepreneur does not have enough money to reimburse its debt towards the bank, thus, all revenues go to the bank and the entrepreneur gets nothing. In this case, the bank starts an audit procedure and recovers the revenue from the project net of these monitoring costs, $(1 - \mu^b)\omega_{t+1} R_{t+1}^K Q_t K_{t+1}$. When $\omega \geq \overline{\omega}^f$, the entrepreneur has enough money to repay the lender the promised amount, $R_{t+1}^B B_{t+1}$. Revenues for the entrepreneurs before debt repayment are $\omega_{t+1} R_{t+1}^K Q_t K_{t+1}$.

The expected profit of the entrepreneur, $\Pi_{f,t+1}^e$, is given by the revenue obtained from the investment project minus the amount of the bank debt repayment:

$$\Pi_{f,t+1}^e = \mathrm{E}_t\{ \int_{\overline{\omega}_{t+1}^f}^{\infty} [\omega_{t+1} R_{t+1}^K Q_t K_{t+1} - R_{t+1}^B B_{t+1}] f(\omega_{t+1}) \mathrm{d}\omega_{t+1} \}. \tag{4}$$

Given that the bank portfolio is not sufficiently diversified, the bank has a non null probability of default. The financial intermediary defaults if (i) the entrepreneur defaults and (ii) the revenues recovered from the entrepreneur are not enough to repay the household. The default threshold, $\overline{\omega}^b$, is obtained, as in the case of entrepreneurs, from the condition that revenues recovered from the firm are just enough to repay households:

$$(1 - \mu^B)\overline{\omega}_{t+1}^b R_{t+1}^K Q_t K_{t+1} = R_{t+1}^A A_{t+1}, \tag{5}$$

where R^A is the rate of return of the household (the deposit rate), as anticipated by the bank. Obviously, the entrepreneur's default threshold is superior to the one of the bank, $\overline{\omega}^f > \overline{\omega}^b$. If the lending intermediary defaults, the household is obliged to engage in a costly audit procedure. The monitoring costs for the household are denoted μ^a and are proportional to the revenue of the bank when the entrepreneur defaults, $\mu^a(1 - \mu^b)\omega_{t+1} R_{t+1}^K Q_t K_{t+1}$. Table 2 summarizes gross revenues obtained by banks and households depending on the state of nature, *i.e.* default or success, of the bank.

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[9] By gross revenues, we mean revenues obtained before any repayment of debt takes place.

Table 2. Gross revenues from the lending and borrowing operations computed from the perspective of the bank.

	Default of the bank and of the firm $(\omega < \overline{\omega}^b)$	Default of the firm $(\overline{\omega}^b < \omega < \overline{\omega}^f)$	Success $(\omega \geq \overline{\omega}^f)$
Bank	0	$(1-\mu^b)\omega_{t+1}R_{t+1}^K Q_t K_{t+1}$	$R_{t+1}^B B_{t+1}$
Household	$(1-\mu^a)(1-\mu^b)\omega_{t+1}R_{t+1}^K Q_t K_{t+1}$	$R_{t+1}^A A_{t+1}$	$R_{t+1}^A A_{t+1}$

Note: When the bank goes bankrupt, it gets nothing and all that it recovers from the firm goes to the household after the latter pays the auditing costs, $(1-\mu^a)(1-\mu^b)\omega_{t+1}R_{t+1}^K Q_t K_{t+1}$. When the entrepreneur defaults, but the bank has enough resources to pay the household, the household gets the whole amount established in the deposit contract, $R_{t+1}^A A_{t+1}$, whereas the bank gets as gross revenue what it remains after paying the audit costs, $(1-\mu^b)\omega_{t+1}R_{t+1}^K Q_t K_{t+1}$. In the good state of nature, when neither the entrepreneur, nor the bank default, the bank gets the agreed sum for the credit, $R_{t+1}^B B_{t+1}$, and the household, the agreed sum for the deposit, $R_{t+1}^A A_{t+1}$.

Using the results from Table 2, we can aggregate and obtain profits for the bank and firm, respectively. The bank's profit is computed as its revenue from the credit relation with the entrepreneur minus the payment made to the household[10]:

$$\Pi_{b1,t+1}^e = E_t\{ \int_{\overline{\omega}_{t+1}^b}^{\overline{\omega}_{t+1}^f} [(1-\mu^b)\omega_{t+1}R_{t+1}^K Q_t K_{t+1} - R_{t+1}^A A_{t+1}]f(\omega_{t+1})d\omega_{t+1} +$$

$$[1 - F(\overline{\omega}_{t+1}^f)][R_{t+1}^B B_{t+1} - R_{t+1}^A A_{t+1}]\}, \tag{6}$$

with $[1 - F(\overline{\omega}_{t+1}^f)]$ the probability of success for the entrepreneur's investment project. Note that the household's revenue also represents its profit[11]:

$$\Pi_{a1,t+1}^e = E_t\{ \int_0^{\overline{\omega}_{t+1}^b} (1-\mu^a)(1-\mu^b)\omega_{t+1}R_{t+1}^K Q_t K_{t+1}f(\omega_{t+1})d\omega_{t+1} +$$

$$(1 - F(\overline{\omega}_{t+1}^b))R_{t+1}^A A_{t+1}\}. \tag{7}$$

In deciding whether to grant or not the loan to the entrepreneur, the bank compares the profit it would obtain from the lending operation with the revenue it would get if it had invested the money at a predetermined risk free rate[12], r_{t+1}. The bank agrees to the contract only if the expected return from lending is at least equal to this opportunity cost:

$$\Pi_{b1,t+1}^e = N_{t+1}^b R_{t+1}, \tag{8}$$

where N^b represents the net worth of banks.

Likewise, from the point of view of the bank, the household will agree to lending funds to the bank only if its expected profit is at least equal to the opportunity cost for these funds:

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[10] The '1' that appears as a subscript for profits reminds us that we are dealing with the first optimization program and that profits for the bank and household are computed from the perspective of the bank.

[11] The household doesn't have any debt to repay.

[12] $R_{t+1} = 1 + r_{t+1}$.

$$\Pi^e_{a1,t+1} = A_{t+1}R_{t+1}. \tag{9}$$

Equations (8) and (9) represent the participation constraints of the bank and household to the financing of the entrepreneur. Finally, the expected profit maximization under these two constraints yields the external finance premium of the firm defined as $S^f_t = \mathrm{E}\{\frac{R^K_{t+1}}{R_{t+1}}\}$:

$$S^f_t = \Psi^f \left(\frac{Q_t K_{t+1}}{N^f_{t+1} + N^b_{t+1}} \right), \text{ with } \Psi^{f\prime}(\cdot) > 0. \tag{10}$$

Note that the external finance premium of the entrepreneur doesn't depend only on its own financial situation, but also on the financial soundness of the bank. Thus, the entrepreneur bears a higher interest rate that also covers the financing cost of the bank. We recognize here the bank capital channel that acts like a financial accelerator.

2.1.2 Bank's Maximization Program

The second maximization program allows us to determine the bank's external finance premium. This time the analysis is done from the point of view of the household who does not know the bank's balance sheet composition, but the reasoning is very much the same as in the case of the entrepreneur. The household judges the relationship with the bank by looking at the aggregate return on banking assets, R^B. Households are aware that the realization of R^B is subject to an idiosyncratic risk[13], ε. The threshold below which the bank defaults on its commitments toward the household is given by the following equation:

$$\bar{\varepsilon}_{t+1}R^B_{t+1}B_{t+1} = R^A_{t+1}A_{t+1}. \tag{11}$$

Gross revenues of the bank and of the household are summarized in Table 3.

Table 3. Revenues from the lending and borrowing operations computed by the household.

