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Policy mandates for macro-prudential and monetary policies in a new Keynesian framework

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Abstract

In the aftermath of the financial crisis, the role of monetary policy and macro-prudential regulation in promoting financial stability is under discussion. The old debate concerning whether monetary policy should respond to credit and asset price bubbles was revived, whereas macro-prudential regulation is being assessed as an alternative macroeconomic tool to deal with financial imbalances. The paper explores both sides of the debate in a New Keynesian framework with financial frictions by comparing the welfare and stabilisation impacts of distinct policy regimes. First, we investigate whether there is a welfare benefit from monetary policy leaning against financial instability. We show that monetary policy rules of this type perform better than conventional monetary rules. Second, by introducing macro-prudential regulation in the model, results from optimal policy analysis suggest also that there are welfare gains, even in the case in which monetary and macro-prudential authorities are independent and react to their own policy goal.

JEL classification: E30, E50, G28.

Keywords: monetary policy, macro-prudential policy, DSGE, financial frictions.

Non-technical summary

This paper aims at investigating the role of monetary policy in promoting financial stability and its interaction with macro-prudential regulation. Before the financial crisis, there was a broad consensus in the literature stating that monetary policymakers should target price stability without taking pre-emptive measures to avoid the development of asset prices bubbles. However, some argue that monetary policy should also react to financial variables, such as credit and indebtedness, and help countervailing the development of financial imbalances. On the other hand, policymakers and researchers in general advocate the need for a macro-prudential oversight of the financial system, to monitor and mitigate the building up of systemic risks across financial institutions and throughout time.

We address both sides of the debate by developing a model with price stickiness, financial imperfections and a macro-prudential oversight of the banking system. Our focus is on standard monetary policy measures and we suggest as a macro-prudential tool a non-neutral tax / subsidy scheme. Optimal policy exercises are conducted to assess the gains (or losses) in terms of social welfare of these alternative policy regimes.

First, we evaluate whether monetary policy should respond to financial variables, such as credit, credit spreads or asset prices, under the assumption of the existence of disruptions in the banking system. Second, we introduce a macro-prudential instrument to examine the impact of having a macro-prudential regulator reacting countercyclically to financial imbalances. This exercise is performed under two policy mandates[1]. We assume that each policy targets its own policy goal, meaning that monetary policy pursues price stability and macro-prudential policy focus on financial stability. Then, we extend the analysis by assuming that monetary policy also reacts to financial imbalances, in order to replicate an unified institutional mandate, in which both monetary and macro-prudential policies target financial stability objectives.

It is worth highlighting that in this paper we do not compare coordination in the form of joint maximization with non-cooperative Nash equilibrium for non-coordination, since, for both regimes, the same welfare criteria is being used. Nonetheless, with given forms of simple rules, a Nash equilibrium would be a 'team-optimal solution' and offer an identical solution as with coordination.

We show that, in a model featuring financial frictions, a leaning against the financial imbalances monetary policy rule would perform better in terms of maximizing welfare than a standard, conventional monetary policy rule. However, rules responding to credit spreads and

[1] The expressions "policy mandate" and "policy regime" are used indistinctly throughout the paper. They refer to the institutional arrangements of monetary policy and macro-prudential regulation, and should not be mistaken with the arguments of central bank loss function.

asset prices would be related to higher inflation volatility, as claimed in the literature. As a matter of compromise between welfare maximization and macroeconomic stability, our results suggest that a monetary policy rule that could accomplish this balance would be one feeding back on credit only, given that it provides a smaller welfare loss compared to a standard Taylor rule, at the same time it delivers lower inflation, output and interest rate volatility.

In the case of scenarios encompassing a macro-prudential policy approach, our findings from optimization exercises are interesting from a policy perspective. First, they confirm the countercyclical nature of macro-prudential tools. More important, we show the deployment of macro-prudential regulation together with standard monetary policy improves welfare, regardless of the target selected in the analysis and, to some extent, of the type of policy mandate under assessment (separate or unified). The welfare maximization is achieved, though, under a partially unified mandate featuring a macro-prudential rule that reacts simultaneously to credit and credit spreads. The welfare gains from introducing macro-prudential regulation are, in the best case scenario, around 0.07% in consumption equivalence terms. This improvement is, in fact, small, but aligned with previous findings in the literature (see, for instance, De Paoli and Paustian [2012], Angelini et al. [2011]). Inflation stabilization, on the other hand, is better accomplished in a separate mandate, in which we have a standard Taylor rule feeding back on inflation and output gaps, and a macro-prudential rule responding to credit and spreads.

Therefore, our findings, despite showing macro-prudential regulation improves welfare in every policy mandate considered in the analysis, do not provide a definite answer in terms of the institutional mandates monetary and macro-prudential policies. A separate policy regime seems to perform also well in what welfare improvement is concerned. This finding is not fully aligned with the consensus among policy makers and academics towards the joining of macro-prudential regulation and monetary policy under a same authority.

1 Introduction

Prior the financial crisis of 2007 there was a convergent mindset on policy goals, the instruments necessary to achieve them, and their implications for stabilising the economy. Back then, there was a common view that central banks should focus on price stability goals and clean up after the bubbles burst.[2] As a consequence of the financial crisis and its disruptive effects on economic welfare, the debate regarding the role of monetary policy and traditional regulatory and prudential frameworks on promoting macroeconomic stability was revived. It is argued that the great recession was a consequence of an excessively lax monetary policy stance that contributed to the increasing of housing price inflation (Taylor [2007, 2010], Hofmann and Bogdanova [2012]). On the other hand, a large literature emphasizes the failure of financial and banking regulation as a financial stabilisation tool (Blanchard et al. [2010], Fund [2011]).

Although it is clear that the achievement of financial stability[3] is crucial for the pursuit of macroeconomic stability, there is no consensus on what economic policy should target the stability of the financial system. Mishkin [2011] suggests that monetary policy should lean against credit-driven bubbles only (rather than responding to irrational exuberance bubbles), pointing out that in the case of credit bubbles the argument about the difficulty in detecting asset price bubbles is no longer valid. On the other hand, Vinals [2012] considers that monetary policy rules should also lean by reacting to financial variables, such as credit and indebtedness, but only in the pursuit of price stability. In addition, Curdia and Woodford [2010] suggest a Taylor Rule that also reacts contemporaneously to credit spreads, showing that a modified Taylor Rule of this kind can not only decrease the distortions originated by a financial shock, but also improve the economy reaction to different types of shocks.

In turn, it is argued that macro-prudential regulation should deal with financial market distortions, while monetary policy should concentrate solely on stabilising inflation in order to counter-act the fluctuations of output caused by price rigidities. Notwithstanding, this type of institutional framework raises some concerns. A main topic in the design of an effective institutional mandate for macro-prudential policy is how it should interact with monetary policy. Even though we agree that price and financial stability are intermediate objectives to attain the ultimate goal of macroeconomic stability, there are side effects from monetary policy on macro-

[2]See Mishkin [2011] for a summary of the general doctrine stating that monetary policy should only focus on inflation and output stability.

[3]There is still a lack of a common definition of financial stability. As summarized by Galati and Moessner [2012], financial stability can be defined in terms of the degree of robustness of the financial system to external shocks or, in turn, it can be interpreted as the resilience of the financial system to shocks originated from within the system that can be associated to bank fragility. For the Bank of England, 2009, the source of shocks is not so relevant, since financial stability should be "*fundamentally concerned with maintaining a stable provision of financial services to the wider economy - payments services, credit supply, and insurance against risk*".

prudential targets (such as credit or leverage) and from macro-prudential policies on monetary targets (such as output and inflation). For instance, as pointed out by Beau et al. [2011], it is likely that the implementation of a macro-prudential policy can alter the transmission mechanism of monetary policy, since it acts through the same bank lending and balance sheet channels of monetary policy.

Under different economic circumstances, the outcomes on financial and price stability of both policies can be complementary, independent or conflicting (Beau et al. [2011]). In particular, the conflict of interest outcome will depend on the type and dissemination of supply and demand imbalances across the financial system and the real economy and on whether financial imbalances play a role in the monetary policy framework (Beau et al. [2011], Galati and Moessner [2012]). Moreover, some authors advocate the existence of a risk taking channel, through which a loose monetary policy can contribute and even promote the creation of asset bubbles, requiring a more aggressive intervention from the macro-prudential regulator to mitigate its effects in the banks' balance-sheets and in the financial systems (Borio and Zhu [2008]). In turn, considering a situation characterized by an asset bubble and by downside risks to price stability, macro-prudential policy would limit credit and liquidity growth. This action could have adverse effects in aggregate activity increasing the disinflationary pressures and forcing the monetary policymaker to intervene by lessening even further the monetary policy stance. Under these economic conditions, the necessary measures to control financial stability may have a negative impact on price stability, resulting in a conflicting outcome (Beau et al. [2011]).

Therefore, a main question in this debate is how macro-prudential policy tools should be set together with monetary policy, since both ultimately target macroeconomic stability. Following the Tinbergen principle, there should be at least one instrument associated to each policy goal. Assuming price and financial stability as two distinct objectives, then monetary policy should target the first one and macro-prudential policy should concentrate on counterveiling financial imbalances. If we agree with this straight assignment of policy objectives, a consequent issue refers to the allocation of the policy instruments, namely whether the central bank, as the monetary policy maker, should set the two policy instruments to achieve both price and financial stability, or macro-prudential tools should be allocated to an independent authority.

The economic literature investigating these issues is still in its infancy, though there are a number of papers offering preliminary insights and suggesting different ways of combining monetary policy and macro-prudential regulation. Despite the distinctive features of the models used to assess these questions, all in all the findings suggest that there are sources of conflict, mainly when these policies are not coordinated and shocks affect the demand side of the economy (De Paoli and Paustian [2012], Bean et al. [2010], Beau et al. [2011], Angelini et al. [2011], Angeloni [2010]).

This paper contributes to both sides of the debate and has two main purposes. Departing from a New Keynesian model with financial frictions, the first aim is to investigate whether there is a welfare benefit from monetary policy that leans against the wind by performing welfare analysis. In this part of the study, macro-prudential policies are absent. Specifically, our model-based analysis enables us to examine the potential trade-offs of using simple monetary policy rules that feed back on financial variables, such as deviations of credit, credit spreads or asset prices from its steady state values, by comparing it with a standard Taylor rule. Two policy mandates are suggested to conduct this analysis. A policy mandate featuring a conventional monetary policy stance encompassing a standard Taylor rule with interest rate smoothing and responding to inflation and output gaps and a policy mandate in which the standard Taylor rule is augmented to feed back on financial variables. The former policy mandate is used throughout the paper as a baseline case.

The main findings of this analysis suggest it is welfare improving to have a monetary policy stance that responds countercyclically to asset prices. Nonetheless, there is a trade-off in terms of inflation stabilization, since an augmented Taylor rule of this type would involve more prices volatility than a standard one. A compromise between welfare maximization and inflation stability seems to be achieved under a policy regime characterised by an augmented Taylor rule that feeds back on deviations of credit from its steady-state path.

