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Abstract

This paper examines the macroprudential roles of bank capital regulation and monetary policy in a Dynamic Stochastic General Equilibrium model with endogenous financial frictions and a borrowing cost channel. We identify various transmission channels through which credit risk, commercial bank losses, monetary policy and bank capital requirements affect the real economy. These mechanisms generate significant financial accelerator effects, thus providing a rationale for a macroprudential toolkit. Following credit shocks, countercyclical bank capital regulation is more effective than monetary policy in promoting financial, price and overall macroeconomic stability. For supply shocks, macroprudential regulation combined with a strong response to inflation in the central bank policy rule yield the lowest welfare losses. The findings emphasize the importance of the Basel III regulatory accords and cast doubt on the desirability of conventional Taylor rules during periods of financial distress.

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Keywords: Bank Capital Regulation, Macroprudential Policy, Basel III, Monetary Policy, Borrowing Cost Channel.

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1 Introduction

The global financial crisis of 2007-2009 followed by the Great Recession have emphasized the importance of developing macroeconomic models which study the interactions between the financial system and real business cycles. In the aftermath of the crisis, it is now clear that restrictions in lending, higher borrowing costs and financial regulation, all which directly impact the credit markets, have translated into distortions in the wider economy. As a consequence, a growing number of research papers and policy discussions on the role of financial intermediation, credit risk and bank capital in the transmission of various shocks to the real economy have emerged in the past few years.[1]

The general consensus in the literature is that credit market frictions and risk sensitive bank capital regulation (in the form of Basel II) can exacerbate procyclicality in the financial system and real economy (see Covas and Fujita (2010), Liu and Seeiso (2012) and Angeloni and Faia (2013) for Basel II procyclicality).[2] These potential adverse consequences have led to a substantial shift in the policy debate, which now not only focuses on the banks' individual solvency captured by bank adequacy requirements (microprudential policies), but also on the role of macroprudential tools in preventing and managing the build-up of financial imbalances. The new Basel III Accords, set to be fully implemented by 2018, intend to enforce banks to increase the quality of their assets, raise the capital adequacy ratio, hold countercyclical bank capital buffers and set loan loss provisions in a timely manner before credit risk materializes (see Basel Committee of Banking Supervision (BCBS) (2011) for further details and Saurina (2009) for a critical assessment of dynamic provisioning systems). The objectives of the Basel III regulatory measures are to enhance financial stability, encourage more restricted lending in economic booms, mitigate systemic risk and allow the financial sector to better absorb losses associated with an eruption of a negative credit cycle. Beyond the direct reforms Basel III imposes on the global banking system, can countercyclical bank capital buffers, which rise during economic upturns and thus limit credit growth, also promote overall macroeconomic stability? To answer this question it is important to fully analyze the interactions between the financial sector and the macroeconomic conditions. In this context, we need to comprehend the effectiveness of monetary policy rules in achieving price and output stability when credit market frictions and regulatory requirements prevail.

This paper contributes to the growing macrofinance literature by promoting a further understanding on financial-real sector linkages, and studying the interactions between bank capital regulation and monetary policy in a Dynamic Stochastic General Equilibrium (DSGE) model with a borrowing cost channel and endogenous financial frictions. These market imperfections include collateralized lending, financial regulation, risk of default at

[1] These papers include Gertler and Kiyotaki (2010), Gertler and Karadi (2011), Meh and Moran (2010), Gerali, Neri, Sessa and Signoretti (2010), and Christiano, Motto and Rostagno (2013), among others.

[2] In the literature of macrofinance, procyclicality refers to aspects of financial and/or economic policies which can exacerbate credit and real sector fluctuations, and not necessarily to a positive correlation between two variables. Therefore, countercyclical regulation is aimed at mitigating these amplification or procyclical effects.