	Default ($\varepsilon < \bar{\varepsilon}$)	Success ($\varepsilon \geq \bar{\varepsilon}$)
Bank	0	$\varepsilon_{t+1}R^B_{t+1}B_{t+1}$
Household	$(1 - \mu^a)\varepsilon_{t+1}R^B_{t+1}B_{t+1}$	$R^A_{t+1}A_{t+1}$

Note: In the default scenario, the household proceeds to a costly audit and gets to keep the revenues of the bank net of these audit costs, $(1 - \mu^a)\varepsilon_{t+1}R^B_{t+1}B_{t+1}$, whereas the bank gets nothing. In case of success, the bank has enough money to repay the household the agreed amount, $R^A_{t+1}A_{t+1}$. Revenues for the bank before debt repayment are $\varepsilon_{t+1}R^B_{t+1}B_{t+1}$.

Therefore, the profit for the bank is:

$$\Pi^e_{b2,t+1} = \mathrm{E}_t\{ \int_{\bar{\varepsilon}_{t+1}}^{\infty} [\varepsilon_{t+1}R^B_{t+1}B_{t+1} - R^A_{t+1}A_{t+1}]f(\varepsilon_{t+1})\mathrm{d}\varepsilon_{t+1}\}, \tag{12}$$

whereas the profit for the household is given by:

---

[13] This risk is given by a random variable, ε, following a distribution that presents the same characteristics as the one of ω.

$$\Pi^e_{a2,t+1} = E_t\{ \int\limits_0^{\bar{\varepsilon}_{t+1}} (1 - \mu^a)\varepsilon_{t+1}R^B_{t+1}B_{t+1}f(\varepsilon_{t+1})\mathrm{d}\varepsilon_{t+1} + (1 - F(\bar{\varepsilon}_{t+1}))R^A_{t+1}A_{t+1}]\}, \qquad (13)$$

where $(1 - F(\bar{\varepsilon}_{t+1}))$ represents the probability of success for the bank. Similarly to the firm's situation, the participation constraint for the household to the financing of the bank is given by the condition that expected profits are at least equal to the opportunity cost:

$$\Pi^e_{a2,t+1} = R_{t+1}A_{t+1}. \qquad (14)$$

The optimizing behavior of the bank yields the following external finance premium, $S^b_t = \frac{R^B_{t+1}}{R_{t+1}}$:

$$S^b_t = \Psi^b\left(\frac{B_{t+1}}{N^b_{t+1}}\right), \text{ with } \Psi^{b\prime}(\cdot) > 0. \qquad (15)$$

As expected, the external finance premium depends only on the bank's financial leverage.

The description of the banking sector is completed by the evolution of entrepreneurial net worth and bank capital. In the case of entrepreneurs, net worth is composed of accumulated profits, V^f_t, and entrepreneurial wages, W^f_t:

$$
\begin{aligned}
N^f_{t+1} &= \gamma^f(V^f_t + W^f_t) \\
&= \gamma^f(Q_{t-1}R^K_t K_t - \\
&\quad - \left[R_t + \frac{\mu^b \int\limits_0^{\bar{\omega}^f_{t+1}} \omega_{t+1}f(\omega_{t+1})\mathrm{d}\omega_{t+1} + \mu^a(1-\mu^b)\int\limits_0^{\bar{\omega}^b_{t+1}} \omega_{t+1}f(\omega_{t+1})\mathrm{d}\omega_{t+1}}{Q_{t-1}K_t - N^f_t} Q_{t-1}R^K_t K_t \right] (Q_{t-1}K_t - N^f_t) + \\
&\quad + W^f_t),
\end{aligned}
\qquad (16)
$$

where γ^f represents the part of entrepreneurs that stays in business at t. Accumulated profits are equal to the return on capital minus the repayment of borrowings. The ratio of default costs to quantity borrowed reflects the external finance premium of the entrepreneur. The entrepreneurs who default at time t exit the business and consume their residual equity:

$$C^f_t = (1 - \gamma^f)V^f_t. \qquad (17)$$

The same reasoning applies to bank capital. However, this time, the banks that exit the market (with a probability $1 - \gamma^b$) transfer a part (t^b) of their equity to new or existing banks

on the market. Thus, their net worth and consumption are:

$$
\begin{aligned}
N_{t+1}^b &= \gamma^b V_t^b + (1 - \gamma^b) t^b V_t^b \\
&= [\gamma^b + (1 - \gamma^b) t^b] \{ R_t^K B_t -
\end{aligned}
\tag{18}
$$

$$
- \left[R_t + \frac{\mu^a (1 - \mu^b) \int_0^{\overline{\omega}_{t+1}^b} \omega_{t+1} f(\omega_{t+1}) \mathrm{d}\omega_{t+1}}{Q_{t-1} K_t - N_t^f - N_t^b} Q_{t-1} R_t^K K_t \right] (Q_{t-1} K_t - N_t^f - N_t^b) \}
$$

and

$$
C_t^b = (1 - \gamma^b)(1 - t^b) V_t^b.
\tag{19}
$$

Having the expressions for the two external finance premiums, we can now move on to introducing the banking sector into the dynamic general equilibrium framework. The rest of the model being fairly standard, we give, in what follows, only the main intuitions on the functioning of the economy.

2.2 A Brief Overview of the General Equilibrium

Households are infinitely-lived agents who decide on their consumption, savings and work-time so as to maximize their intertemporal utility function:

$$
E_t \sum_{k=0}^{\infty} \beta^k \left[\frac{\sigma_c}{\sigma_c - 1} C_{t+k}^{\frac{\sigma_c - 1}{\sigma_c}} - \frac{\sigma_h}{\sigma_h + 1} H_{t+k}^{\frac{\sigma_h + 1}{\sigma_h}} \right],
\tag{20}
$$

where β represents the subjective discount rate of the representative household, C is the consumption and H is the number of hours worked. σ_c represents the intertemporal elasticity of substitution, whereas σ_g is elasticity of disutility associated with work. The household is subject to the following budgetary constraint:

$$
P_t C_t + D_t + A_t \leq W_t H_t + A_{t-1} R_t^A + D_{t-1} R_t - T_t + \Delta_t.
\tag{21}
$$

Households' resources come from wages (W), remunerated deposits at the bank (A), savings (D) remunerated at the risk free rate and profits from the retail activity[14] (Δ). Their revenue is consumed by paying taxes (T), buying retailer goods (C) at price P and investing their savings. The first order conditions are standard and yield the equilibrium consumption level, as well as the optimum level of labor supply[15].

Retailers are introduced in the model only to motivate sticky prices. They buy wholesale goods from entrepreneurs, differentiate them at no cost and sell them in a monopolistic competition market. As in Calvo (1983), only a part of the retailers, θ, can change prices in a given period, independent of history. The optimizing behavior of retailers involves the maximization

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[14] Households are the owners of retail firms.
[15] For more details on this issue, see Badarau and Levieuge (2011).

of the present value of future dividends subject to a constraint of expected demand for retail goods. The equilibrium solution allows us to obtain the New Keynesian Phillips curve:

$$\pi_t = \beta E_t[\pi_{t+1}] + \kappa \rho_t, \tag{22}$$

with π the log-deviation of inflation relative to its steady-state, κ a parameter depending on θ, and ρ the real marginal cost of a representative retailer.

Capital producers differentiate their goods according to the needs of entrepreneurs. This process demands an adjustment cost which permits a variable price of capital. The adjustment cost function is modeled as in Badarau and Levieuge (2011):

$$\Phi(I_t, K_t) = \frac{\phi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t, \tag{23}$$

with $\phi > 0$. I_t denotes aggregate investment expenditures, K_t the aggregate capital stock and δ the depreciation rate of capital. Then, the evolution of the capital stock is given by:

$$K_{t+1} = (1 - \delta)K_t + I_t. \tag{24}$$

Entrepreneurs produce wholesale goods by combining capital (K) bought from capital producers and labor supplied by households (H) and by entrepreneurs themselves (H^f, constant and normalized to one). The production technology is a Cobb-Douglas function with constant returns to scale:

$$Y_t = O_t K_t^\alpha [H_t^\Omega (H^f)^{1-\Omega}]^{1-\alpha}, \tag{25}$$

where $1 - \Omega$ represents the share of income going to entrepreneurial labor and O an exogenous technology parameter.