The second main goal is to analyse the impact on welfare of introducing in the model macro-prudential policies reacting counter-cyclically to financial imbalances. Again, the financial imbalances are captured by financial variables like deviations of credit, credit growth, credit spreads and loans-to-output ratio from their steady state values. By extending the framework to include macro-prudential tools alongside with a monetary policy instrument (i.e. the policy interest rate), it is possible to assess how the institutional arrangements of monetary policy and macro-prudential regulation could be designed in the most effective way. In fact, it is not consensual in the academic literature whether the monetary authority should also concentrate responsibilities in banking regulation and supervision. Arguments favouring an independent banking regulator, namely potential sources of conflict between the two policies and reputation damage for the central bank in the event of financial distress or bank failures, oppose to arguments benefiting an unified mandate, which privileges the central bank's role as lender-of-last-resort and coordination synergies.

Against this background, we suggest two more policy mandates which we can compare and evaluate in terms of their social welfare implications. The criterion used to assess the most effective institutional mandate is obtained from the welfare analysis, in which policy rules are optimised to deliver the best level of lifetime utility. We start by examining a separate policy mandate, in which each policymaker targets their own policy goal: the monetary policymaker (i.e the central bank) pursues price stability and the macro-prudential regulator focus on financial stability[4]. This institutional mandate is compared with an unified regime, where both monetary and macro-prudential policies react to financial imbalances. This comparison is made across all policy mandates considered in the analysis, to rank the ones that minimize welfare losses.

The way banking regulation is introduced in the macroeconomic model, it is feasible to assess the impact on welfare of a macro-prudential toolkit comprising a tax on loans and a subsidy on bank net worth. This is a innovative feature of the framework, since previous studies considering banking regulation instruments usually focus on a single tool. We show that a tax on loans proves to be more welfare improving than the subsidy on net worth. For this reason, we opt for describing in detail the optimal policy exercises when a tax on loans is considered, although we also comment briefly on the results attained when the macro-prudential instrument is a subsidy on net worth.

Findings from these optimal policy exercises suggest that there are welfare gains from introducing macro-prudential regulation, even when considering a separate regime given by two independent agencies reacting to their own policy goal. In particular, gains are slightly higher under an unified regime, in which both policies feed back on credit and spreads. However, these gains are small as also shown by Angelini et al. [2011], De Paoli and Paustian [2012] and Bailliu et al. [2012].

The model developed in this study extends the Gertler et al. [2012] framework in several directions. The most important innovation comes from the introduction of nominal frictions, in order to investigate the interaction of macro-prudential regulation and monetary policy. Hence, our focus is on conventional monetary policy rather than credit policy. In addition, we simplify the banking sector component of the model, ruling out the role of outside equity. In this case, banks' net worth increases are given solely by retained profits. The macro-prudential tool is also distinct, since we suggest a non-neutral tax / subsidy scheme.

The remaining of the paper is organized as follows. Section 2 describes the model, by first considering an unregulated banking sector and then comparing this baseline model with one extended to introduce macro-prudential regulation. Calibration of fundamental parameters is also described in this part of the paper. Section 3 explains and performs welfare analysis. This section shows and interprets the optimal policy results for the policy mandates described above (standard monetary policy stance, a monetary policy rule that leans against the build up

[4]The separate mandate aims at mimicking the institutional arrangements of monetary and macro-prudential policies in Germany, Finland and Norway, while the unified mandate represents the institutional regimes in New Zealand, United Kingdom, Belgium and in the Euro Area.

of financial imbalances, and for alternative policy regimes that encompass a macro-prudential policy rule). Section 4 concludes.

2 The Model

In this section, we introduce a model with financial frictions and macro-prudential regulation. The model follows closely Gertler et al., 2012, but it is extended to include New Keynesian features, in order to address the interplay between conventional monetary policy and macro-prudential regulation. Financial frictions impact on real economy through the amount of funds that are available to the banks, affecting the liabilities side of their balance sheet. The economy is populated by four types of economic agents: households, final goods producers, capital goods producers, retail producers and banks.

2.1 Households

In this model, there is a continuum of households of measure unity. Each household consumes, saves and provides labour. The individuals belonging to each household can be either workers or bankers, by a fraction of f and $1-f$, respectively. The fraction f of workers provide labour and the wages they earn come back to the household. On the other hand, the fraction $1-f$ of bankers manage one of the banks that is owned by the households and return to the household they belong the any dividends they make over the period they manage the bank. It is also assumed that members can interchange roles. Bankers may become workers every period with probability $1-\sigma_B$, which is independent of how long the individual has performed that role. Thus, the probability that a member of the household stays as a banker is given by σ_B. The banker only returns the accumulated earnings to his / her family when he / she exits from the bank. The assumption of a finite horizon for bankers is needed in order to avoid the accumulation of net worth beyond a certain threshold, that would made them independent of external funding. Conversely, every period a similar number of workers randomly becomes bankers.

Households utility is given by

$$\Lambda_t = \Lambda(C_t, L_t) = \frac{((C_t - \chi C_{t-1})^{(1-\varrho)} L_t^{\varrho})^{1-\sigma_c} - 1}{1-\sigma_c} \tag{1}$$

where C_t is real consumption and L_t is leisure. Single period utility Λ_t is an increasing non-separable Cobb-Douglas function of consumption relative to external habit, χC_{t-1}, and leisure L_t and has a functional form consistent with a balanced growth path. The parameters σ_c and

ϱ refers to the elasticity of consumption and the households preferences, respectively.

Let D_t be the amount of deposits made by households on banks[5] at time t, that pay R_t^{ex} ex post gross real interest rate adjusted for gross inflation, T_t lump sum taxes, Υ_t the net transfers from financial and non-financial firms owned by households and W_t the nominal wage.

Therefore, the household budget constraint is given by

$$C_t + D_{t+1} = W_t L_t + \Upsilon_t + R_t^{ex} D_t + T_t \tag{2}$$

In a cashless version of the model, household behaviour is then described by

$$\begin{aligned}
\Lambda_t &= \Lambda(C_t, L_t) = \frac{((C_t - \chi C_{t-1})^{(1-\varrho)} L_t^{\varrho})^{1-\sigma_c} - 1}{1-\sigma_c} \\
\Lambda_{C,t} &= (1-\varrho)(C_t - \chi C_{t-1})^{(1-\varrho)(1-\sigma_c)-1}(1-h_t)^{\varrho(1-\sigma_c)}) \\
\Lambda_{L,t} &= \varrho(C_t - \chi C_{t-1})^{(1-\varrho)(1-\sigma_c)} L_t^{\varrho(1-\sigma_c)-1} && (3) \\
R_t^{ex} &= \frac{R_{n,t-1}}{\Pi_t} && (4) \\
\Lambda_{C,t} &= \beta E_t\left[R_{t+1}^{ex}\Lambda_{C,t+1}\right] && (5) \\
\frac{\Lambda_{L,t}}{\Lambda_{C,t}} &= \frac{W_t}{P_t} && (6) \\
L_t &\equiv 1 - h_t && (7)
\end{aligned}$$

where $R_{n,t}$, our monetary policy instrument, is the gross nominal interest rate set in period t to pay out interest in period $t+1$, $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ where P_t is the retail price level, h_t is hours worked and $\frac{W_t}{P_t}$ is the real wage. R_t^{ex} in the Fischer and Euler equations, (4) and (5) respectively, is the ex ante real interest rate.

The Euler consumption equation (5), where $\Lambda_{C,t} \equiv \frac{\partial \Lambda_t}{\partial C_t}$ is the marginal utility of consumption and $E_t[\cdot]$ denotes rational expectations based on agents observing all current macroeconomic variables (i.e., 'complete information'), describes the optimal consumption-savings decisions of the household. It equates the marginal utility from consuming one unit of income in period t with the discounted marginal utility from consuming the gross income acquired, by saving the income. Equation (6) equates the real wage with the marginal rate of substitution between consumption and leisure.

[5]Both deposits and government debt are one period real bonds that pay the same gross real return from t to $t-1$.

2.2 Goods Producers

Goods producers behaviour is given by

$$
\begin{aligned}
Y_t^W &= F(A_t, h_t, K_t) = (A_t h_t)^\alpha K_{t-1}^{1-\alpha} && (8)\\
Y_t &= (1-c) Y_t^W && (9)\\
\frac{P_t^W}{P_t} F_{h,t} &= \frac{P_t^W}{P_t} \frac{\alpha Y_t^W}{h_t} = \frac{W_t}{P_t} && (10)\\
K_t &= (1-\delta) K_{t-1} + (1 - S(X_t)) I_t && (11)
\end{aligned}
$$

Demand for capital is given by

$$
R_{k,t} = \frac{(1-\alpha)\frac{P_t^W}{P_t} Y_t^W / K_{t-1} + (1-\delta) Q_t}{Q_{t-1}} \tag{12}
$$

Equation (8) is a Cobb-Douglas production function for the wholesale sector that is converted into differentiated goods in (9) at a cost cY_t^W. K_t is physical capital that goods producers buy to capital producers and A_t is the productivity shock. From the optimization problem we get Equation (10) for the demand of labour, where $F_{h,t} \equiv \frac{\partial F_t}{\partial h_t}$ equates the marginal product of labour with the real wage, and 11 for the demand for capital. Demand for capital is given by the return on capital $R_{k,t}$, that equalizes the gross marginal product of capital net of depreciation (δ). P_t and P_t^W are the aggregate price indexes in the retail and wholesale sectors respectively. Capital accumulation is given by (11) and we assume convex investment adjustment costs a la Smets and Wouters [2007]. Note here K_t is *end-of-period* t capital stock. The production of physical capital is determined in the next subsection.

2.3 Capital Producers

To determine investment, following Smets and Wouters [2007], we introduce capital producing firms that at time t convert I_t of output into $(1-S(X_t))I_t$ of new capital sold to goods producers at a real price Q_t, commonly known as Tobin's Q. They then maximize with respect to $\{I_t\}$ expected discounted profits

$$
E_t \sum_{k=0}^{\infty} D_{t,t+k} \left[Q_{t+k} (1 - S\left(I_{t+k}/I_{t+k-1}\right)) I_{t+k} - I_{t+k} \right]
$$

where $D_{t,t+k} = \beta^k \left(\frac{\Lambda_{C,t+1}}{\Lambda_{C,t}}\right)$ is the real stochastic discount rate over the interval $[t, t+k]$. Defining $X_t \equiv \frac{I_t}{I_{t-1}}$ results in the first-order condition

$$Q_t(1 - S(X_t) - X_t S'(X_t)) + E_t \left[D_{t,t+1}\, Q_{t+1} S'(X_{t+1}) X_{t+1}^2\right] = 1$$

We complete this set-up with the functional form for $S(X)$,

$$S(X) = \phi_X (X_t - (1 + g_t))^2$$

where g is the balanced growth rate. Note that along a balanced growth path $X_t = 1 + g_t$ and investment costs disappear. This is a convenient property because then the steady state is unchanged from introducing investment costs.