the firm level, and commercial bank losses.[3] We show that default costs in the banking sector are covered by risk sensitive bank capital adequacy requirements, which in turn may initially mitigate procyclicality in financial variables. At the same time, credit risk induces further bank capital losses, resulting in an increase in the cost of bank capital as well as stricter regulatory requirements, both which lead to higher borrowing costs.[4] Firms in this setup must borrow from commercial banks to finance labour costs. Therefore, the refinance rate, bank capital and the various credit market frictions described above (all which endogenously impact the lending rate) translate into changes in the behaviour of the marginal costs and the rate of price inflation through the borrowing cost channel.[5] Similar types of short term borrowing costs have been utilized and empirically examined in the literature since the contribution of Ravenna and Walsh (2006). These papers include Chowdhury, Hoffmann and Schabert (2006), Tillmann (2008), Fernandez-Corugedo, McMahon, Millard and Rachel (2011) and De Fiore and Tristani (2013).[6] Building on this literature, the borrowing cost channel in our model is enhanced by a richer banking environment, regulatory requirements and various credit frictions, which can explain important links between the financial sector and the real business cycle.

The simulated model suggests that countercyclical financial regulation is very effective at fostering financial and price stability (by moderating the borrowing cost channel effect), whereas a mildly credit augmented Taylor rule performs well in terms of attenuating output fluctuations (through an intertemporal substitution effect). From a policy perspective we conclude that: a) If the economy is hit by credit shocks then by setting countercyclical bank capital requirements, regulatory authorities can achieve the anti-inflation target of monetary policy as well as reduce central bank losses (measured in terms of inflation and output gap volatility). In this state, central banks should react mainly to GDP and/or mildly to financial indicators and less to price inflation; b) Following technology shocks, macroprudential regulation can restore the traditional hawkish stance of monetary policy, which in combination yield the lowest welfare losses. Under these conditions, central banks can contribute to price stability through the standard demand channel of monetary policy without amplifying inflationary pressures via the monetary policy cost channel. Hence, for productivity shocks, there are no gains from a credit augmented monetary policy "lean-

[3] We use bank losses and default costs in the banking sector interchangeably throughout the paper.

[4] Bratsiotis, Tayler and Zilberman (2014) also study the interactions between financial frictions, reserve requirements (not included in this model) and monetary policy in a DSGE model with a role for investments and physical capital. In their paper the firms risk of default is fully transmitted to the bank's risk of default. Here we show that bank capital requirements can mitigate default costs in the banking system.

[5] Indeed, we refer to this channel as the "borrowing cost channel" and not the standard "cost channel of monetary transmission" as is common in this literature. The "cost channel of monetary policy", affected by changes in the policy rate, is only part of the wider "borrowing cost channel", which in our model is driven mostly by regulatory requirements and credit market frictions.

[6] At the same time, other papers, including Rabanal (2007) and Kaufmann and Scharler (2009) find limited evidence of the cost channel transmission mechanism. The issue of the cost channel is therefore still subject to debate, but for the purpose of this paper, this channel is employed to explain part of the linkages between the financial side and the real economy.

ing against the credit cycle". Our model therefore indicates that financial distortions, countercyclical regulation and different types of shocks significantly alter the transmission mechanism of monetary policy and its optimal behaviour.

This paper is related to the following strands of literature. First, it contributes to Agénor and Aizenman (1998) and its New Keynesian counterpart framework developed in Agénor, Bratsiotis and Pfajfar (2013), by introducing a rationale for bank capital (and explicitly modeling its costs), default costs in the banking sector, financial risk shocks originating in the banking system, countercyclical bank capital regulation and a credit augmented type monetary policy rule. More specifically, we evaluate macroprudential policies in a framework capable of generating a negative relationship between the loan rate spread and GDP, without relying on the costly state verification mechanism and borrowers' net worth used in the Bernanke, Gertler and Gilchrist (1999) financial accelerator type models.[7] In fact, the additional financial imperfections and Basel II type regulatory rules introduced in our model amplify the countercyclical correlation between output and borrowing costs, and induce further financial accelerator effects. The relatively small scale nature of our setup also allows us to clearly disentangle and intuitively demonstrate the different transmission mechanisms linking the credit market conditions to the macroeconomy, and explain the implications for optimal simple policy rules.