Entrepreneurs' optimization program consists in maximizing profits[16] under the capital accumulation constraint. Note that entrepreneurs internalize the adjustment costs of capital producers. First order conditions give the classic result of production factors being paid according to their marginal productivities, but also an equation for the expected return on capital:

$$E_t[R_{t+1}^K] = E_t\left[\frac{\rho_{t+1}\alpha\frac{Y_{t+1}}{K_{t+1}} - \frac{\phi}{2}\left[\delta^2 - (\frac{I_{t+1}}{K_{t+1}})^2\right] + (1-\delta)Q_{t+1}}{Q_t}\right]. \tag{26}$$

The expected return on capital is equal the expected marginal productivity of capital after deduction of adjustment costs and taking into account the residual value of capital[17].

The government gathers taxes (T) and engages in public expenditures (G). The evolution of these expenditures is given by:

$$g_t = \rho_g g_{t-1} + \varepsilon_g, \tag{27}$$

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[16] Revenues from the production process minus production costs like wages, capital adjustment costs and capital investment.

[17] Given that credit contracts last only one period, the entrepreneur is required to sell its capital at the end of this period in order to reimburse his debt to the bank.

where g is the log-deviation of public expenditures relative to the steady-state, ε_g is an exogenous shock to government spending and $\rho_g < 1$.

The central bank in charge with monetary policy uses a Taylor-type rule which takes the general form:

$$r_t^n = \beta_0 r_{t-1}^n + (1 - \beta_0)(\beta_\pi \pi_t + \beta_y y_t) + \varepsilon_r, \qquad (28)$$

where r^n represents the deviation of the nominal interest rate from steady state, y is the output gap (log-deviation of output from steady state), and ϵ_r is an exogenous monetary policy shock. We will see in the results section that this rule can be modified to include other variables besides inflation and output.

In addition to monetary and budgetary shocks, we can also have technological shocks, ε_o, that affect the technological factor in the production function:

$$o_t = \rho_o o_{t-1} + \varepsilon_o, \text{ with } \rho_o < 1 \text{ and } o_t = \log O_t. \qquad (29)$$

Finally, the equilibrium on the goods and service markets holds:

$$Y_t = C_t + C_t^f + C_t^b + I_t + G_t. \qquad (30)$$

The model allows us to analyze the response of the economy to the various shocks presented above. However, the scenario in which we are interested is the one where a financial shock occurs. We present hereafter the boom-bust process that permits the inclusion of the financial shock in the model.

2.3 The Boom and Bust Process

Not only the recent experience, but also crises before 2007, tend to reveal the fact that asset prices are prone to bubbles that have a potential damaging effect on the economy. We argue that such bubbles actually hide the build-up of risk in the economy and that this risk materializes once the bubble bursts. To introduce the bubble in our model, we build on the work of Bernanke and Gertler (1999) and Tetlow (2005). The bust that appears immediately after the bubble's collapse is intended to help obtain a complete economic cycle. Therefore, in the analysis part, this will allow us to see how the central bank could have intervened to reduce the fluctuations in economic variables. However, the mechanism introduced here is completely *exogenous*, so, the monetary authority can affect neither its amplitude, nor its duration[18]. Hence, results will be analyzed for all other variables, but not for the boom-bust process.

Booms and busts occur whenever the market price of capital, denoted Z, varies from its fundamental value, Q. The boom-bust is summarized by the difference between these two prices: $u_t = Z_t - Q_t$. Bubbles exist because a *positive shock* makes market prices superior to the fundamental value, $Z_t > Q_t$. If the bubble exists, it persists with probability p and grows at rate $\frac{a}{p}R^K$. The bubble crashes with probability $1 - p$. Investors only know the probabilities

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[18] It would be equally interesting to study the capacity of the monetary authority to prick the bubble. This can be achieved by considering an endogenous bubble. This is not the object of this paper, but can be developed in future research.

and growth rates attached to the bubble which permits them to compute the expected value of the process. The bubble is summarized by the following formula:

$$u_{t+1} = \begin{cases} \frac{aR^K}{p} u_t & \text{if the bubble persists, (p)} \\ 0 & \text{otherwise, (1-p)} \end{cases} \qquad (31)$$

with $p < a < 1$. In calibrating the model, we establish the number of boom periods to four and set $p = 0.6$. To be as close as possible to a rational bubble we fix $a = 0.98$. Knowing that, after a bubble, the economy does not recover immediately, we deliberately introduce a sequence of *negative shocks* to obtain the bust phase, when $Z_t < Q_t$. The collapse of the bubble generates panic between investors, so financial markets derive from fundamentals in the opposite direction relative to the boom phase. For symmetrie reasons, the bust lasts as long as the bubble. A final shock is introduced in period nine to end the bust process. Figure 1 shows the boom-bust process obtained for an initial shock equal to 1% of the steady-state fundamental price.
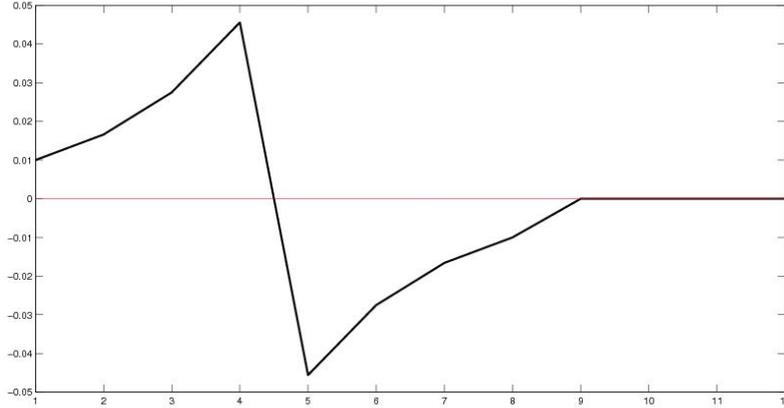
Figure 1: The boom and bust process

We also introduce in our model speculative behavior by imposing that investment decisions be taken based on speculative prices, which seems a reasonable assumption with respect to recent market events. The boom-bust process also influences the balance sheet of the entrepreneur as assets are evaluated at market value. Thus, when a bubble occurs, the financial position of the firm improves artificially, therefore, the premium for external finance is affected. The opposite effect is obtained during the bust. Note also that the bubble-bust process supposes a speculative return on capital, R^Z, that is related to R^K in the following manner:

$$R_{t+1}^Z = R_{t+1}^K [b + (1-b)\frac{Q_t}{Z_t}], \qquad (32)$$

with $b = a(1-\delta)$.

The next section presents the dynamics of the model when considering different monetary policy rules and policy objectives. However, in order to obtain these results, we first determined the steady-state, log-linearized the model around this steady-state and calibrated it. A list of

parameter values is provided in the Appendix.

3   Results and Policy Implications

We comparatively examine different scenarios for the monetary policy rule and loss function and analyze, for all these cases, the reaction of the model economy to financial shocks. The purpose of this analysis is twofold. First, we try to see what the improvements would have been if the central bank had monitored and reacted to a financial risk indicator, the credit-to-GDP ratio, before the crisis. This case is analyzed under the assumption that the loss function of the central bank integrates only output and inflation variability. We conduct our analysis by comparing the dynamics of the economy under a standard Taylor rule and an augmented one. Second, we ask ourselves whether a central bank, endowed with an additional financial stability objective, can succeed in complying with all its objectives. In order to achieve our goal, we analyze optimal simple rules and discuss the variances of economic variables obtained under different loss functions. In what follows, we develop and analyze progressively all these scenarios, but before all else, we study the reaction of our model to the financial shocks that hit the economy.