2.4 Retail Producers

In order to introduce sticky prices used in New Keynesian DSGE model, we follow the technique proposed by Calvo [1983]. We assume that there is a probability of $1 - \xi$ at each period that the price of each retail good m is set optimally to $P_t^0(m)$. If the price is not re-optimised, then it is held fixed. For each retail producer m, given its real marginal cost MC_t, the objective is at time t to choose $\{P_t^0(m)\}$ to maximize discounted nominal profits

$$E_t \sum_{k=0}^{\infty} \xi^k DN_{t,t+k} Y_{t+k}(m) \left[P_t^0(m) - P_{t+k} MC_{t+k}\right] \tag{13}$$

subject to the equation for demand for investment by each producer

$$Y_{t+k}(m) = \left(\frac{P_t^0(m)}{P_{t+k}}\right)^{-\zeta} Y_{t+k} \tag{14}$$

where $DN_{t,t+k} \equiv \beta^k \frac{\Lambda_{C,t+k}/P_{t+k}}{\Lambda_{C,t}/P_t}$ is the *nominal* stochastic discount factor over the interval $[t, t+k]$. The solution to this is

$$E_t \sum_{k=0}^{\infty} \xi^k DN_{t,t+k} Y_{t+k}(m) \left[P_t^0(m) - P_{t+k} MC_{t+k} MS_{t+k}\right] = 0 \tag{15}$$

where an exogenous *stochastic mark-up* to the steady-state $MS \equiv \frac{1}{1-\frac{1}{\zeta}}$ has been introduced. The mark-up shock follows a AR1 process, which is described in 2.7.

With *indexing* by an amount $\gamma \in [0,1]$, price dynamics in equilibrium are given by

$$
\begin{aligned}
H_t - \xi\beta E_t[\tilde{\Pi}_{t+1}^{\zeta-1} H_{t+1}] &= Y_t \Lambda_{C,t} && (16)\\
J_t - \xi\beta E_t[\tilde{\Pi}_{t+1}^{\zeta} J_{t+1}] &= \left(1/(1-(\frac{1}{\zeta}))\right) MC_t MS_t Y_t \Lambda_{C,t} && (17)\\
\tilde{\Pi}_t &\equiv \frac{\Pi_t}{\Pi_{t-1}^{\gamma}} && (18)\\
1 &= \xi \Pi_t^{\zeta-1} + (1-\xi)\left(\frac{J_t}{H_t}\right)^{1-\zeta} && (19)\\
\Delta_t &= \xi \tilde{\Pi}_t^{\zeta} \Delta_{t-1} + (1-\xi)\left(\frac{J_t}{H_t}\right)^{-\zeta} && (20)
\end{aligned}
$$

where Δ_t is a measure of price dispersion across retail firms each setting their prices at different periods.

Real marginal costs in the retail sector are given by

$$MC_t = \frac{P_t^W}{P_t} \tag{21}$$

The aggregate resource constraint in the economy is expressed by

$$Y_t = C_t + G_t + I_t \tag{22}$$

The real side of the model is completed with a balanced budget constraint with lump-sum taxes.

2.5 Banks

The banking sector model is inspired in Gertler and Karadi [2011] and Gertler et al. [2012], with some differences. First, we assume that total net worth is given by the initial transfer from households to new bankers and it accumulates through retaining profits. In our model, we rule out the role of outside equity and therefore increases in the net worth of the banks are made exclusively through retained earnings. This feature has an important implication for macro-prudential policy, since a bank is likely to need more time to recover from a shortage of net worth, making the impact of macro-prudential regulation more significant (Angelini et al. [2011]).

Financial frictions affect real activity via the impact of funds available to the banks, but there is no friction in transferring funds between banks and nonfinancial firms. Given a certain deposit level a bank can lend frictionlessly to nonfinancial firms against their future profits. In this regard, firms offer to banks a perfect state contingent security.

First, we start by describing a *laissez faire* version of the banking sector, in which banking regulation is not enforced. Then, macro-prudential regulation is introduced and we show how it changes the banking sector equilibrium.

2.5.1 The *Laissez-Faire* Banking Sector

The activity of the bank can be summarized in two stages. In the first one, banks raise deposits and equity from the households, over the period $[t, t+1]$, the 'time period t'. In the second stage banks use these deposits to make loans to firms. Loans (s_t) are priced at a price Q_t. Therefore, $Q_t s_t$ correspond to the amount of loans that banks provide in period t. The asset against which the loans are obtained is end-of-period capital K_t. Capital depreciates at a rate δ in each period.

The banking sector's balance sheet is simple: the assets side is determined by loans, while the liabilities side comprises household deposits and net worth. This implies a banking sector's balance sheet of the form:[6]

$$Q_t s_t = n_t + d_t \tag{23}$$

where s_t are claims on future returns from one unit of a goods producer's capital at the end-of-period t to finance capital acquired at the end of period t for use in period $t+1$. Q_t is the price of a unit of capital. Therefore $Q_t s_t$ are the amount of loans that coincide fully to the assets of the bank and they equal the sum of deposits (d_t) and net worth (n_t).

Net worth of the bank accumulates according to:

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - R_t^{ex} d_{t-1} \tag{24}$$

$R_{k,t}$ are real returns on bank assets given by

$$R_{k,t} \quad = \quad \frac{[Z_t + (1-\delta)Q_t]}{Q_{t-1}}$$

where Z_t is the gross return (marginal product) of capital and $Z_t + (1-\delta)Q_t$ represents the net return after depreciation.

Banks face an exogenous probability of exiting of $1 - \sigma_B \epsilon \; [0,1]$ per period and therefore survive for $i-1$ periods and exit in the ith period with probability $(1-\sigma_B)\sigma_B^{i-1}$. Given the fact that the representative bank pays dividends only when it exits, the banker's objective is to

[6] In a slight departure from notation elsewhere, lower case denotes the representative bank. Upper case variables later denote aggregates.

maximize expected discounted terminal wealth V_t

$$V_t = E_t \sum_{i=0}^{\infty} (1-\sigma_B)\sigma_B^i \Lambda_{t,t+1+i} n_{t+1+i} \tag{25}$$

where $\Lambda_{t,t+i} = \beta^i \frac{\Lambda_{C,t+i}/P_{t+i}}{\Lambda_{C,t}/P_t}$ is the stochastic discount factor, subject to an incentive constraint for lenders (households) to be willing to supply funds to the banker.

To understand this dynamic problem better we can substitute for d_t from (23) and rewrite (24) as

$$n_t = R_t^{ex} n_{t-1} + (R_{k,t} - R_t^{ex}) Q_{t-1} s_{t-1} \tag{26}$$

which says that net worth at the end of period t equals the gross return at the real riskless rate $R_t^{ex} n_{t-1}$ plus the excess return over the latter on the assets. With these returns and Q_t exogenous, the bank net worth in all future periods is determined by its choice of $\{s_{t+i}\}$ subject to a borrowing constraint.

To motivate an endogenous constraint on the bank's ability to obtain funds, we introduce the following simple agency problem as in Gertler and Kiyotaki [2010]. We assume that in the period of time from having obtained funds from households and making loans, but before paying their debts to its creditors, the bankers may steal a fraction of assets $\Theta \epsilon [0,1]$ to his / her family. In the recognition of this possibility, households limit the funds they lend to banks. The fraction of funds that a banker can divert is determined by the balance sheet composition. If a banker diverts assets for his / her personal gain, he defaults on his debt and shuts down and the creditors may re-claim the remaining fraction $1-\Theta$ of funds. Because creditors are aware of the bank's incentive to divert funds, they will restrict the amount of funds they provide to the bank. In this way a borrowing constraint may arise. In order to ensure that bankers do not divert funds the following incentive constraint must hold:

$$V_t \geq \Theta_t Q_t s_t \tag{27}$$

The incentive constraint states that for households to be willing to supply funds to a bank, the banker's franchise value V_t must be at least as large as his / her gain from diverting funds.

The optimization problem for the bank is to choose a path for borrowing, $\{s_{t+i}\}$, to maximize V_t subject to (23) and (24) or equivalently (26) and (27). To solve this problem we guess a linear solution of the form:

$$V_t = V_t(s_t, n_t) = \mu_{s,t} Q_t s_t + \nu_{d,t} n_t = \mu_{s,t} Q_t s_t + \nu_{d,t} n_t \tag{28}$$

where $\mu_{s,t} \equiv \frac{\nu_{s,t}}{Q_t} - \nu_{d,t}$ is the excess value of bank assets over deposits and $\nu_{d,t}$ is the marginal value of deposits.

The banker's Bellman equation for a given path of n_t can be written in the form

$$V_{t-1}(s_{t-1}, n_{t-1}) = E_t \Lambda_{t,t+1}[(1-\sigma_B)n_t + \sigma_B \max_{s_t} V_t(s_t, n_t)] \tag{29}$$

Then, we perform the optimization by $\max_{s_t} V_t(s_t, n_t)$ subject to the incentive constraint (27). The Lagrangian for this problem is

$$\mathcal{L}_t = V_t + \lambda_t[V_t - \Theta Q_t s_t] = (1+\lambda_t)V_t - \lambda_t \Theta Q_t s_t \tag{30}$$

where $\lambda_t > 0$ if the constraint binds and $\lambda_t = 0$ otherwise.

The first order conditions for the optimization problem are:

$$\begin{aligned} s_t &: (1+\lambda_t)\mu_{s,t} = \lambda_t \Theta \\ \lambda_t &: \mu_{s,t} Q_t s_t + \nu_{d,t} n_t \geq \Theta Q_t s_t \end{aligned}$$

We now define ϕ_t to be the leverage ratio of the representative bank that satisfies the incentive constraint:

$$Q_t s_t = \phi_t n_t \tag{31}$$

where ϕ_t is given by

$$\phi_t = \frac{\nu_{d,t}}{\Theta - \mu_{s,t}} \tag{32}$$

Using (31) we can write (28) as

$$V_t = [\mu_{s,t}\phi_t + \nu_{d,t}]n_t \tag{33}$$

and hence (29) becomes

$$\begin{aligned} V_t(s_t, n_t) &= E_t \Lambda_{t,t+1}[1 - \sigma_B + \sigma_B(\mu_{s,t+1}\phi_{t+1} + \nu_{d,t+1})]n_{t+1} \\ &\equiv E_t \Lambda_{t,t+1}\Omega_{t+1} n_{t+1} \\ &= E_t \Lambda_{t,t+1}\Omega_{t+1}[R_{k,t+1}Q_t s_t - R^{ex}_{t+1} d_t] \end{aligned} \tag{34}$$

using (24) and defining $\Omega_t = 1 - \sigma_B + \sigma_B(\nu_{d,t} + \phi_t \mu_{s,t})$. Ω_{t+1} is a term augmenting $\Lambda_{t,t+1}$, the household's stochastic discount factor, given that banker's horizon is different from household's, due to the exit probability bankers have to face. With $\sigma_B > 0$, Ω_{t+1} represents the shadow value of an extra unit of net worth.