Second, this model relates to recent contributions which have studied the performance of countercyclical rules along with the conduct of a 'lean against the credit cycle' type of monetary policy. For example, in a simple monetary model with financial elements, N'Diaye (2009) shows that countercyclical regulation can support monetary policy in mitigating output fluctuations while maintaining financial stability. Kannan, Rabanal and Scott (2012), Angelini, Neri and Panetta (2012) and Angeloni and Faia (2013) illustrate that depending on the nature of the shock, a combination of a credit-augmented Taylor rule together with a Basel III-type countercyclical rule, may be optimal in minimizing a central bank loss function. Moreover, Suh (2014) demonstrates that macroprudential policy affecting directly the financial market conditions has a limited impact on prices as opposed to monetary policy. Contributing to these models, we employ a rich borrowing cost channel which highlights the importance of Basel III in promoting financial, price and macroeconomic stability, as well as the welfare detrimental aspects of conventional monetary policy. Indeed, even credit augmented Taylor rules generate only marginal benefits for financial shocks and have no role following supply shocks.

Third, following financial shocks we obtain a significant trade-off between output and inflation, supporting De Fiore and Tristani (2013) and Gilchrist, Schoenle, Sim and Zakrajsek (2014). In the latter, financially weak firms are more likely to increase prices during a crisis period as an attempt to maintain cash flows, leading to a rise in aggregate inflation and violating the so called 'divine coincidence' of monetary policy.[8] In the borrowing

[7] Most empirical evidence show a strong negative relationship between loan rate spreads and GDP fluctuations (see Nolan and Thoenissen (2009) and Gerali, Neri, Sessa and Signoretti (2010) for example).

[8] In the financial accelerator models which operate through investment demand, output and inflation exhibit a strong co-movement (apart from cost push shocks). Thus, lowering the policy rate can simultaneously stabilize both output and inflation.

cost channel framework of De Fiore and Tristani (2013), an aggressive easing of monetary policy under commitment is optimal in response to adverse financial shocks. Unlike their model, we generate a countercyclical loan rate spread regardless of the type of shock (more consistent with the data as explained above). Additionally, instead of characterizing a fully optimal (Ramsey) monetary policy, we study how credit market frictions *and* Basel III type rules interact with simple standard and augmented Taylor rules, and compute the optimal policy combination which minimizes macroeconomic volatility. To the best of our knowledge, this model is a first attempt to model the interplay between bank capital, countercyclical regulation and the role of standard and augmented monetary policy in a DSGE model with a borrowing cost channel altered by meaningful endogenous financial imperfections.

This paper proceeds as follows. Section 2 presents the model with a detailed analysis of the agents behaviour. Section 3 provides a discussion on the parameter calibration, whereas Section 4 simulates the model following financial and supply shocks. In Section 5 we examine the roles of monetary policy and macroprudential regulation in promoting overall macroeconomic stability. Section 6 concludes.

2 The Model

The economy consists of six types of agents: households (who are also labour suppliers), a final good (FG) firm, intermediate good (IG) firms, a competitive labour contractor, competitive commercial banks and a central bank, which also acts as the financial regulator.

At the beginning of the period and following the realization of aggregate shocks, the representative bank receives deposits from households, issues bank capital to satisfy regulatory requirements and decides on the loan rate using a break even condition. The risk in our model stems from the possibility of IG firms defaulting on their loans as their production is subject to idiosyncratic productivity shocks, which are unobservable when the loan contract is agreed. Furthermore, the loan rate decision of each bank is made in light of this risk, along with the bank's expected ability to obtain the IG firms' collateral seized in the case of default (explained below), bank capital requirements, and the costs of paying back gross interest on deposits and bank capital to households.[9] For a given loan rate, the IG firms decide on the level of employment, prices and loans, with the latter used to fund wage payments to households, who supply differentiated labour via the labour contractor.[10] At the same time, households choose the level of consumption, deposits and bank capital given their total income comprised of distributed profits, total returns from holding bank capital

[9] As bank capital prices and dividend policies resulting from changes in the price of equity are not modeled in this framework, bank capital in our model is treated more like bank debt rather than equity. In the Basel terminology, bank capital in this model therefore consists of "tier 2" capital and not "tier 1" capital, which consists of equity stock and retained earnings. Nevertheless, there is still an ongoing debate on whether under the new Basel III regulatory rules, banks would also be allowed to hold capital in the form of loss-absorbing debt such as contingent convertible bonds.