3.1   Reactions to Baseline Rules

The financial shock concerns capital prices and triggers the boom-bust process. As mentioned above, this process is completely exogenous, so the central bank cannot influence it. To illustrate the functioning of the model, we start with a standard Taylor rule that we label *Rule 1*:

$$r_t^n = \beta_0 r_{t-1}^n + (1 - \beta_0)(\beta_\pi \pi_t + \beta_y y_t). \text{ (Rule 1)}$$

The beta coefficients are chosen so as to match the optimum of a central bank that has as objectives inflation and output stabilization[19]. The impulse response functions are shown in Figure 2. Panel (*a*) gives the dynamics of the main aggregate macroeconomic variables, whereas in panel (*b*) we can see the reaction of the credit market to the boom-bust process.

For the first four periods that correspond to the bubble, we observe an accumulated increase in the output gap, mainly brought about by investments. Because investment decisions are made based on speculative asset prices, the bubble process triggers the increase in aggregate investment over this period. The difference in dynamics between output and investment is justified by the consumption behavior of agents. Actually, as real interest rates are superior to their steady state value, the substitution and wealth effects overweigh the income effect. Thus, the consumption level is below the steady state, but increasing during the boom period[20]. As expected, inflation raises as the economy overheats and the central bank's response to these economic developments is an increase in its nominal interest rate. However, even if the value of the interest rate is above steady state, this increase is not sufficient to limit speculative behavior

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[19] Optimization results are: $\beta_0 = 0.38$, $\beta_\pi = 2.70$ and $\beta_y = 1.41$.

[20] Results are not reported here, but consumption stays below the steady state during the boom phase and passes above this value during the bust.
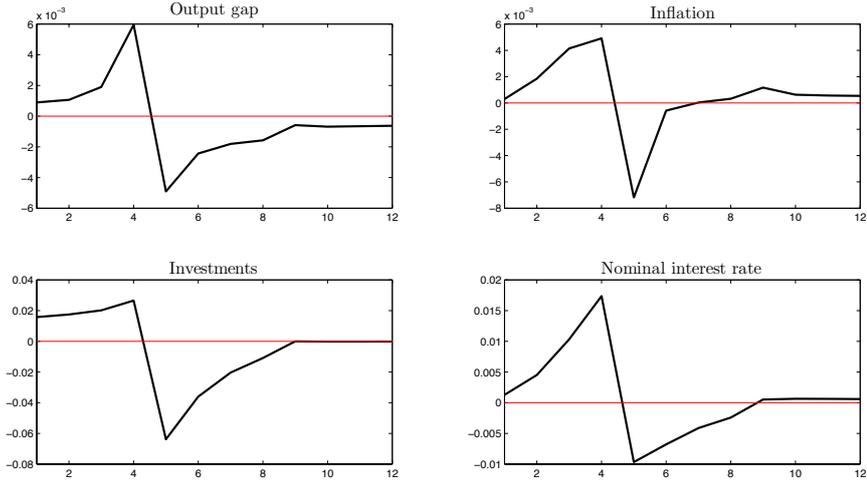
(a)
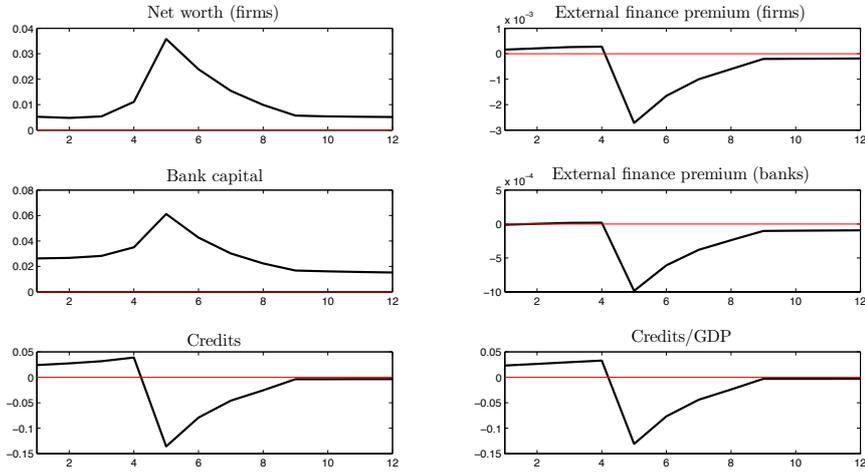
(b)

Figure 2: Dynamics under Rule 1 with optimum coefficients

and restrict risk-taking. Once the negative shock hits the economy, all these variables plunge. During all this period the monetary authority maintains a low interest rate, trying to fight the decline in inflation and output. The asymmetric behavior of the output gap is again determined by consumption. Investments are drastically reduced, as the market value of capital declines in the bust giving agents no incentive to invest despite the small external finance premium.

Turning to credit markets, we notice an overall increase in entrepreneur's net worth during the bubble phase. This is justified by the fact that net worth comes mostly form the accumulation of profits, so the more the entrepreneur advances through the boom phase, the more profits he will gain. Notice also that, because net worth is determined based on results of the previous period, the entrepreneurial net worth reaches its maximum in the fifth period when

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the negative financial shock occurs[21]. The reaction during the bubble phase is even more pronounced for the bank's net worth. This happens because banks profit from the bubble in two ways. First, their credit activity increases, lending more than before. Second, they benefit from a better recovery of loans, as entrepreneurs have a higher ability to repay their debt. Moving on to external finance premiums, we see that they initially have a rather constant dynamic. Recall that the external finance premium is a function of the financial position − assets over capital − of both the firm and bank. Thus, an improvement in net worth should diminish the cost of external finance. However, as investments are now made on market value, their increase basically offsets the positive effect of net worth. Although financial conditions for credits do not improve during the first four periods, there is an increase in credits and in credits over GDP, due to the speculative behavior that generates a more than normal demand for funds. In the fifth quarter the value of assets reduces drastically and at the same time net worths stay high. This determines the external finance premiums to plummet. During the bust phase, net worths start diminishing and premiums increase slowly from their "floor" values. Despite the low premium (below steady-state value) on external finance, the demand for credits during the bust remains below the steady-state. This is justified by the agent's lack of incentives to invest[22].

We next study the reaction of the economy to a more accommodative standard Taylor rule. Our approach is justified by the fact that during the recent bubble, central banks maintained interest rates at a lower level compared to what the Taylor rule would have predicted. In the case of the Fed, such evidence is provided by Taylor (2007). The purpose of this exercise is to see how keeping interest rates too low can encourage risk accumulation and increase cycle volatility. We use the same Rule 1, but change the coefficient for β_π to 1.5 (compared to 2.70 at optimum). We present in Figure 3 the comparison between the *optimal* Rule 1 (black solid line) and the *accommodative* Rule 1 (dashed red line).
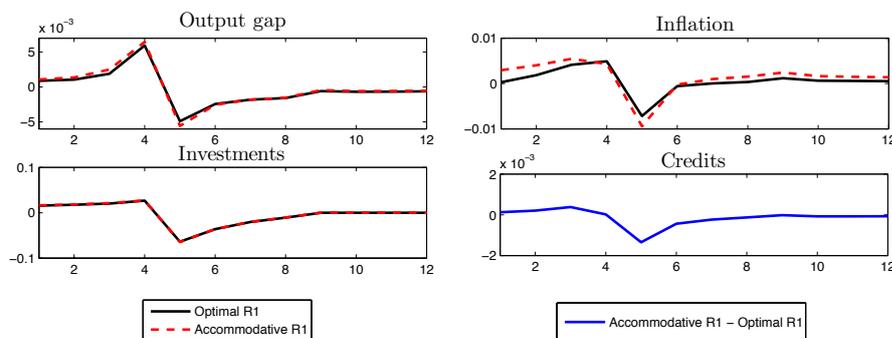
Figure 3: Optimal versus Accommodative Rule 1

The impulse response functions show us that a monetary authority which is less concerned with stabilizing inflation performs worse on all variables of interest. During the bubble, even if the increase in investments is only marginal, the expansion in output gap is more pronounced,

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[21] Net worth is a predetermined variable in the model.