Comparing (34) with (28) and equating coefficients of s_t and d_t, we arrive at the determination of $\nu_{s,t}$ and $\nu_{d,t}$:

$$\begin{aligned}\nu_{d,t} &= E_t \Lambda_{t,t+1} \Omega_{t+1} R^{ex}_{t+1} \\ \nu_{s,t} &= E_t \Lambda_{t,t+1} \Omega_{t+1} Q_t R_{k,t+1}\end{aligned}$$

Hence

$$\mu_{s,t} \equiv \frac{\nu_{s,t}}{Q_t} - \nu_{d,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} (R_{k,t+1} - R^{ex}_{t+1}) \tag{35}$$

At the aggregate level the banking sector balance sheet is:

$$Q_t S_t = N_t + D_t$$

At the aggregate level net worth is the sum of existing (old) bankers and new bankers:

$$N_t = N_{o,t} + N_{n,t}$$

Net worth of existing bankers equals earnings on assets held in the previous period net cost of deposit finance, multiplied by a fraction σ_B, the probability that they survive until the current period:

$$N_{o,t} = \sigma_B \{(Z_t + (1-\delta) Q_t) S_{t-1} - R^{ex}_t D_{t-1}\}$$

Since new bankers cannot operate without any net worth, we assume that the family transfers to each one the fraction $\xi_B/(1-\sigma_B)$ of the total value assets of exiting entrepreneurs. This implies:

$$N_{n,t} = \xi_B [Z_t + (1-\delta) Q_t] S_{t-1} \tag{36}$$

The complete banking sector model is given by:

$$\begin{aligned}S_t &= K_t \\ (1+\lambda_t)\mu_{s,t} &= \lambda_t \Theta \\ Q_t S_t &= \frac{\phi_t N_t}{(1+\xi_B R_{k,t} \phi_t)} \\ \phi_t &= \frac{\nu_{d,t}}{\Theta - \mu_{s,t}} \\ N_t &= R_{k,t}(\sigma_B + \xi_B) Q_{t-1} S_{t-1} - \sigma_B R^{ex}_t D_{t-1} \\ D_t &= Q_t S_t - N_t\end{aligned}$$

$$\begin{aligned}
\nu_{d,t} &= E_t \Lambda_{t,t+1} \Omega_{t+1} R^{ex}_{t+1} \\
\mu_{s,t} &= E_t \Lambda_{t,t+1} \Omega_{t+1} (R_{k,t+1} - R^{ex}_{t+1}) \\
\Omega_t &= 1 - \sigma_B + \sigma_B (\nu_{d,t} + \phi_t \mu_{s,t}) \\
R_{k,t} &= \frac{Z_t + (1-\delta) Q_t}{Q_{t-1}} \\
Z_t &= \frac{(1-\alpha) P^W_t Y^W_t}{K_{t-1}}
\end{aligned}$$

2.5.2 The Regulated Banking Sector

In this section we introduce macro-prudential regulation, assuming a tax / subsidy scheme, in the lines of Gertler et al. [2012] and De Paoli and Paustian [2012]. We assume two different instruments, that alter the balance-sheet composition of the banks. One instrument is a tax / subsidy on loans and it changes according to different macro-prudential policy rules. On the other hand, we also introduce a subsidy / tax on the net worth of banks. Based on some recent literature modeling macro-prudential regulation, the choice of the instruments does not aim at reproducing exactly the current countercyclical capital requirements defined in Basel III regulatory framework. However, as countercyclical time-varying capital requirements, it also reacts countercyclically to financial variables variations, such as credit, credit-to-GDP ratio and credit spreads.

Total taxes from the macro-prudential regulation scheme are given by

$$T^{MR}_t = \tau_t Q_t S_t - \tau^s_t N_t \tag{37}$$

The macro-prudential regulatory scheme differs from Gertler et al. [2012] in the sense that it is non-neutral in terms of its fiscal impact.

The timing of the tax regime is as follows. In period $t-1$, tax and subsidy rates τ_{t-1}, τ^s_{t-1} are set to be paid or received on the value of end-of-period $t-1$ (or beginning of period t) loans $Q_{t-1}s_{t-1}$ and end-of-period net worth n_{t-1} respectively. The net worth of the bank then accumulates in period t according to:

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - R^{ex}_t d_{t-1} + \tau^s_{t-1} n_{t-1} - \tau_{t-1} Q_{t-1} s_{t-1} \tag{38}$$

That is, net worth equals gross returns minus gross costs of borrowing, plus subsidies minus taxes carried over over from the previous period. Banks are atomistic and take the tax rate and subsidy as exogenous.

With this timing for taxes or subsidies, the balance sheet of the bank in period t remains as before:

$$Q_t s_t = n_t + d_t \tag{39}$$

which says that net worth plus subsidies plus deposits can be used to finance loans net of tax.

As before we can substitute for d_t from (39) and rewrite (38) to give

$$\begin{aligned} n_t &= R_t^{ex} n_{t-1} + (R_{k,t} - R_t^{ex}) Q_{t-1} s_{t-1} - T_{t-1}^{MR} \\ &= (R_t^{ex} + \tau_{t-1}^s) n_{t-1} + (R_{k,t} - R_t^{ex} - \tau_{t-1}) Q_{t-1} s_{t-1} \end{aligned} \tag{40}$$

which says that net worth at the end of period t equals the gross return at a real riskless rate plus the excess return over the latter on the assets plus subsidies minus taxes carried over from the previous period.

The optimization problem for the regulated banking sector is similar to the one described above, but it takes into account the changes in the balance-sheet derived from the introduction of regulatory tools.

Aggregation follows as before and now total net taxes from the macro-prudential regulation scheme are given by

$$T_t^{MR} = \tau_t Q_t S_t - \tau_t^s N_t \tag{41}$$

The government budget constraint now becomes

$$G_t = T_t + T_t^{MR} \tag{42}$$

so that tax revenues from the scheme alter the lump-sum taxes required to finance government expenditure.

The complete banking model is summarized by

$$\begin{aligned} S_t &= K_t \\ (1+\lambda_t)\mu_{s,t} &= \lambda_t \Theta \\ Q_t S_t &= \phi_t N_t \\ \phi_t &= \frac{\mu_{n,t}}{\Theta - \mu_{s,t}} \\ N_t &= R_{k,t}(\sigma_B + \xi_B) Q_{t-1} S_{t-1} - \sigma_B R_t^{ex} D_{t-1} - \sigma_B T_{t-1}^{MR} \\ D_t &= Q_t S_t - N_t \\ T_t^{MR} &= \tau_t Q_t S_t - \tau_t^s N_t \\ \mu_{n,t} &= E_t \left[\Lambda_{t,t+1} \Omega_{t+1} (R_{t+1}^{ex} + \tau_t^s) \right] \end{aligned}$$

$$
\begin{aligned}
\mu_{s,t} &= E_t\left[\Lambda_{t,t+1}\Omega_{t+1}(R_{k,t+1} - R^{ex}_{t+1} - \tau_t))\right] \\
\Omega_t &= 1 - \sigma_B + \sigma_B(\mu_{d,t} + \phi_t\mu_{s,t}) \\
R_{k,t} &= \frac{Z_t + (1-\delta)Q_t}{Q_{t-1}} \\
Z_t &= \frac{(1-\alpha)P^W_t Y^W_t}{K_{t-1}}
\end{aligned}
$$

with τ^s_t or τ_t exogenous. Clearly in the absence of taxes or subsidies, i.e. $\tau_t = \tau^s_t = 0$, we get back to the previous set-up.

It is worth highlighting that $\mu_{s,t}$, the excess value of assets over deposits, and $\mu_{n,t}$, the excess value of net worth over debt are similar to $\nu_{d,t}$ and $\nu_{s,t}$, apart from the fact that they are affected by the macro-prudential regulation instruments, τ_t and τ^s_t. The inclusion of macro-prudential instruments of this kind alters the shadow value of assets and net worth, by altering the cost of borrowing and the interest margin of lending (spreads). Therefore, it modifies the franchise value of banks and, in particular, it has an impact on the optimal composition of banks' balance sheets. The cost of borrowing, R^{ex}_{t+1}, increases by τ^s_t, the subsidy on net worth, which makes more attractive for banks to fund themselves by raising net worth instead of collecting deposits. On the other hand, the interest margin obtained from lending activities decreases by τ_t, the tax on loans, making lending less profitable.

2.6 Policy Rules

To close the model, we introduce monetary and macro-prudential policy rules. We suggest not only a standard Taylor rule but also monetary rules that lean against the wind, by responding to financial variables behaviour, such as deviations of credit and asset prices from their steady state. We also propose alternative macro-prudential rules which also feed back on variables related to the financial sector, to assess the performance of these financial indicators in improving social welfare. A comparison across different policy rules is implemented and the optimal rules are those whose policy coefficients maximize social welfare, measured by the inter-temporal utility.

We follow the approach of using optimal simple and implementable rules as recommended in Schmitt-Grohe and Uribe [2007]. Their paper favours this kind of policies given their advantage of setting policy variables as a function of a small number of easily observable, macroeconomic indicators, since it does not require knowledge of the efficient levels of output or credit. At the same time, these policy rules provide the same level of welfare as the Ramsey-optimal policy. Moreover, this approach is commonly used in the macroeconomic literature, see for example Bailliu et al. [2012] and Lambertini et al. [2013].

Based on this set of monetary and macro-prudential policy rules, four policy mandates are investigated. The first policy regime assumes a sole monetary policy mandate, featuring a standard Taylor rule pursuing inflation stability. In this policy mandate, macro-prudential tools are ignored and this institutional framework is set as a baseline case, that will be compared with policy regimes comprising leaning against the wind monetary rules and macro-prudential policy. This leads us to the second policy regime, in which a leaning against the wind monetary policy is considered.

The third and fourth policy regimes result from the extension of the first and second regimes to include macro-prudential policy instruments. In the third policy regime, macro-prudential rules are introduced alongside with a standard monetary policy rule. This regime mimics an institutional framework in which the central bank is in charge of price stability only and the macro-prudential authority is concerned with financial stability. In this case, there are two economic authorities that operate independently of each other. The fourth regime relaxes this assumption by considering a partially unified institutional regime[7], since it is assumed that both the central bank and the macro-prudential authority target financial stability.

2.6.1 Monetary Policy Rules

In these study we assume that monetary policy can be a standard Taylor rule, reacting to inflation and output gaps, or it can also respond to financial variables. Following Curdia and Woodford [2010], we consider an augmented Taylor rule that feeds back on credit spreads. In addition, we also suggest credit and asset prices as alternative financial indicators.

The baseline policy regime is then given by a standard Taylor rule:

$$\log\left(\frac{R_{n,t}}{R_n}\right) = \rho_r \log\left(\frac{R_{n,t-1}}{R_n}\right) + (1-\rho_r)\left[\theta_{r,\pi}\log\left(\frac{\Pi_t}{\Pi}\right) + \theta_{r,y}\log\left(\frac{Y_t}{Y_t^F}\right)\right] + \epsilon_{MPS,t}$$

As already explained, this monetary policy rule is used as a baseline scenario for comparison with the alternative policy rules considered in the analysis.