[10] The labour contractor supplies homogeneous labour to IG firms by aggregating the differentiated labour provided from households and paying each one of them its wages. Thus, the labour aggregator simply acts as an intermediary between households and IG firms.

and deposits from the previous period, as well as labour income.

At the end of the period, the idiosyncratic shocks and hence the firms who default are revealed. As loans are risky, the IG firms pledge output as collateral, which can be seized by the lender in a default scenario. In these bad states of nature, there is also a possibility that the *break even* bank does not recover any collateral and makes a loss. At the aggregate level, bank capital covers for these losses, which are also endogenously related to the firms' credit risk. Furthermore, households, acting as bank holders, know the aggregate state of the economy and can calculate banking sector losses. They account for these default costs by demanding a higher return on bank capital such that they are indifferent between holding risk free deposits and bank capital.

Finally, at the end of the period the commercial bank pays back gross return to households on deposits and bank capital, and all profits are distributed to households. We now turn to describe in more detail the behaviour of each agent in the economy.

2.1 Households

There is a continuum of households, indexed by $i \in (0,1)$, who consume, hold deposits, demand bank capital and supply differentiated labour to a labour aggregator.

The objective of each household i is to maximize the following utility function,

$$U_t = E_{i,t} \sum_{s=0}^{\infty} \beta^s \left\{ \frac{[C_{t+s}]^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} - \frac{H_{i,t+s}^{1+\gamma}}{1+\gamma} \right\}, \tag{1}$$

where $E_{i,t}$ is the expectations operator, conditional on the information of the i^{th} household available up to period t, and $\beta \in (0,1)$ denoting the discount factor. The term C_t denotes consumption at time t, and $H_{i,t}$ the time-t hours worked by household i. The term ς defines the intertemporal elasticity of substitution in consumption, while γ denotes the inverse of the Frisch elasticity of labour supply.

Households hold (real) bank capital, V_t, which pays an interest of i_t^V, and (real) bank deposits, D_t, which bear an interest rate of i_t^D. Hence, total returns from holding bank capital and deposits in period $t-1$ are respectively given by $(1-\xi_{t-1}^V)(1+i_{t-1}^V)V_{t-1}\frac{P_{t-1}}{P_t}$ and $(1+i_{t-1}^D)D_{t-1}\frac{P_{t-1}}{P_t}$, with P_t denoting the price of the final good. The term ξ_{t-1}^V denotes the bank capital risk premium, which is derived endogenously later in the text, but taken as given in the household's optimization problem. Also, in subsequent sections we explain how the risk premium on bank capital relates to the probability of firms defaulting on their loans (Φ_t). Further, households, acting as the bank owners, can calculate the aggregate losses in the banking system.

Following the realization of the aggregate shocks, each household supplies differentiated labour to the labour aggregator and earns a factor payment of $\frac{W_{i,t}}{P_t}H_{i,t}$, where $W_{i,t}$ denotes the nominal wage.

At the end of the period, households receive all profits from IG firms, the commercial banks and the final good firm, denoted respectively by $J_t^{IG} = \int_0^1 J_{j,t}^{IG}dj$, J_t^B and J_t^{FG}. In addition, households pay a lump-sum tax given by the term $Lump_t$ (in real terms).

Finally, once the value of the final good is realized at the end of the period, the representative household purchases it for consumption purposes. Thus, the household's (real) budget constraint can be written as follows,

$$\begin{aligned} C_t + D_t + V_t \quad \leq \quad & (1+i^D_{t-1})D_{t-1}\frac{P_{t-1}}{P_t} + (1-\xi^V_{t-1})(1+i^V_{t-1})V_{t-1}\frac{P_{t-1}}{P_t} + \\ & + \frac{W_{i,t}}{P_t}H_{i,t} + \int_0^1 J^{IG}_{j,t}dj + J^B_t + J^{FG}_t - Lump_t. \end{aligned} \tag{2}$$