[22] The model does not include a credit rationing mechanism, so the amount of credit is determined from the equilibrium of the credit market.

mostly due to consumption effects. Less stabilization is also observed during the bust phase. Moreover, inflation volatility is higher in the accommodative scenario. The last panel of Figure 3, shows the difference between the level of credits obtained under the accommodative and the optimal rule. During the bubble phase, this difference is positive proving a higher credit expansion when the central bank does not react as much to inflation. Similarly, during the bust phase, credits tend to decrease more under the accommodative rule.

In view of these results, we can safely conclude that a more accommodative monetary policy stance can only worsen the amplitude of cycles and thus encourage the build-up of risk. The following subsection aims at revealing the effects of introducing a financial indicator in the Taylor rule.

3.2 Augmented Taylor Rules

We now consider the case of a central bank still endowed with the traditional objectives of output and inflation stability, but which integrates in its monetary policy rule a reaction to credits-to-GDP[23]. The aim is to see how the central bank could intervene to improve the reaction of the economy in case of a financial bubble, by only acting on its main instrument, the interest rate. Two types of comparisons are performed, depending on whether the central bank uses the optimal coefficients or more accommodative ones. The augmented Taylor rule takes the following form:

$$r_t^n = \beta_0 r_{t-1}^n + (1 - \beta_0)(\beta_\pi \pi_t + \beta_y y_t + \beta_{by} by_t), \ \text{(Rule 2)}$$

with by_t the log-deviation of the credit-to-GDP ratio from its steady state. For the first comparison, we place ourselves in the accommodative case and compare the dynamics under Rule 1 and Rule 2. Recall that for β_0 and β_y we use optimal values, whereas β_π is fixed to 1.5. We take β_{by} equal to 0.1, which seems reasonable, given that the central bank does not have a financial stability objective and only monitors the evolution of credits in the economy. The results of the comparison are reported in Figure 4.
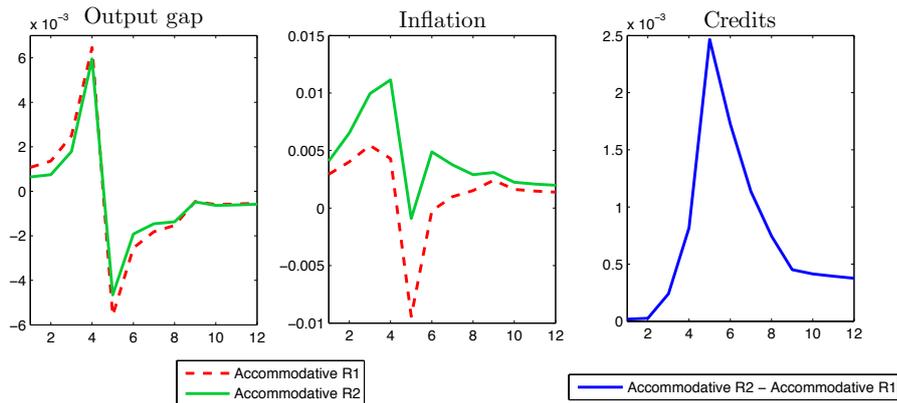
Figure 4: Rule 1 versus Rule 2 (accommodative case)

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[23] In the literature, we can find augmented Taylor rules in several papers. Only as an example, Bernanke and Gertler (1999) consider asset prices in the Taylor rule, Angeloni and Faia (2009) include bank leverage and asset prices, and more recently, Beau et al. (2011) add nominal credit growth to the standard Taylor rule.

The dashed red line corresponds, just as before, to the first rule, whereas the green solid line represents the dynamics under Rule 2. We report in Figure 4 only the three variables of interest for the monetary authority. When the central bank takes into account credits-to-GDP in setting the interest rate, a higher nominal rate will prevail in the economy. However, this rate will not achieve its objectives. The output gap is the only variable that is better stabilized, not only in the boom phase, but during the bust as well. Nevertheless, the stability of output does not come from good fundamentals. By rising its interest rate, the central bank fails to discourage speculative investors. Actually, higher interest rates attract only risky agents (Stiglitz and Weiss, 1981). Therefore, productive investments are reduced (but still increasing) compared with the case where the central bank reacts only to inflation and output deviations. Less investments translate in a lower supply. Moreover, consumption is also reduced compared to its level under Rule 1, due to the real interest rate. Lower consumption and investments affect aggregate demand. As a consequence, a relative reduction in output is obtained, but with the cost of a more volatile inflation, as the demand decreases less than the supply does, compared with Rule 1 levels. Rule 2 brings about a higher inflation relative to Rule 1. The last panel gives the difference between the levels of credits under the second and the first rule. As the difference is always positive, the stability of credits is better preserved under Rule 1 during the bubble, and under Rule 2 throughout the bust. Knowing that the increase in the credit-to-GDP ratio is due to a larger increase in credits as compared to the one in GDP, we can conclude that more risky credits are distributed to the economy in this scenario. Therefore, had the accommodative central bank chosen to lean against the wind before the crisis, we would have been confronted, once the bubble burst, to a potentially worse economic outcome, with more credits defaulting. All in all, Rule 2, in its accommodative forme, performs worse than Rule 1, leading us to the conclusion that leaning against the wind is not always a good idea. This depends on the aggressiveness of the monetary policy as we will see in the following.

Consider now the case where the central bank uses the optimal coefficients in the interest rate rule. Similarly to the first scenario, we compare Rule 1 and Rule 2 under the optimal parameters for β_0, β_π and β_y. For β_{by} we consider two values, a small reaction, 0.1, and a more important one, 0.5.

In Figure 5, the black solid line is used to represent the dynamics under the optimal Rule 1, whereas the orange dashed line stands for the augmented Taylor rule. In the optimal case, a small response to credits-to-GDP has a beneficial effect on output and credit stabilization throughout the boom-bust process. However, the same cannot be asserted for inflation. If in the first periods of the boom, inflation is lower under the augmented Taylor rule, as the bubble continues and grows in value, inflation becomes higher. The bust phase does not improve things with regard to inflation. For a central bank that is more concerned with financial imbalances ($\beta_{by} = 0.5$), relative to one that has no such concerns, the improvements obtained in limiting the output gap and the credit cycles are clear. However, inflation is undoubtedly more volatile. An obvious difference in the IRFs of inflation appears between the upper and lower panel of Figure 5. This can be explained by the interaction between demand and supply. Through the same mechanisms as above, a rise in the central bank's interest rate has as effect a greater
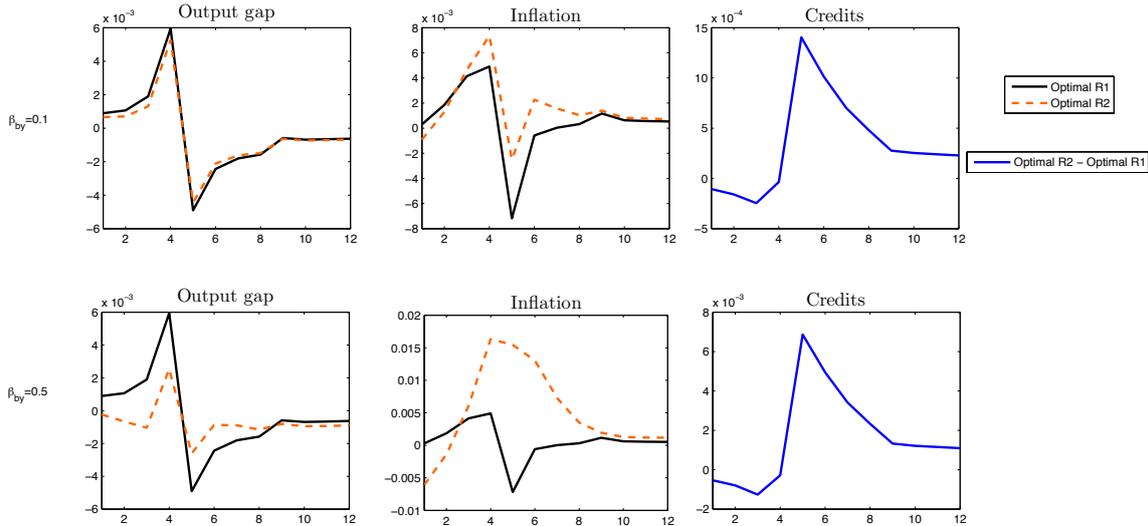
Figure 5: Rule 1 versus Rule 2 (optimal case)