The general augmented monetary policy rule takes the form:

$$\begin{aligned}\log\left(\frac{R_{n,t}}{R_n}\right) &= \rho_r \log\left(\frac{R_{n,t-1}}{R_n}\right) + (1-\rho_r)\left[\theta_{r,\pi}\log\left(\frac{\Pi_t}{\Pi}\right) + \theta_{r,y}\log\left(\frac{Y_t}{Y_t^F}\right) + \theta_{r,Q}\log\left(\frac{Q_t}{Q}\right)\right. \\ &+ \left.\theta_{r,s}\log\left(\frac{1+E_t\left[R_{k,t+1}-R^{ex}_{t+1}\right]}{1+R_k-R^{ex}}\right) + \theta_{r,QS}\log\left(\frac{Q_t s_t}{Qs}\right)\right] + \epsilon_{MPS,t}\end{aligned}$$

where $E_t[R_{k,t+1} - R^{ex}_{t+1}]$ is the credit spread, $Q_t s_t$ is credit and Q_t is Tobin's Q, that represents

[7] In contrast with a fully unified institutional regime, that would be one in which both the monetary and the macro-prudential authorities would target price and financial stability.

asset prices in this model. The coefficient ρ_r controls for the degree of interest rate smoothing, while $\theta_{r,\pi}$, $\theta_{r,y}$, $\theta_{r,Q}$, $\theta_{r,s}$, and $\theta_{r,Qs}$ control for the degree of aggressiveness of the policy rate response to inflation, output, asset prices, spreads and credit, respectively. Lastly, $\varepsilon_{v,t}$ is an i.i.d. monetary policy shock. The variables without time subscripts denote their respective steady state values and Y_t^F refers to the flexi-price output.

This general augmented simple rule is divided in four different combinations, depending on the financial indicator(s) chosen to infer the their effectiveness in improving welfare outcomes. Therefore, we examine simple augmented Taylor rules feeding back alternatively on credit, credit spreads, assets prices or credit and credit spreads simultaneously.

2.6.2 Macro-prudential Policy Rules

The objectives, instruments and targets of monetary policy rules are already quite established in the literature. In contrast, issues still remain concerning the objective of macro-prudential policy and what tools should be used in order to achieve its goal.[8] In this paper, we follow the view of the Bank of England, 2009 (BoE, 2009, thereafter), that establishes that macro-prudential regulation is implemented to assure financial stability through the monitoring of the credit supply during upswings and downturns. The BoE (2009) approach states that macro-prudential policy has the role of creating a capital buffer during upswings and relax credit conditions during economic downturns. The view that credit booms are related to financial and business cycle crisis is claimed by Minsky [1972] and it is underpinned in empirical works, including Jorda et al. [2011] and Schularick and Taylor [2012]. Against this background, the paper provides a characterization of macro-prudential policy as a macroeconomic stabilisation policy instrument rather than as a means of preventing financial crises.

The literature suggests a range of indicator variables related to credit booms,[9] such as credit growth, output growth, credit-to-GDP ratio, credit spreads, among others. The Basel Committee on Banking Supervision (2010) underscores the advantages of using credit-to-GDP ratio over credit growth, namely referring that this measure being a ratio, it is not affected by the cyclical behaviour of credit demand, since it is normalised by the size of the economy (given by output). In addition, it shows smoother behaviour patterns than credit growth.

Focusing our analysis on one financial indicator only may be misleading to assess the effectiveness of macro-prudential policy. Based on the literature, we suggest the use of credit, credit spreads, loan-to-GDP ratio and credit growth as deviations from their steady state. We examine different simple Taylor-type macro-prudential rules feeding back on these indicator variables.

[8] For a discussion, see Galati and Moessner 2012.

[9] See Bank of England, 2011 and Basel Committee on Banking Supervision, 2010.

Regarding the regulatory tools, we first select the tax on loans, τ_t, to be used alongside the nominal interest rate.[10] The general form of the macro-prudential regulation rule is then given by

$$
\begin{aligned}
\log\left(\frac{1+\tau_t}{1+\tau}\right) &= \rho_\tau \log\left(\frac{1+\tau_{t-1}}{1+\tau}\right) + (1-\rho_\tau)[\alpha_{\tau,QS}\log\left(\frac{Q_t s_t}{Qs}\right) \\
&+ \alpha_{\tau,s}\log\left(\frac{1+E_t\left[R_{k,t+1}-R^{ex}_{t+1}\right]}{1+R_k-R^{ex}}\right) + \alpha_{\tau,QS/Y}\log\left(\frac{\frac{Q_t s_t}{Y_t}}{\frac{Q_s}{Y^F_t}}\right) + \alpha_{\tau,\Delta Qs}\frac{cg_t}{cg_{ss}}] + \epsilon_{MRS,t}
\end{aligned}
$$

where $\frac{Q_t S_t}{Yt}$ represents the loan-to-GDP ratio at time t , $cg_t = \frac{Q_t s_t}{Q_{t-1}s_{t-1}}$ represents credit growth at time t regarding the previous period $t-1$ and cg_{ss} is the steady state value of cg_t. The remaining feedback variables are credit spreads and credit, as already described for the monetary policy rule. In addition, the coefficients of the macro-prudential policy rule are given by ρ_τ, which measures the degree of persistence of the macro-prudential instrument, $\alpha_{\tau,Qs}$, $\alpha_{\tau,s}$, $\alpha_{\tau,\Delta Qs}$ and $\alpha_{\tau,Qs/Y}$, which denote the degree of response of the macro-prudential policy tool to deviations in credit, credit spreads, credit growth and loan-to-GDP ratio. We expect $\alpha_{\tau,Qs}, \alpha_{\tau,Qs/Y}, \alpha_{\tau,\Delta Qs} > 0$ and $\alpha_{\tau,s} < 0$, as conditions to ensure a counter-cyclical macro-prudential regulation. If credit, credit growth and loan-to-GDP ratio exceed their respective steady states, taxes are raised thereby lowering loans and dampening the business cycle; on the other hand, if credit spreads exceed their steady state, taxes are lowered, increasing lending and bursting the business cycle. As before, variables without time subscripts denote their respective steady state values and Y^F_t refers to the flexi-price output.

2.7 Shock Processes

Our dynamic stochastic general equilibrium model features standard macroeconomic shocks as well as a financial crisis shock. Regarding the former, we consider monetary policy (MPS_t), macro-prudential policy (MRS_t), government spending (G_t), technology (A_t), trend $(1+g_t)$ and mark-up (MS_t) shocks. In what concerns the financial crisis shock (ψ_t), we follow Gertler and Karadi [2011], that suggest a capital quality shock to mimic the subprime crisis of 2007/2008. All the shocks follows a AR1 process of the form:

$$\log(MPS_t) = \varrho_{MPS}\log(MPS_{t-1}) + \epsilon_{MPS} \tag{43}$$

[10]For this purpose, we set the subsidy on net worth equal to zero, $\tau^s_t = 0$. We also perform optimal policy analysis by assuming a subsidy on net worth as a macro-prudential policy tool and compare the outcomes.

$$
\begin{aligned}
\log(MRS_t) &= \varrho_{MPS} \log(MRS_{t-1}) + \epsilon_{MRS} && (44)\\
\log(G_t) &= (1-\varrho)\log G + \varrho_G \log G_{t-1} + \epsilon_G && (45)\\
\log(A_t) &= \varrho_A \log(A_{t-1}) + \epsilon_A && (46)\\
\log(1+g_t) &= \log(1+g) + \epsilon_{Atrend} && (47)\\
\log(MS_t) &= \varrho_{MS} \log(MS_{t-1}) + \epsilon_{MS} && (48)\\
\log(\psi_t) &= \varrho_{\psi} \log(\psi_{t-1}) - \epsilon_{\psi} && (49)
\end{aligned}
$$

where ϵ_{MPS}, ϵ_{MRS}, ϵ_G, ϵ_A, ϵ_{Atrend}, ϵ_{MS}, ϵ_{ψ} $\sim i.i.d.\ N(0, \sigma^2_{\epsilon_i})$.

2.8 Calibration of Fundamental Parameters

The values for the model parameters are summarized in Table 1. We choose standard values in the literature for preference and technology parameters and we define as a time unit a quarter.

Table 1: Calibrated Parameters

Macroeconomic Parameters	**Symbol**	**Value**
Discount factor	β	0.9921
Growth Rate	g	0.0184/4
Government expenditure-output ratio	g_y	0.20
Labour Share	α	0.70
Depreciation rate	δ	0.025
Habit in consumption	χ	0.7
Substitution elasticity of goods	ζ	7.0
Fixed cost	c	$\frac{1}{\zeta} = 0.14929$
Preference parameter	ϱ	0.8806
Investment parameter	ϕ_x	2.0
Indexing parameter	γ	0.2
Elasticity of Consumption	σ_c	2.0
Banking Parameters		
Bankers Survival Probability	σ_B	0.975
Transfer for New Bankers	ξ	0.002
Asset divertibility	Θ	0.410

Regarding the banking sector parameters, our calibration follows closely the one adopted in Gertler and Kiyotaki [2010] and Gertler et al. [2012]. We set σ_B, the rate of survival of banks, by assuming that banks survive for 40 quarters on average (10 years). Therefore, $40 = \frac{1}{1-\sigma_B}$ and $\sigma_B = 0.975$. The values of the fractions of initial net worth and assets divertibility, ξ and Θ

respectively, are computed to hit an economy wide leverage ratio of four and to have an average credit spread of 100 basis points per year. In the AR1 shock processes, standard deviations of i.i.d shocks are calibrated at 1% and persistence parameters at 0.75. The preference parameter ϱ is calibrated to hit a hours worked steady-state target of $h = 0.35$.

3 Welfare Analysis

We compare the performance of alternative policy regimes in terms of social welfare. This section is structured in two subsections, based on the policy regimes under analysis. The first subsection deals with policy regimes in which only monetary policy rules are considered. Specifically, a standard monetary policy stance is implemented and used as a baseline scenario to which alternative policy regimes are compared. These alternative policy regimes consider augmented Taylor rules responding to financial imbalances. Welfare analysis is then conducted for both policy regimes and results are shown and commented.

The next subsection presents policy regimes featuring not only monetary policy rules, but also macro-prudential policy rules, under separate and partially unified mandates.

In each policy regime, the optimal policy rules are those whose policy coefficients grant the consumption and hours worked paths that maximize the inter-temporal utility (Λ), given by

$$\Lambda_t = E_t \left[(1-\beta) \sum_{t=0}^{\infty} \beta^t \Lambda_{T+t} \right] \tag{50}$$

where $\Lambda_t = U(C_t, h_t)$ is the household's single-period utility function.