2.1.1 Consumption, Savings and Bank Capital Decisions

The first order conditions with respect to C_t, D_t and V_t (taking the rate of returns and prices as given) yield the following solutions,

$$C_t^{-\frac{1}{\varsigma}} = \beta E_t(1+i^D_t)\frac{P_t}{P_{t+1}}C_{t+1}^{-\frac{1}{\varsigma}}, \tag{3}$$

$$(1+i^V_t) = \frac{(1+i^D_t)}{(1-\xi^V_t)}. \tag{4}$$

Equation (3) is the standard Euler equation determining the optimal consumption path. Equation (4) is the no arbitrage condition, relating the rate of return on bank capital to the risk free deposit rate. In equilibrium, the interest rate on bank capital is set as a premium over the deposit rate due to the default costs in the banking sector (derived later in the text).[11]

2.1.2 The Wage Decision

The wage setting environment follows Erceg, Henderson and Levin (2000), and Christiano, Eichenbaum and Evans (2005), where each household i supplies a unique type of labour ($H_{i,t}$) with $i \in (0,1)$. All these types of labour are then aggregated by a competitive labour contractor into one composite homogenous labour (N_t) using the standard Dixit-Stiglitz (1977) technology given by,

$$N_t = \left(\int_0^1 H_{i,t}^{\frac{\lambda_w-1}{\lambda_w}} di\right)^{\frac{\lambda_w}{\lambda_w-1}}, \tag{5}$$

with $\lambda_w > 1$ representing the constant elasticity of substitution between the different types of labour. The i^{th} household therefore faces the following demand curve for its labour,

$$H_{i,t} = \left(\frac{W_{i,t}}{W_t}\right)^{-\lambda_w} N_t, \tag{6}$$

[11] Markovic (2006) also derives a no arbitrage condition between the bank capital rate and the risk free rate, with the mark-up depending on an exogenously given risk of default (among other variables). In this model, the default costs in the banking sector, which determine the bank capital - deposit rate spread, are endogenous with respect to both the risk of default at the firm level and the bank capital to loan ratio.

where W_t denotes the aggregate nominal wage paid for one unit of the composite labour. The zero profit condition for the labour aggregator, obtained by substituting (6) in (5), yields the economy wide wage equation, $W_t = \left[\int_0^1 W_{i,t}^{1-\lambda_w} di\right]^{\frac{1}{1-\lambda_w}}$.

Calvo (1983)-type nominal rigidity is assumed in the wage setting such that in each period a constant fraction of $1-\omega_w$ workers are able to re-optimize their wages while a fraction of ω_w index their wages according to last period's price inflation rate (π_{t-1}). These non re-optimizing households therefore set their wages according to $W_{i,t} = \pi_{t-1} W_{i,t-1}$. Moreover, if wages have not been set since period t, then at period $t+s$ the real relative wage for household i becomes $\frac{W_{i,t+s}}{W_{t+s}} = \frac{\Pi^s W_{i,t}}{W_{t+s}}$, where $\Pi^s = \pi_t \times \pi_{t+1} \times .... \times \pi_{t+s-1}$. Consequently, the demand for labour in period $t+s$ is $H_{i,t+s} = \left(\frac{\Pi^s W_{i,t}}{W_{t+s}}\right)^{-\lambda_w} N_{t+s}$.

In equilibrium all re-optimizing households choose the same wage $(\widehat{W_t^*})$, and the optimal relative wage in a log-linearized form (denoted by hat) is given by $\widehat{\left(\frac{W_t^*}{W_t}\right)} = \left(\frac{\omega_w}{1-\omega_w}\right) \widehat{\pi_t^W}$, with $\widehat{\pi_t^W} \equiv \widehat{W_t} - \widehat{W_{t-1}}$ denoting the log-linearized wage inflation. In the absence of wage rigidities ($\omega_w = 0$), the real wage equals to the wage mark-up $(\frac{\lambda_w}{\lambda_w - 1})$ multiplied by the marginal rate of substitution between leisure and consumption (MRS_t). Specifically, $\frac{W_t}{P_t} = \frac{\lambda_w}{\lambda_w - 1} MRS_t$, where $MRS_t = N_t^{\gamma} C_t^{\frac{1}{\varsigma}}$ and $N_t = H_t$.[12]