reduction in aggregate supply than the one in demand, relative to the levels obtained under Rule 1. This triggers the higher inflation rate.

When the central bank decides to lean against the wind, these results conclude to the existence of a trade-off between inflation, on the one hand, and credit and output stabilization, on the other. Therefore, even when the central bank uses optimal coefficients when leaning against the wind, the flexibility of the monetary authority remains limited by the occurrence of this trade-off.

In view of the analyses performed thus far, we believe that using a financial risk indicator when setting the interest rate, does not necessarily mean a better outcome for the economy as a whole. Hence, an accommodative central bank would thus not have improved the economic situation, if it had reacted to the credit-to-GDP ratio before the crisis. Instead, it would have obtained lower economic growth (the GDP is always better stabilized) and this without achieving price or financial stability. Without a doubt, the interest rate that integrates a response to credit-to-GDP is not the most adequate instrument for limiting risk-taking (admitting that credit expansion is accompanied by risk-taking). Therefore, a central bank that still takes interest in a macroprudential objective needs to explore other options at hand to see how it can improve economic dynamics. Another possibility is to integrate the credit-to-GDP ratio in the central bank's loss function, thus openly declaring a financial stability objective. This represents the object of the next subsection.

3.3 Optimization of the Central Bank's Behavior

In this subsection, we analyze a central bank that has an explicit financial stability objective and optimize its behavior under the standard (Rule 1) and the augmented Taylor rule (Rule 2). The additional objective is adopted by including the variance of the credit-to-GDP ratio

into the loss function of the bank. In order to conduct our analysis, we compare results to a benchmark case where the monetary authority has only the traditional objectives of output and inflation stabilization. Several specifications of the loss function are considered. Coefficients obtained under these scenarios are given in Table 4.

Table 4. Optimal response coefficients

	$L_{CB0} = 1.5var(\pi) + var(y)$	$L_{CB1} = 1.5var(\pi) + var(y) + 0.10var(by)$	$L_{CB2} = 1.5var(\pi) + var(y) + 0.19var(by)$
Rule1	$\beta_0 = 0.38, \beta_\pi = 2.70, \beta_y = 1.41$	$\beta_0 = 0.38, \beta_\pi = 3.53, \beta_y = 1.77$	$\beta_0 = 0.38, \beta_\pi = 5.54, \beta_y = 2.63$
Rule2	$\beta_0 = 0.36, \beta_\pi = 2.70, \beta_y = 1.41, \beta_{by} = 0.05$	$\beta_0 = 0.29, \beta_\pi = 3.55, \beta_y = 1.77, \beta_{by} = 0.13$	$\beta_0 = 0.32, \beta_\pi = 5.54, \beta_y = 2.63, \beta_{by} = 0.19$

Note: The table presents the coefficients obtained from the optimization of the three loss functions (for each of the two interest rate rules).

Under both Rule 1 and Rule 2, a central bank that intends to stabilize credit cycles, besides its traditional objectives, has to be more aggressive to both inflation and output gap. When considering the augmented Taylor rule, we can also see a more aggressive reaction to credits-to-GDP compared to the benchmark case. As during the recent crisis the central bank was blamed for keeping rates too low for too long, this aggressiveness can be seen as a way of fighting against the risk-taking channel in the future, should the central bank take charge of the macroprudential objective. By using higher coefficients for its response function, the monetary authority reduces risk incentives, thus diminishes the danger of risk accumulation. The following figure reinforces these arguments.
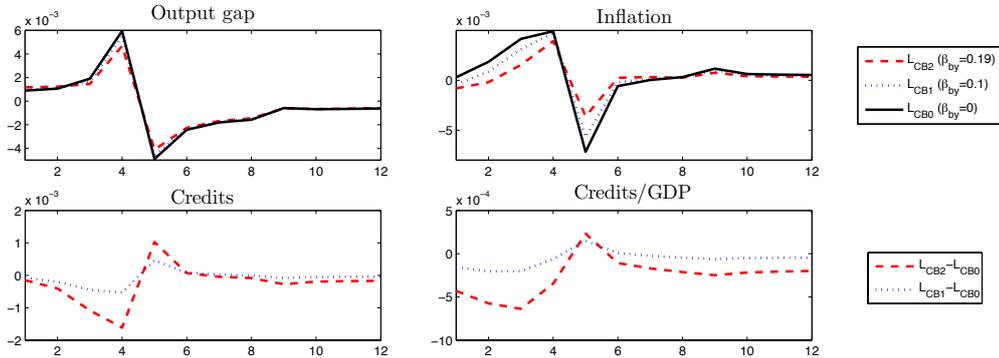
Figure 6: Dynamics under L_{CB0}, L_{CB1} and L_{CB2}

Figure 6 presents the evolution of reference variables when the central bank minimizes L_{CB0} compared to the results obtained when optimizing the second and third loss function, L_{CB1} and L_{CB2}, respectively. For all three functions, the standard Taylor rule was used. The higher the importance given to the financial stability objective, the higher the coefficients used by the monetary authority in the interest rate rule and the better the inflation and output stability will be. In addition, the credit cycle is attenuated both in the boom and bust side, proving the benefits of a more aggressive monetary policy. Simulations show that the higher the coefficient associated with the macroprudential objective, the better the credit cycle reacts. Importantly, this figure reveals no arbitrage between the price and financial stability objectives. By using a loss function like L_{CB1} or L_{CB2}, the central bank performs better in stabilizing both

inflation and credit cycles. Compared to the situation in which the macroprudential objective is addressed only with the interest rate rule, the use of the loss function for this purpose seems a better solution for the central bank.

In what follows, we engage in a comparison of variances in order to determine under which scenario the central bank performs best. In Table 5 we present the changes in variance for the case when a standard Taylor rule is used.

Table 5. Changes in variance under the standard Taylor rule

L_{CB0}	L_{CB1}	L_{CB2}
Reference	$\sigma^2_{\pi_1} = 83.19\%$	$\sigma^2_{\pi_2} = 40.62\%$
case	$\sigma^2_{y_1} = 70.82\%$	$\sigma^2_{y_2} = 58.12\%$
Normalized	$\sigma^2_{b_1} = 99.32\%$	$\sigma^2_{b_2} = 98.85\%$
to 100%	$\sigma^2_{by_1} = 99.76\%$	$\sigma^2_{by_2} = 99.64\%$

Note: Variances in the table are computed with respect to the reference case.