These welfare comparisons across policy regimes can also be interpreted in terms of consumption equivalence calculation. Given a particular equilibrium path for consumption and hours worked, C_t and h_t, we compute the increase in the steady-state single-period utility, following a 1% increase in consumption:

$$CE_t \equiv \Lambda_t \left(1.01C_t, 1.01C_{t-1}, h_t\right) - \Lambda_t \left(C_t, C_{t-1}, h_t\right) \tag{51}$$

Then, we compute the consumption equivalence percentage ($ce_1(\%)$) by first selecting the rule among a set of distinct policy rules that maximizes welfare (Λ^*) and using it as a benchmark. Then, we calculate the welfare deviation of each policy rule from the maximum welfare value (Λ^*) and we normalise it by the percentage change in consumption in the deterministic steady-state that would give households the same unconditional expected utility in the stochastic economy, $CE = 0.00224$, in our model. Among a subset of policy regimes, figure $ce_1(\%)$ represents the loss in welfare from considering policy regimes distinct from the one that maximizes welfare. For the policy regime that maximises welfare we set $ce_1^*(\%) = 0\%$. The consumption equivalence percentage is useful to compare welfare outcomes within each subset of policy regimes.

Nevertheless, a measure of welfare performance is needed to compare outcomes across all sets of policy regimes, which is represented by $ce_2(\%)$. The normalisation procedure is then adopted to make the comparison of welfare outcomes across different policy regimes more comprehensible. By departing from the consumption equivalence concept, the normalisation is calculated by the welfare deviation of each policy rule (Ω_0) from the welfare figure obtained under *laissez faire* (i.e. under a standard Taylor rule). The denominator of this ratio remains the same,$CE = 0.00224$. Therefore, we obtain a measure of the change of welfare for each policy regime over the standard Taylor regime. A negative figure indicates a welfare cost and a positive figure indicates a welfare gain.

The parameters of the model are kept constant across all policy regimes.

3.1 Optimal Standard Taylor Rule and Leaning-Against-The-Wind Monetary Policy

With the aim of investigating whether, in a macroeconomic model with nominal and financial frictions, monetary policy should also respond to financial imbalances, we compute optimal simple rules for monetary policy feeding back on financial variables. For this purpose, we compare an interest rate smoothing standard Taylor rule, that reacts to inflation and output gaps, with augmented rules that also respond to financial variables, such as credit, credit spreads and asset prices. Then, from a set of monteray policy rules, we identify the one that is welfare maximizing. Three different augmented monetary rules are considered in this analysis: a rule reacting to inflation, output and credit gaps; a rule targeting inflation, output and credit spreads gaps and a rule responding to inflation, output and Tobin's Q gaps. The format of these rules was described in section 2.6.1.

Table 2 summarises the computation results for the welfare-optimised coefficients for each of these monetary policy rules.[11]

[11] The computation procedures are implemented in Dynare 4.2.4, using a second-order perturbation solution of the model with a particular policy rule interfaced with a standard Matlab minimization procedure.

Table 2: Optimal Monetary Policy Rules - Optimised Coefficients

#	Policy Regimes	ρ_r	$(1-\rho_r)\theta_{r,\pi}$	$(1-\rho_r)\theta_{r,y}$	$(1-\rho_r)\theta_{r,QS}$	$(1-\rho_r)\theta_{r,s}$	$(1-\rho_r)\theta_{r,Q}$
1	Std Taylor Rule (TR)	0.1697	4.4243	0.0711	-	-	-
2	Aug TR react. Credit	0.7029	5.0000	0.0000	0.0316	-	-
3	Aug TR react. Spreads	0.5335	4.4803	0.0000	-	-1.9619	-
4	Aug TR react. Tobin's Q	0.2053	3.4922	0.0000	-	-	0.5174

We find that monetary policy should respond to increases in credit or asset prices regarding their steady-state values by raising interest rates, on one hand. On the other hand, monetary policy should lower interest rates in the case of a rise in credit spreads. Thus, results show that an optimal monetary policy that leans against the wind would react countercyclically to credit, credit spreads or even asset prices. The finding associated to a simple rule that also reacts to credit spreads is in line with results from Curdia and Woodford [2010], which also demonstrate that monetary policymakers should relax the monetary policy stance whenever credit spreads increase. Previous literature does not back up our result for a rule feeding back on asset prices. In particular, in a model with credit market imperfections, Faia and Monacelli [2007] show that an optimal monetary policy strategy is one that reacts to asset prices increases by lowering interest rates.

Our findings also show that the optimal reaction to output fluctuations around its flexi-price level would be zero, whenever we consider a monetary policy stance feeding back on financial variables.

The policy regimes are ranked using a welfare criterion. Table 3 shows the computed welfare outcomes, both in absolute (Λ) and normalised ($ce_2(\%)$) terms. As already mentioned, the normalisation procedure is adopted to facilitate comparison of welfare performance across policy regimes in distinct tables and it is calculated by dividing the welfare outcome in absolute terms for each policy rule by the welfare outcome under *laissez faire*, which, in our model, we assume it is given by the welfare outcome under the standard Taylor rule. Table 3 is completed with the consumption equivalence criterion($ce_1(\%)$)[12] and the standard deviations of interest rates (σ_r), inflation (σ_π) and output (σ_y).

[12]As explained in Section 3, we compute the consumption equivalence percentage by first selecting the rule that maximizes welfare (Λ^*) and using it as a benchmark. Then, we calculate the welfare deviation from each policy rule from the maximum welfare value (Λ^*) and we normalise it by the percentage change in consumption in the deterministic steady-state that would give households the same unconditional expected utility in the stochastic economy.

Table 3: Optimal Monetary Policy Rules - Welfare Losses / Gains and Std Deviations

#	Policy Regimes	Λ	Welfare Loss ce_1 (%)	Welfare Gain ce_2 (%)	σ_r	σ_π	σ_y
1	Std Taylor Rule (TR)	-1.886534	0.0615	baseline	0.0119	0.0020	0.0230
2	Aug TR react. Credit	-1.886529	0.0593	0.0022	0.0097	0.0018	0.0227
3	Aug TR react. Spreads	-1.886480	0.0375	0.0241	0.0100	0.0027	0.0210
4	Aug TR react. Tobin's Q	-1.886396	0.0000	0.0615	0.0103	0.0036	0.0189

Welfare outcomes suggest that the monetary policy rule that minimizes welfare losses is an augmented one that reacts to asset prices (captured by the variable Tobin's Q in this model). Compared to this rule, the alternative regimes imply welfare losses ranging from 0.04% (policy regime 3) to 0.06% (policy regime 1) in terms of consumption equivalence. Moreover, every augmented Taylor rule considered in this analysis would perform better than the standard, conventional Taylor rule, as indicated by the welfare gains figures. In fact, a standard Taylor rule is more welfare costly than leaning against the wind policy mandates in a macroeconomic framework in which financial frictions are also modelled, implying a welfare loss of 0.06% in $ce_1(\%)$.

From the point of view of inflation stabilisation however, a rule responding to credit spreads would have a worse performance than a standard one. In fact, rules reacting to credit spreads and asset prices are related to higher inflation volatility, as claimed in the literature. Therefore, our results suggest that the monetary policy rule that seems to make a compromise between welfare maximization and inflation stability is one reacting to fluctuations in credit around its steady-state, since it delivers a smaller welfare loss than a standard Taylor rule, at the same time it proportionates lower inflation, output and interest rate volatility.

3.2 Optimal Monetary and Macro-prudential Policies

In this section, we assess the effectiveness of macro-prudential policy in terms of welfare maximization and macroeconomic stabilisation. We also determine the most efficient institutional arrangement of monetary and macro-prudential policies. The macro-prudential instrument adopted in this exercise is a tax on bank loans, τ_t, although given the way the banking regulation is modelled in this paper, it is feasible to apply the same type of welfare analysis using a subsidy on net worth instead. This innovative feature of the model allows us to compare the effectiveness of different kind of macro-prudential tools in terms of welfare impact. In the case of choosing a subsidy on net worth, the welfare gains are not as large as in the situation a tax on loans is selected. For this reason, we opt for showing in detail the optimal policy outcomes when a tax on loans is considered as a macro-prudential instrument, although we comment briefly on the results attained when the macro-prudential tool is a subsidy on net worth.

Our analysis is conducted based on two additional policy mandates. First, we consider a policy mandate featuring macro-prudential policy rules alongside a standard monetary policy stance. In other words, we assume that each policy maker, i.e. the monetary authority and the macro-prudential regulator, focuses on their own policy objective, suggesting that the monetary authority sets interest rates to respond to fluctuations in inflation and output, whereas the macro-prudential regulator sets taxes on loans to control for deviations of financial variables from their paths. Second, we propose a policy regime in which both monetary and macro-prudential rules respond to financial imbalances, to assess a partially unified institutional mandate. In this case, we admit a monetary policy maker that not only pursues price stability, but it is also concerned about the stability of the financial system as a whole, as a mean to maximize households' utility. Therefore, we suggest an augmented monetary policy rule, alongside a macro-prudential policy rule.[13]

Then, we recover the welfare and macroeconomic stabilization outcomes from 2.6.1 for the baseline case given by a standard Taylor rule, and we contrast them with the results obtained for policy regimes comprising macro-prudential regulation.

As before, we assess the welfare losses / gains using consumption equivalence measures. Furthermore, the stabilization effects of adding macro-prudential policy on output, inflation and interest rates are investigated as well, by computing the volatility for each of these three variables. Since we are interested in assessing the impact of macro-prudential regulation in normal times as well as abnormal times, a multi-shock environment is considered, including all the shocks already described above: productivity, government spending, mark-up, monetary policy, macro-prudential policy, capital quality and trend shocks. Then, we optimize macro-prudential policies in this multi-shock scenario, considered more realistic since macro-prudential regulation is expected to deal with different sources of economic shocks simultaneously (Angelini et al. 2011).

Results from computation of optimal simple rules are shown in the following sections for each policy mandate: separate and partially unified.

[13] We could have suggested a totally unified policy mandate, by assuming that macro-prudential policy reacts not only to financial imbalances, but also to price stability (by considering it was also feeding back on inflation fluctuations around its steady-state). Nonetheless, we consider that a partially unified regime is a more realistic scenario, since there is a consensual view among academics and policy makers that the macro-prudential policy goals should focus exclusively on financial system stability, leaving inflation volatility as a monetary policy responsibility.

3.2.1 Results for the Separate Policy Mandate

To simulate a separate mandate, we assume that each policymaker is solely concerned with their own policy goal. The monetary policymaker is a conventional one in the sense it targets price stability only, by following a standard Taylor rule. On the other hand, to investigate the role of macro-prudential policy in stabilising the economy, we define alternative types of macro-prudential policy rules, by considering distinct financial stability targets. Against this background, a macro-prudential rule is set that reacts exclusively to credit, credit spreads, loan-to-GDP ratio or credit growth. Admitting the possibility of having a macro-prudential policy rule feeding back on more than one financial indicator, we also analyse a rule reacting to credit and credit spreads, simultaneously.