Finally, as in Erceg, Henderson and Levin (2000) the wage inflation equation is shown to satisfy,

$$\widehat{\pi_t^W} = \beta E_t \widehat{\pi_{t+1}^W} + \frac{(1-\omega_w)(1-\beta\omega_w)}{(\omega_w)(1+\gamma\lambda_w)} \left[\widehat{MRS_t} - \widehat{\left(\frac{W_t}{P_t}\right)}\right], \tag{7}$$

where real wages evolve according to,

$$\widehat{W_t^R} \equiv \widehat{\left(\frac{W_t}{P_t}\right)} = \widehat{\left(\frac{W_{t-1}}{P_{t-1}}\right)} + \widehat{\pi_t^W} - \widehat{\pi_t^P}, \tag{8}$$

with $\widehat{\pi_t^P} \equiv \widehat{P_t} - \widehat{P_{t-1}}$ representing the log-linearized price inflation rate as a deviation from its steady state. The motivation for including sticky wages is twofold: First, sticky wages are necessary to match the sluggish and persistent behaviour of real wages observed in data, and are important for obtaining a persistent response of inflation without relying on implausible values for price stickiness (as in Christiano, Eichenbaum and Evans 2005). Second, wage stickiness is crucial for achieving a co-movement between output, real wages and labour following technology shocks, a feature which is difficult to capture in these class of models (see DiCecio (2009) for further details). Loans in this model are provided for working capital financing, and therefore in order to produce a plausible, data consistent and positive relationship between real wages, loan demand and GDP, it is essential to introduce wage rigidities. As shown later, real wages move countercyclically with the loan rate, and can mitigate a rise in credit risk following adverse shocks associated with higher borrowing costs. The behaviour of real wages is thus important for explaining part of the linkages between the financial system and real economy.

[12] The full derivation of the wage setting environment is provided upon request.

2.2 Final Good Firm

A perfectly competitive representative FG firm assembles a continuum of intermediate goods ($Y_{j,t}$ with $j \in (0,1)$), to produce final output (Y_t) using the standard Dixit-Stiglitz (1977) technology,

$$Y_t = \left(\int_0^1 Y_{j,t}^{\frac{\lambda_p - 1}{\lambda_p}} dj \right)^{\frac{\lambda_p}{\lambda_p - 1}}, \tag{9}$$

where $\lambda_p > 1$ denotes the constant elasticity of substitution between the differentiated intermediate goods. The FG firm chooses the optimal quantities of intermediate goods that maximize its profits, taking as given both the prices of the intermediate goods ($P_{j,t}$) and the final good price (P_t). This optimization problem yields the demand function for each intermediate good,

$$Y_{j,t} = Y_t \left(\frac{P_{j,t}}{P_t} \right)^{-\lambda_p}. \tag{10}$$

Imposing the above zero profit condition (equation 10) into equation (9) results in the usual definition of the final good price,

$$P_t = \left[\int_0^1 P_{j,t}^{1-\lambda_p} dj \right]^{\frac{1}{1-\lambda_p}}. \tag{11}$$

2.3 Intermediate Good Firms

A continuum of IG producers, indexed by $j \in (0,1)$, operate in a monopolistic environment and are subject to Calvo (1983)-type nominal rigidities in their price setting. Each IG firm j uses the homogeneous labour supplied by the labour contractor, and faces the following linear production function,

$$Y_{j,t} = Z_{j,t} N_{j,t}, \tag{12}$$

where $N_{j,t}$ and $Z_{j,t}$ are the amount of *homogenous* labour employed and the total productivity shock experienced by firm j, respectively. Moreover, the shock $Z_{j,t}$ follows the process,

$$Z_{j,t} = A_t \varepsilon_{j,t}^F. \tag{13}$$

The term A_t denotes a common economy wide technology shock which follows the $AR(1)$ process, $A_t = (A_{t-1})^{\varsigma^A} \exp(\alpha_t^A)$, where ς^A is the autoregressive coefficient and α_t^A a normally distributed random shock with zero mean and a constant variance. The expression $\varepsilon_{j,t}^F$ represents an idiosyncratic shock with a constant variance distributed uniformly over the interval $(\underline{\varepsilon}^F, \bar{\varepsilon}^F)$.