The specification of the loss function L_{CB_2} clearly yields the best results in terms of cycle reduction as compared to both other specifications. This means that, as long as the social loss function is defined on these nominal, real and/or financial variables, the variance would be minimal under L_{CB_2}, which will implicitly translate in a lower loss. However, the improvement in the stabilization of financial variables remains limited under L_{CB_1} and L_{CB_2} compared to the reference case. This improvement is more pronounced during the bubble phase and the first period of bust as it can also be seen in Figure 6. The central bank having a financial stability objective, but acting on the standard Taylor rule, has, however, a limited scope of action in terms of aggressiveness in response to output and inflation. The limitation comes from the fact that the monetary authority cannot indefinitely increase the coefficients in the reaction function as it becomes more concerned with the financial stability objective. Actually, a coefficient of 0.2 given to the financial stability objective in the loss function represents a threshold in our model, beyond which the optimization no longer leads to results consistent with the requirements prescribed by the monetary policy rule.

We turn now to the case where the augmented Taylor rule is used when minimizing the loss function of the central bank. For clarity reasons, the reference with respect to which variances are computed remains the case of a traditional central bank (standard Taylor rule and traditional objectives). Results for this case are presented in Table 6.

Table 6. Changes in variance under the augmented Taylor rule

L_{CB0}	L_{CB1}	L_{CB2}
$\sigma^2_{\pi} = 109\%$	$\sigma^2_{\pi_1} = 87.25\%$	$\sigma^2_{\pi_2} = 57.49\%$
$\sigma^2_{y} = 71\%$	$\sigma^2_{y_1} = 48.03\%$	$\sigma^2_{y_2} = 40.15\%$
$\sigma^2_{b} = 99.3\%$	$\sigma^2_{b_1} = 96.64\%$	$\sigma^2_{b_2} = 96.31\%$
$\sigma^2_{by} = 98.76\%$	$\sigma^2_{by_1} = 99.47\%$	$\sigma^2_{by_2} = 98.59\%$

Compared to the results of the previous table, introducing credit/GDP into the monetary policy rule, allows the central bank to reduce the cycles of financial variables, but at the same time, increases the variability in inflation. This situation illustrates well the idea of a trade-off between these two objectives. The output gap is far better stabilized when the augmented Taylor rule is used by the central bank. A higher interest rate, as a reaction to both output and credits-to-GDP, limits the expansion of credits in the economy, therefore investments and output are reduced. Moreover, the effect on output is also triggered by the adjustment in consumption which depends mainly on the dynamics of the real interest rate in the economy. As investment decisions are taken based on speculative prices, credits are less reactive than the output gap to the higher interest rate, which reflects both the lower performance on stabilizing credits-to-GDP compared to credits and the poorer stabilization of credits-to-GDP under L_{CB1} compared to L_{CB0}.

The analysis of the variances in Table 6 shows that including credits-to-GDP in the monetary policy rule allows for a better stabilization of real economic activity. Moreover, there is a gain in terms of financial variables' stabilization, but it remains very limited if the central bank uses (only) the interest rate as an instrument for financial stabilization. However, all this comes at the expense of inflation stabilization, which remains nevertheless the main objective of a central bank. The higher the response of the interest rate to financial variables, the greater the loss in terms of price stability. Therefore, the effects of the monetary policy can be potentially harmful to social welfare.

Indeed, as the central bank becomes more concerned with the financial stability objective by giving it a more significant weight (more than 0.2 in our model), the interest rate becomes implicitly more reactive to the credit-to-GDP ratio[24]. To illustrate this situation, Table 7 presents the optimization results obtained by using different coefficients (greater than 0.2) for the financial stability objective.

Table 7. Changes in variance when the financial stability objective plays a more important role

$L_{CB1} = 1.5var(\pi) + var(y) + 0.5var(by)$	$L_{CB2} = 1.5var(\pi) + var(y) + var(by)$
$\beta_0 = 0.45, \beta_\pi = 5.54, \beta_y = 2.63, \beta_{by} = 0.39$	$\beta_0 = 0.7, \beta_\pi = 5.55, \beta_y = 2.62, \beta_{by} = 0.87$
$\sigma^2_{\pi_1} = 148.78\%$	$\sigma^2_{\pi_2} = 459.18\%$
$\sigma^2_{y_1} = 35.29\%$	$\sigma^2_{y_2} = 41.24\%$
$\sigma^2_{b_1} = 94.99\%$	$\sigma^2_{b_2} = 93.02\%$
$\sigma^2_{by_1} = 97.54\%$	$\sigma^2_{by_2} = 95.46\%$

Note: Variances in the table are computed with respect to the reference case.

The analysis of the variance for the different variables in Table 7 shows that when the central bank puts more weight on financial stability, inflation volatility becomes much higher. This is justified by the fact that the increase in the nominal rate affects output, creating a deficit of supply over the demand for goods and services, with the effect of rising prices (see also the

[24] This is in line with the results obtained by Agenor et al. (2011): "The greater the degree of interest rate smoothing, and the stronger the policy-maker's concern with macroeconomic stability, the larger is the sensitivity of the regulatory rule to credit growth gaps."

discussion in the previous subsection).

Bearing in mind the results of this analysis, we conclude that, in order to avoid the trade-off between inflation and financial stability, the central bank should maintain price stability by using the nominal interest rate and find other instruments for properly addressing the financial stability objective.

4   Conclusions

The recent crisis revealed flaws in both monetary and financial regulation. We have learned at great expense that price stability is a necessary, but not sufficient condition to financial stability, the same as microprudential regulation is not enough to ensure the financial stability objective. The need of a macroprudential regulation is no longer a question to policymakers. Rather, the questions that arise now are who should take on this objective and how should it be defined and quantified. In this paper, given the fact that we engage in an ex-post analysis, we consider that the only eligible authority that could have reacted to financial risk before the crisis was the central bank. With this in mind, we restrict the definition of financial stability objective to maintaining a stable credit cycle. Adding a financial stability objective without giving the central bank a new instrument leaves little choice in terms of actions. We study in the paper two possibilities. First, the monetary authority uses the interest rate rule to mitigate credit development and thus, risk-taking. The second and last option for the central bank is to integrate the credit-to-GDP indicator into its loss function.

Before the crisis, monetary policy was undoubtedly accommodating. A first result of our paper shows that the reaction of the central bank to the chosen financial indicator, would have only reduced economic growth, without being able to limit the expansion of speculative credit. Moreover, leaning against the wind, even when the central bank behaves in an optimal way, does not necessarily lead to better performances. The flexibility of the central bank is limited in this case by the trade-off between stabilizing inflation and credit cycles, questioning the possibility of using an augmented Taylor rule for the purpose of maintaining financial stability. This conclusion is reinforced by the analysis of the case when the central bank explicitly declares a financial stability objective. The optimal behavior is obtained by using higher coefficients on both inflation and output in the standard Taylor rule. However, this behavior leads only to a small improvement in credit cycles. Higher coefficients should also be used when the central bank applies the augmented Taylor rule. The problem in this case is nonetheless, the occurrence of the trade-off. Although the "aggressiveness" of the monetary policy stance has the virtue of limiting the effects of the risk taking channel, its benefits remain limited, first because coefficients cannot be raised indefinitely, and second, because the financial stability objective has to have a rather small weight in the loss function in order to avoid trade-offs.

We believe that an additional objective for the monetary authority, like the one of financial stability, should not be responded to with the same instrument, the nominal interest rate. This joins Tinbergen's rule result which states that in order for economic policy to be effective, the number of instruments used must be equal to the number of objectives pursued.

The conclusions of this paper open the way to future research. More precisely, as the interest rate is not an adequate instrument for the central bank to deal with financial stability, other instruments should be proposed and their effectiveness should be studied. Using again the propositions of the Basel III agreement ($BIS, 2011$), we believe that capital requirements or more precisely, the counter-cyclical buffer, can be used as a second instrument for the central bank. This would help introduce a credit rationing mechanism in the model, as well as limit risk incentives. Moreover, the definition of financial stability should be enlarged to allow for a more realistic analysis.