The coefficients are computed jointly for each type of rule, and their optimised values are shown below, in Table 4:

Table 4: Separate Mandate - Optimised Coefficients

#	**Policy Regimes**	**Monetary Policy Rules**		
		ρ_r	$(1-\rho_r)\theta_{r,\pi}$	$(1-\rho_r)\theta_{r,y}$
1	STR (Std Taylor Rule)	0.1697	4.4243	0.0711
5	STR + MR Credit	0.3770	3.5734	0.0473
6	STR + MR Cred. Spreads	0.9411	1.6036	1.0000
7	STR + MR Loan-to-Y Ratio	0.3285	3.3181	0.0744
8	STR + MR Credit Growth	0.3814	3.5988	0.0455
9	STR + MR Credit & Spreads	0.6128	1.6821	1.0000

#	**Policy Regimes**	**Macro-prudential Policy Rules**				
		ρ_τ	$(1-\rho_\tau)\alpha_{\tau,QS}$	$(1-\rho_\tau)\alpha_{\tau,s}$	$(1-\rho_\tau)\alpha_{\tau,QS/Y}$	$(1-\rho_\tau)\alpha_{\tau,cg_t/cg_{ss}}$
1	STR (Std Taylor Rule)	-	-	-	-	-
5	STR + MR Credit	0.0000	0.0145	-	-	-
6	STR + MR Cred. Spreads	0.1195	-	-1.5600	-	-
7	STR + MR Loan-to-Y Ratio	0.0000	-	-	0.0167	-
8	STR + MR Credit Growth	0.0000	-	-	-	0.0146
9	STR + MR Credit & Spreads	0.0000	0.0079	-1.7147	-	-

There are two main findings from this exercise. First, introducing an additional policy instrument (i.e. a tax on bank loans) leads to a decrease on the aggressiveness of the response of a standard Taylor rule to deviations of inflation from its steady state. Under a standard Taylor rule, the degree of aggressiveness is $(1-\rho_t)\theta_{r,\pi} = 4.4$, whereas under a policy regime that combines both a standard Taylor rule and a macro-prudential rule, it ranges from a minimum of

$(1-\rho_t)\theta_{r,\pi} = 1.6$ when reacting to fluctuations credit spreads, to a maximum of $\theta_{r,\pi} = 3.6$, when responding to fluctuations in credit or credit growth around their steady-state. Therefore, the need for the monetary policy maker to react strongly to fluctuations of inflation rates around its steady-state is attenuated when macro-prudential policy is in place. This result may suggest that macro-prudential authority can give a hand to the monetary policy maker in certain economic circumstances. Regarding its effects on the magnitude of monetary policy reaction to the output gap, results are mixed, since although some policy regimes, such as 5 and 8, register output gap optmised coefficients below the baseline rule, there are other policy regimes in which this does not verify (policy regimes 6, 7 and 9).

Second, the optimal reaction of macro-prudential policy is a rise in the tax on loans to increases in credit and loan-to-GDP ratio and a cut on taxes following a rise in credit spreads. Hence, results confirm the countercyclical nature of macro-prudential regulation. Moreover, it is worth noting that the degree of persistence of the macro-prudential instrument is non-existent for almost all the policy rules considered in this analysis, except when a policy regime comprising a standard Taylor rule and a macro-prudential rule feeding back on credit spreads is in place. In this policy regime, the optimal response for the macro-prudential policy tool is 0.1195.

Table 5 shows the computed welfare losses and standard deviations for interest rates, inflation and output for each macro-prudential rule. An important result of this analysis is that macro-prudential regulation improves welfare. This is observed based on the consumption equivalence outcomes, since the largest loss in consumption is achieved when monetary policy alone reacts to the shocks affecting this economy (0.06% of consumption loss, when comparing with the welfare maximizing policy regime featuring a standard Taylor rule and a macro-prudential policy rule feeding back on spreads and credit). In the case macro-prudential regulation is deployed, the welfare loss decreases, achieving its minimum in a mandate in which a standard Taylor rule is coupled with a macro-prudential rule reacting to both credit and credit spreads. Nonetheless, the gains of having macro-prudential policy are small in this economy, varying from a minimum of 0.04% (policy regime 6) to a maximum of 0.06% (policy regime 9). This finding is in line with the conclusions of Angelini et al. [2011] and De Paoli and Paustian [2012], whom also found modest gains of introducing macro-prudential regulation based on alternative economic frameworks.

Table 5: Separate Mandate - Welfare Losses / Gains and Std Deviations

#	Policy Regimes	Λ	Welfare Loss ce_1 (%)	Welfare Gain ce_2 (%)	σ_r	σ_π	σ_y
1	STR only	-1.88653	0.0638	Baseline	0.0119	0.0020	0.0230
5	STR + MR Credit	-1.88644	0.0228	0.0415	0.0114	0.0021	0.0157
6	STR + MR Credit Spreads	-1.88645	0.0263	0.0375	0.0094	0.0023	0.0155
7	STR + MR Loan-to-GDP Ratio	-1.88645	0.0245	0.0392	0.0116	0.0022	0.0159
8	STR + MR Credit Growth	-1.88644	0.0223	0.0415	0.0113	0.0021	0.0157
9	STR + MR Credit & Spreads	-1.88639	0.0000	0.0638	0.0102	0.0017	0.0143

The findings suggest that the policy regime that minimizes welfare losses also attains a lower volatility of inflation and output, thus being more efficient in stabilising the economy. In what concerns the measure of inflation stability, a "Std TR only" is preferable to a policy regime comprising macro-prudential policy, since the inflation volatility is lower under this regime ($\sigma_\pi = 0.0020$). Regarding output stabilization, this is better achieved under policy regimes that couples a standard Taylor rule with a macro-prudential rule, reaching its minimum under a "Std TR + MR reacting to Credit Spreads" mandate.

Rules that target different proxies for credit imbalances, such as credit deviations from steady state values, loan-to-GDP ratio and credit growth, provide very similar results in terms of welfare. However, the rule that seems to work best is the one reacting to credit growth, since it delivers the lowest welfare loss (0.0223%, in consumption equivalence terms). This rule also minimizes inflation and output volatility, as well as a rule reacting to credit deviations from its steady-state values. Among these three rules, the macro-prudential policy rule that performs worst is the one reacting to loan-to-GDP ratio, since it does not improve the outcomes produced by the other two alternative rules: inflation and output are more volatile and welfare loss is larger under this policy arrangement. In addition, a macro-prudential policy rule feeding back exclusively on credit spreads does not provide better outcomes than the one responding to loan-to-GDP ratio, both in terms of welfare and inflation stabilization.

Furthermore, from the analysis of the standard deviations obtained for interest rates, the conclusion is that including macro-prudential policy in this set up decreases the probability of hitting the zero lower bound, since the volatility of interest rates declines when a macro-prudential policy arrangement is introduced.

3.2.2 Results for the Partially Unified Policy Mandate

In this section, the welfare and stabilization outcomes from the joint optimization of mandates composed by monetary policy rules reacting to financial variables and macro-prudential regulation are explored. This exercise aims at mimicking a partially unified institutional regime, in which both monetary and macro-prudential policies feed back on financial stability variables. This regime is different from a complete unified regime, which would be characterized by each policy targeting both price and financial stability. However, it seems unrealistic to assume that macro-prudential regulation would be also concerned about inflation stabilization, being more likely to consider a wider scope of intervention for monetary policy.

It should be noted though that, unlike for example De Paoli and Paustian [2012] and Gelain et al. [2013], we are not comparing coordination in the form of joint maximization with a non-cooperative Nash equilibrium for non-coordination. For both regimes the *same* welfare criteria is used, so with given forms of simple rules a Nash equilibrium would be a 'team-optimal solution' and give an identical outcome as with coordination (see Basar and Olsder [1982], chapter 6). Rather the unified and separate mandates both jointly (though it could be in a Nash equilibrium) maximize the welfare, but under different constraints on the rules that reflect the different targets for the nominal and regulatory instruments in the two cases.

In order to simulate a partially unified regime, we consider alternative combinations of augmented Taylor rules and macro-prudential regulation rules. First, we assume that both monetary and macro-prudential rules feed back on deviations of credit from its steady state. The second and third policy regime alternatives combine a monetary policy and macro-prudential rule reacting both to credit spreads and loan-to-value ratio, respectively. As a last combination, we broaden the range of financial targets that policies feed back on, assuming that they react jointly to credit and credit spreads.

Tables 6 and 7 show the optimised coefficients under these alternative policy combinations. Results are in line with the ones obtained for a separate regime. First, the optimal magnitude of monetary policy reaction to inflation decreases whenever macro-prudential regulation is deployed suggesting that monetary policy does not need to be that aggressive whenever macro-prudential tools are in place. Second, the optimal macro-prudential policy is of a countercyclical nature, since it responds positively to deviations of credit and loan-to-GDP ratio from their respective steady-state values and negatively to deviations of credit spreads from their steady-state values.

Table 6: Partially Unified Mandate - Monetary Policy Optimised Coefficients

#	**Policy Regimes** **Aug TR + MR**	**Monetary Policy Rules**						
		ρ_r	$\theta_{r,\pi}$	$\theta_{r,y}$	$\theta_{r,QS}$	$\theta_{r,s}$	$\theta_{r,QS/Y}$	$\theta_{r,cg_t/cg_{ss}}$
10	Reacting to Credit	0.396	3.782	0.010	0.014	-	-	-
11	React. to Spreads	0.231	3.212	1.058	-	-0.415	-	-
12	React. to Loan-to-GDP Ratio	0.366	3.566	0.042	-	-	0.022	-
13	React. Credit Growth	0.387	3.715	0.036	-	-	-	0.015
14	React. to Cred. & Spreads	0.331	2.808	0.945	0.027	-0.518	-	-

Table 7: Partially Unified Mandate - Macro-prudential Policy Optimised Coefficients

#	**Policy Regimes** **Aug TR + MR**	**Macro-prudential Policy Rules**				
		ρ_τ	$\alpha_{\tau,QS}$	$\alpha_{\tau,s}$	$\alpha_{\tau,QS/Y}$	$\alpha_{\tau,cg_t/cg_{ss}}$
10	React. to Credit	0.00	0.014	-	-	-
11	React. to Spreads	0.00	-	-2.369	-	-
12	React. to Loan-to-Y Ratio	0.00	-	-	0.016	-
13	React. Credit Growth	0.00	-	-	-	0.014
14	React. to Cred. & Spreads	0.00	0.016	-1.817	-	-

Table 8 shows computation outputs for welfare losses and standard deviations for the partially unified alternative policy regimes. To facilitate comparison across the alternative policy regimes, this table also displays the baseline policy regime, given by a standard Taylor rule only, and the policy regime with better performance so far in what concerns welfare maximization, given by a separate regime featuring a standard Taylor rule and a macro-prudential policy rule responding to credit and spreads.

In what regards the impact of different policy mandates on welfare losses, we conclude that the partially unified regime promotes an increase in welfare compared to a separate mandate, but only when macro-prudential regulation reacts simultaneously to credit and credit spreads (the welfare gain is 0.07%, greater than the attained by policy regime 9, 0.06%). Otherwise, a separate regime is preferable to a partially unified one, according to these outcomes. Nevertheless, the gains from coordination are still modest: in consumption equivalence terms, a separate regime implies a 0.01% welfare loss and a standard Taylor rule implies a 0.07% loss, when compared to a partially unified regime that reacts to credit and credit spreads.