Every firm j must borrow from a representative commercial bank in order to pay households wages in advance. Specifically, let $L_{j,t}$ be the amount borrowed by firm j, then the (real) financing constraint must equal to,

$$L_{j,t} = W_t^R N_{j,t}. \tag{14}$$

2.3.1 The Default Space

Financing working capital needs bears risk and in case of default the commercial bank expects to seize firm's output ($Y_{j,t}$) with a probability of χ_t, with $\chi \in (0, 1)$ denoting the steady state value of this probability. In these bad states of nature, there is also a possibility of $(1 - \chi_t)$ that the *break even* bank cannot recover the IG firm's collateral and therefore makes a loss (similar to Jermann and Quadrini (2012)). The term χ_t is assumed to follow the $AR(1)$ shock process, $\chi_t = (\chi_{t-1})^{\varsigma^\chi} \exp(\alpha_t^\chi)$, where ς^χ denotes the degree of persistence while α_t^χ is a random shock with a normal distribution and a constant variance. A shock to the probability of recovering collateral (χ_t) represents a financial (credit) shock in this model, as it affects directly the value of output the bank can seize in case of default as well as the credit risk at the firm level.

In the good states of nature, where the firms do not default, each firm pays back the commercial bank principal plus interest on the loans granted. Consequently and in line with the willingness to pay approach to debt contracts, default occurs when the expected value of seizable output ($\chi_t Y_{j,t}$) is less then the amount that needs to be repaid to the lender at the end of the period. Specifically,

$$\chi_t Y_{j,t} < (1 + i_t^L) L_{j,t}, \tag{15}$$

where i_t^L denotes the interest rate on loans granted to IG firms.[13]

Let $\varepsilon_{j,t}^{F,M}$ be the cut-off value below which the IG firm decides to default. Thus, using equations (12) and (13), the threshold condition can be defined as,

$$\chi_t \left(A_t \varepsilon_{j,t}^{F,M} \right) N_{j,t} = (1 + i_t^L) L_{j,t}. \tag{16}$$

Substituting equation (14) and solving the above for $\varepsilon_{j,t}^{F,M}$ yields,

$$\varepsilon_{j,t}^{F,M} = \frac{1}{\chi_t A_t} (1 + i_t^L) W_t^R. \tag{17}$$

Therefore, the threshold value, from which the risk of default is derived later in the text, is related to the lending rate, aggregate technology shocks and the real wages. However, in our model, the loan rate *not* only depends on the risk free rate and the finance premium (as in Agénor, Bratsiotis and Pfajfar 2013), but *also* on the probability of the bank recovering collateral (credit risk shocks), the rate of return on bank capital and the bank capital-loan ratio (as shown in subsequent sections). Hence, both the loan rate and probability of default are affected by the nature of the regulatory regime.

2.3.2 Pricing of Intermediate Goods

The IG firm solves a two stage pricing decision problem as soon as the aggregate shocks in period t are realized. In the *first stage*, each IG producer minimizes the cost of employing

[13] Similar to Agénor and Aizenman (1998), we assume for simplicity that no IG firm defaults if the economy is at the good state of nature and the level of output is sufficiently high to cover for the loan repayment.

labour, taking its (real) effective costs ($(1+i_t^L)W_t^R$) as given. This minimization problem yields the real marginal cost,

$$mc_{j,t} = (1+i_t^L)W_t^R \frac{1}{Z_{j,t}}. \tag{18}$$

In the *second stage*, each IG producer chooses the optimal price for its good. Here Calvo (1983)-type contracts are assumed, where a portion of ω_p firms keep their prices fixed while a portion of $1-\omega_p$ firms adjust prices optimally given the going marginal costs and the loan rate (set at the beginning of the period). The firm's problem is to maximize the following expected discounted value of current and future real profits subject to the demand function for each good (equation 10), and taking the marginal costs as given. Formally that is,

$$\max_{P_{j,t+s}} E_t \sum_{s=0}^{\infty} \omega_p^s \Delta_{s,t+s} \left[\left(\frac{P_{j,t+s}}{P_{t+s}} \right)^{1-\lambda_p} Y_{t+s} - mc_{t+s} \left(\frac{P_{j,t+s}}{P_{t+s}} \right)^{-\lambda_p} Y_{t+s} \right], \tag{19}$$

where $\Delta_{s,t+s} = \beta^s \left(\frac{C_{t+s}}{C_t} \right)^{\varsigma^{-1}}$ is the total discount factor.[14]