References

Agénor, P.-R., Alper, K., Pereira da Silva, L. (2011) Capital Regulation, Monetary Policy and Financial Stability. *Working Papers Series 237, Central Bank of Brazil, Research Department.*

Angelini, P., Neri, S., Panetta F. (2011) Monetary and macroprudential policies. *Banca d'Italia Discussion Paper, No. 801.*

Angeloni, I., Faia, E. (2009) A Tale of Two Policies: Prudential Regulation and Monetary Policy with Fragile Banks. *Kiel Working Paper, 1569*, The Kiel Institute for the World Economy, Kiel.

Angeloni, I., Faia, E., Lo Duca, M. (2011) Monetary Policy and Risk Taking. *Working Papers 380, Bruegel.*

Altunbas Y., Gambacorta, L., Marques-Ibanez, D. (2009a) Bank Risk and Monetary Policy. *Bank of Italy Temi di Discussione (Working Paper) No. 712.*

Altunbas Y., Gambacorta, L., Marques-Ibanez, D. (2009b) An Empirical Assessment of the Risk-Taking Channel. *BIS, mimeo.*

Badarau, C., Levieuge, G. (2011) Assessing the Effects of Financial Heterogeneity in a Monetary Union : A DSGE Approach. *Economic Modelling*, Vol. 28, Issue 6, pp. 2451-2461.

Bank of International Settlement (2011) Basel III: A global regulatory framework for more resilient banks and banking systems - revised version June 2011. *Basel Commitee on Banking Supervision.*

Beau, D., Clerc, L., Mojon, B. (2011) Macro-prudential policy and the conduct of monetary policy. *Banque de France Occasional Papers, No. 8.*

Bernanke, B. (2011) Implementing a Macroprudential Approach to Supervision and Regulation. Speech given at the 47th Annual Conference on Bank Structure and Competition, Chicago, Illinois, May.

Bernanke, B., Gertler, M., (1999) Monetary Policy and Asset Price Volatility: New Challenges for Monetary Policy. *Federal Reserve Bank of Kansas City*, pp. 77-128.

Bernanke, B., Gertler, M., Gilchrist, S. (1999) The Financial Accelerator in a Quantitative Business Cycle Framework in J. Taylor and M. Woodford, eds. *Handbook of macroeconomics.* Amsterdam: North- Holland, 2000, pp. 1341-93.

Betbèze,J.-P., Bordes, C., Couppey-Soubeyran, J., Plihon, D. (2011) Banques Centrales et stabilité financičre. *Conseil d'Analyse Économique.*

Borio, C. (2003) Towards a Macroprudential Framework for Financial Supervision and Regulation? *BIS Working Paper No. 128*, Bank for International Settlements, Basel, February.

Borio, C. and P. Lowe (2002) Asset Prices, Financial and Monetary Stability. *BIS Working Paper No. 114*, Bank for International Settlements, Basel, July.

Borio, C., Zhu, H. (2008) Capital regulation, risk-taking and monetary policy: a missing link in the transmission mechanism?. *BIS Working Papers No. 268.*

Calvo G. A. (1983) Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics* 12, 383-398.

Carlstrom, C., Fuerst, T. (1997) Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis. *American Economic Review*, American Economic Association, vol. 87(5), pages 893-910, December.

De Grauwe, P., Gros, D. (2009) A New Two-Pillar Strategy for the ECB. *CEPS Policy Briefs No. 191*, June 2009.

ECB (2008) Financial Stability and Oversight. *Monthly Bulletin*, 10th Anniversary of the ECB, European Central Bank, Frankfurt am Main, pp. 117-132.

Ferguson, R.W. (2002) Should Financial Stability Be an Explicit Central Bank Objective? Speech presented at the IMF Conference on Challenges to Central Banking from Globalized Financial Systems, International Monetary Fund, Washington, D.C., 16-17 September.

Hanson, S., Kashyap, A., Stein, J. (2011) A macroprudential Approach to Financial Regulation. *Journal of Economic Perspectives, 25 (1)*, 3-28.

Ioannidou, V. P., Ongena, S., Peydró, J.-L. (2009) Monetary Policy, Risk-Taking and Pricing: Evidence from a Quasi Natural Experiment. *Discussion Paper 2009-31 S*, Tilburg University, Center for Economic Research.

Jiménez, G., Ongena S., Peydró J.-L., Saurina, J. (2009) Hazardous Times for Monetary Policy: What do Twenty-Three Million Bank Loans Say About the Effects of Monetary Policy on Credit Risk? *Banco de Espana Working Paper No. 0833.*

Kindleberger, C. (2000) Manias, Panics, and Crashes. 5th edition, New York: Wiley.

Lambertini. L, Mendicino, C., Punzi, M.T. (2011) Leaning against boom-bust cycles in credits and housing prices. *Working Paper CELEG, 1104.*

Maddaloni, A., Peydró, J. L. (2009) Bank risk-taking, Securitization and Monetary Policy; Evidence from the bank Lending Survey. *ECB, mimeo.*

Stiglitz, J., Weiss, A. (1981) Credit Rationing in Markets with Imperfect Information. *American Economic Review 71*, 393-410.

Taylor, J. (2007) Housing and Monetary Policy. Jackson Hole Symposium on Housing, Housing Finance, and Monetary Policy, Federal Reserve Bank of Kansas City.

Tetlow, R., (2005) Monetary Policy, Asset Prices and Misspecification: the robust approach to model uncertainty and bubbles. *Issues in Inflation Targeting*, Bank of Canada.

Townsend, R.M. (1979) Optimal contracts and competitive markets with costly state verification. *Journal of Economic Theory 22*, 265-293.

Appendix: Baseline calibration of the DSGE model

Description	Parameter	Value
Intertemporal elasticity of substitution	σ_c	0.75
Elasticity of labor disutility	σ_h	0.32
Subjective discount factor	β	0.99
Part of retailers with unchanged prices on the period	$1 - \theta$	0.66
Capital contribution to GDP	α	0.35
Part of entrepreneurial labor in total labor	$1 - \Omega$	0.01
Part of households labor in total labor	Ω	0.99
Depreciation rate for capital	δ	0.05
Internal capital adjustment costs parameter	ϕ	20
Part of inside capital transfers to survival banks	t^b	0.001
Banks external finance premium elasticity	Ψ_s^b	0.005
Firms external finance premium elasticity	Ψ_s^f	0.025
Steady State: Exogenous fixed values		
Real marginal cost	$\overline{\rho}$	1/1.1
Banks inside capital/ loans ratio	N^b/B	0.2
Firms net wealth/ capital ratio	N^f/K	0.4
Public expenditures/GDP ratio	G/Y	0.16
Firms probability of default	$F(\overline{\omega}^f)$	0.03
Banks probability of default	$F(\overline{\omega}^b)$	0.007
Average external finance premium for firms (in annual basis)	$r^K - r^f$	0.02
Steady State: Calculated values		
Auditing cost for banks	μ^b	0.077
Auditing cost for households	μ^a	0.545
Variance for the ω distribution	σ	0.2531
ω threshold value for banks	$\overline{\omega}^b$	0.52
ω threshold value for firms	$\overline{\omega}^f$	0.6016
Banks probability to leave the market	$1 - \gamma^b$	0.01
Firms probability to leave the market	$1 - \gamma^f$	0.017
Investment/ GDP ratio	I/Y	0.2444
Banks consumption expenses/GDP	C^b/Y	0.006
Firms consumption expenses/GDP	C^f/Y	0.035
Total consumption expenses/GDP	$(C + C^b + C^f)/Y$	0.6