Inflation stabilization, on the other hand, is better achieved in a separate mandate, composed by a standard Taylor rule and macro-prudential regulation responding jointly to credit and spreads. Another result worth highlighting is that, as before, a macro-prudential policy reacting to the loan-to-GDP ratio does not provide an improvement over a rule responding to credit deviations only. This indicator also performs poorly not only in terms of welfare losses minimization, but also regarding inflation, output and interest rate stabilization.

Table 8: Partially Unified Mandate - Welfare Losses and Std Deviations

#	**Policy Regimes**	Λ	Welfare Loss ce_1 (%)	Welfare Gain ce_2 (%)	σ_r	σ_π	σ_y
1	Std TR only	-1.886534	0.0740	Baseline	0.0119	0.0020	0.0230
9	Std TR + MR Credit & Spreads	-1.886391	0.0103	0.0638	0.0102	0.0017	0.0143
	Aug TR + MR						
10	React. to Credit	-1.886437	0.0308	0.0433	0.0112	0.0021	0.0156
11	React. to Spreads	-1.886403	0.0156	0.0584	0.0112	0.0019	0.0151
12	React. to Loan-to-Y Ratio	-1.886440	0.0321	0.0419	0.0113	0.0022	0.0157
13	React. to Credit Growth	-1.886437	0.0308	0.0433	0.0112	0.0021	0.0155
14	React. to Credit & Spreads	-1.886368	0.0000	0.0740	0.0108	0.0018	0.0127

3.3 Subsidy on Net Worth as a Macro-prudential Tool

Since we conceived a model in which is possible to assess the degree of effectiveness of alternative macro-prudential tools, such as a tax on loans or a subsidy on net worth, we performed the same optimal policy approach, but now using a subsidy on net worth as the macro-prudential tool. It should be expected that, when credit surpasses its steady-state path, subsidies on net worth are decreased, thereby contracting loans and dampening the business cycle. In turn, when credit spreads exceed their steady-state values, subsidies on net worth are raised, thereby decreasing loans and dampening the business cycle.

As already mentioned, although the use of a subsidy on net worth is also welfare improving, confirming the importance of adopting macro-prudential tools in counterveiling financial imbalances, it underperforms the tax on loans welfare benefits. Table 9summarises these outcomes.

Table 9: Comparison of Macro-prudential Tools

Subsidy on Net Worth					Tax on Loans	
#	**Policy Regimes**	Λ	Welfare Loss ce_1 (%)	Welfare Gain ce_2 (%)	Welfare Loss ce_1 (%)	Welfare Gain ce_2 (%)
1	Std TR only	-1.88653	0.0384	Baseline	0.0638	Baseline
5	Std TR + MR Credit	-1.88647	0.0080	0.0303	0.0228	0.0415
6	Std TR + MR Spreads	-1.88652	0.0326	0.0058	0.0263	0.0638
9	Std TR + MR Credit & Spreads	-1.88645	0.0000	0.0384	0.0000	0.0392
	Augmented TR + MR					
10	React. to Credit	-1.886468	0.0232	0.0294	0.0308	0.0433
11	React. to Spreads	-1.886472	0.0250	0.0277	0.0156	0.0584
14	React. to Credit & Spreads	-1.886416	0.0000	0.0526	0.0000	0.0740

4 Conclusions

This paper aims at contributing to the debate regarding the role of monetary policy and traditional regulatory and prudential frameworks on promoting macroeconomic stability. We built a DSGE model with price rigidities and financial frictions a la Gertler and Karadi [2011] in order to assess the importance of macro-prudential and monetary policies in improving welfare and stabilising the economy. In particular, we investigate whether it is welfare beneficial to have a monetary policy strategy that also leans against the build up of financial imbalances and we compare it with a policy mandate in which macro-prudential regulation is also considered.

Our optimal policy exercises, obtained in the context of a linearized model that excludes financial (in)stability and default, provide three main findings. First, it is welfare improving to have a monetary policy stance that reacts countercyclically to asset prices. Nonetheless, there is a trade-off in terms of inflation stabilization, since an augmented Taylor rule of this type would involve more prices volatility than a standard one. A compromise between welfare maximization and inflation stability seems to be achieved under a policy regime characterised by an augmented Taylor rule that feeds back on deviations of credit from its steady-state path.

Second, the consideration of a policy mandate in which monetary policy is complemented by macro-prudential regulation is welfare improving, regardless of the type of policy mandate adopted. The welfare maximizing mandate is one in which an augmented Taylor rule reacting to credit and credit spreads is combined with a macro-prudential rule that responds to credit and credit spreads as well. The welfare gains from a partially unified mandate are of the order of a consumption equivalent improvement of 0.07% when compared with the baseline case, given by a standard Taylor rule only. This improvement is, in fact, small, but aligned with previous findings in the literature (see, for instance, De Paoli and Paustian [2012], Angelini et al. [2011]). Inflation stabilization, on the other hand, is better accomplished in a separate mandate, in which we have a standard Taylor rule feeding back on inflation and output gaps, and a macro-prudential rule responding to credit and spreads.

Lastly, the countercyclical nature of macro-prudential instruments is backed by our optimal policy simulations.

The findings of this paper must be interpreted carefully, since they result from DSGE models with typical solution techniques based on log-linearization, which do not allow for the non-linear dynamics that usually characterize boom-bust episodes. Despite the absence of non-linearities in these models, the importance for monetary policy to lean against the wind and for considering macro-prudential policy as an ancillary tool to deal with financial imbalances is entirely confirmed by simply granting a non-negligible role to financial intermediation provided by the banking system.

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Appendix 1

The regulated banking sector

Assuming a tax / subsidy scheme, in the lines of Gertler et al. [2012] and De Paoli and Paustian [2012], total taxes from the macro-prudential regulation scheme are given by

$$T_t^{MR} = \tau_t Q_t S_t - \tau_t^s N_t \tag{52}$$

The timing of the tax regime is as follows. In period $t-1$, tax and subsidy rates τ_{t-1}, τ_{t-1}^s are set to be paid or received on the value of end-of-period $t-1$ (or beginning of period t) loans $Q_{t-1}s_{t-1}$ and end-of-period net worth n_{t-1} respectively. The net worth of the bank then accumulates in period t according to:

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - R_t^{ex} d_{t-1} + \tau_{t-1}^s n_{t-1} - \tau_{t-1} Q_{t-1} s_{t-1} \tag{53}$$

That is, net worth equals gross returns minus gross costs of borrowing, plus subsidies minus taxes carried over over from the previous period. Banks are atomistic and take the tax rate and subsidy as exogenous.

With this timing for taxes or subsidies, the balance sheet of the bank in period t remains as before:

$$Q_t s_t = n_t + d_t \tag{54}$$

which says that net worth plus subsidies plus deposits can be used to finance loans net of tax.

As before we can substitute for d_t from (54) and rewrite (53) to give

$$\begin{aligned} n_t &= R_t^{ex} n_{t-1} + (R_{k,t} - R_t^{ex}) Q_{t-1} s_{t-1} - T_{t-1}^{MR} \\ &= (R_t^{ex} + \tau_{t-1}^s) n_{t-1} + (R_{k,t} - R_t^{ex} - \tau_{t-1}) Q_{t-1} s_{t-1} \end{aligned} \tag{55}$$

which says that net worth at the end of period t equals the gross return at a real riskless rate plus the excess return over the latter on the assets plus subsidies minus taxes carried over from the previous period.

As for the laissez faire banking sector model, the optmisation problem for the banks to chose a path for borrowing to maximize V_t subject to the incentive constraint 57:

$$V_t(s_t, n_t,) = \mu_{s,t} Q_t s_t + \mu_{n,t} n_t \tag{56}$$

s. t.

$$V_t \geq \Theta_t Q_t s_t \tag{57}$$

and write the Bellman equation for a given path for n_t in the form

$$V_{t-1}(s_{t-1}, n_{t-1}) = E_t \Lambda_{t,t+1}[(1-\sigma_B)n_t + \sigma_B \max_{s_t} V_t(s_t, n_t)] \tag{58}$$

Again we perform the optimization $\max_{s_t} V_t(s_t, n_t)$ subject to the incentive constraint. The first order conditions for this optimization problem are as before with a slight notational difference that $\nu_{d,t}$ is replaced with $\mu_{n,t}$:

$$\begin{aligned} s_t &: (1+\lambda_t)\mu_{s,t} = \lambda_t \Theta \\ \lambda_t &: \mu_{s,t} Q_t s_t + \mu_{n,t} n_t \geq \Theta Q_t s_t \end{aligned}$$

Again define ϕ_t to be the leverage ratio:

$$Q_t s_t = \phi_t n_t \tag{59}$$

Assuming the incentive constraint always binds, ϕ_t is given by

$$\phi_t = \frac{\mu_{n,t}}{\Theta - \mu_{s,t}} \tag{60}$$

Using (60) we can write (56) as

$$V_t = [\mu_{s,t}\phi_t + \mu_{n,t}]n_t \tag{61}$$

and hence (58) becomes

$$\begin{aligned} V_t(s_t, n_t) &= E_t \Lambda_{t,t+1}[1-\sigma_B + \sigma_B(\mu_{s,t+1}\phi_{t+1} + \mu_{n,t+1})]n_{t+1} \\ &= E_t \Lambda_{t,t+1}\Omega_{t+1}[(R_{k,t+1} - R^{ex}_{t+1} - \tau_t)Q_t s_t + (R^{ex}_{t+1} + \tau^s_t)n_t] \end{aligned} \tag{62}$$

defining $\Omega_t = 1 - \sigma_B + \sigma_B(\mu_{n,t} + \phi_t \mu_{s,t})$, the shadow value of a unit of net worth, and using (38).

The equilibrium of the banking model is given by

$$\begin{aligned} S_t &= K_t \\ (1+\lambda_t)\mu_{s,t} &= \lambda_t \Theta \\ Q_t S_t &= \phi_t N_t \end{aligned}$$

$$
\begin{aligned}
\phi_t &= \frac{\mu_{n,t}}{\Theta - \mu_{s,t}} \\
N_t &= R_{k,t}(\sigma_B + \xi_B)Q_{t-1}S_{t-1} - \sigma_B R_t^{ex} D_{t-1} - \sigma_B T_{t-1}^{MR} \\
D_t &= Q_t S_t - N_t \\
T_t^{MR} &= \tau_t Q_t S_t - \tau_t^s N_t \\
\mu_{n,t} &= E_t \left[\Lambda_{t,t+1} \Omega_{t+1} (R_{t+1}^{ex} + \tau_t^s) \right] \\
\mu_{s,t} &= E_t \left[\Lambda_{t,t+1} \Omega_{t+1} (R_{k,t+1} - R_{t+1}^{ex} - \tau_t)) \right] \\
\Omega_t &= 1 - \sigma_B + \sigma_B (\mu_{d,t} + \phi_t \mu_{s,t}) \\
R_{k,t} &= \frac{Z_t + (1-\delta)Q_t}{Q_{t-1}} \\
Z_t &= \frac{(1-\alpha)P_t^W Y_t^W}{K_{t-1}}
\end{aligned}
$$

with τ_t^s or τ_t exogenous. Clearly in the absence of taxes or subsidies, i.e. $\tau_t = \tau_t^s = 0$, we get back to the previous set-up.

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