Denoting P_t^* as the optimal price level chosen by each firm at time t, and using the definition of the total discount factor, the first order condition of the above problem with respect to P_t^* yields the optimal relative price equation,[15]

$$Q_t = \frac{P_t^*}{P_t} = \left(\frac{\lambda_p}{\lambda_p - 1} \right) \frac{E_t \sum_{s=0}^{\infty} \omega_p^s \beta^s C_{t+s}^{-\frac{1}{\varsigma}} Y_{t+s} mc_{t+s} \left(\frac{P_{t+s}}{P_t} \right)^{\lambda_p}}{E_t \sum_{s=0}^{\infty} \omega_p^s \beta^s C_{t+s}^{-\frac{1}{\varsigma}} Y_{t+s} \left(\frac{P_{t+s}}{P_t} \right)^{\lambda_p - 1}}, \tag{20}$$

with $Q_t = \frac{P_t^*}{P_t}$ denoting the relative price chosen by firms adjusting their prices at period t and $pm = \left(\frac{\lambda_p}{\lambda_p - 1} \right)$ representing the price mark-up.

Finally, using the aggregate price equation (11) with the Calvo sticky price assumption, and log-linearizing equation (20) yields the familiar form of the New Keynesian Phillips Curve (NKPC),

$$\widehat{\pi_t^P} = \beta E_t \widehat{\pi_{t+1}^P} + \frac{(1-\omega_p)(1-\omega_p \beta)}{\omega_p} \widehat{mc_t}. \tag{21}$$

In this model, the marginal cost is determined directly by the cost of borrowing from the commercial bank (from equation 18). Therefore, monetary policy, bank capital and the

[14] The IG firms are owned by the households and therefore each firm's discount value is $\beta^s \left(\frac{C_{t+s}}{C_t} \right)^{\varsigma^{-1}}$. Intuitively, $\left(\frac{C_{t+s}}{C_t} \right)^{\varsigma^{-1}}$ is the marginal utility value (in terms of consumption) of a one unit increase of IG firms profits in period t.

[15] The sibscript j is dropped because all re-optimizing firms choose the same price so everything becomes time dependent.

regulatory regime, all which impact the loan rate as shown in the next sections, have also a direct effect on the marginal cost and thus the rate of price inflation. To fix ideas, we refer to the channel which links between the loan rate, marginal cost and inflation as the borrowing cost channel.

2.4 The Banking Sector

2.4.1 Balance Sheet Identity

Consider a continuum of perfectly competitive representative banks indexed by $k \in (0,1)$, who can raise funds through either deposits (D_t), or issuing bank capital (V_t) in accordance with regulation (as explained below). Both deposits and bank capital are used to finance the IG firms labour costs and act as liabilities to households. Each bank k lends to a continuum of firms and therefore its balance sheet in real terms can be written as,[16]

$$L_t = D_t + V_t, \tag{22}$$

where $L_t \equiv \int_0^1 L_{j,t} dj$ is the aggregate lending to IG firms.

2.4.2 Lending Rate Decision

The lending rate is set at the beginning of the period before IG firms engage in their production activity and prior to their labour demand and pricing decisions. As IG firms may default on their loans at the end of the period due to idiosyncratic shocks, the repayments to the commercial bank, for a given contract, are uncertain. Each bank k expects to break even every period such that the expected income from lending to a continuum of IG firms is equal to the total costs of borrowing these funds (comprised of deposits and bank capital) from households. Specifically,

$$\begin{aligned} & \int_{\varepsilon_{j,t}^{F,M}}^{\bar{\varepsilon}^F} \left[(1+i_t^L)L_{j,t}\right] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F + \int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} \left[\chi_t Y_{j,t}\right] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F \\ = \; & (1+i_t^V)V_t + (1+i_t^D)D_t + cV_t, \end{aligned} \tag{23}$$

where $f(\varepsilon_{j,t}^F)$ is the probability density function of $\varepsilon_{j,t}^F$. The first element on the left hand side is the repayment to the bank in the non-default states while the second element is the expected return to the bank in the default states accounted for the probability the bank recovers collateral (χ_t).[17] The expression $(1+i_t^V)V_t + (1+i_t^D)D_t$ is the return to households for holding bank capital and saving deposits, which are both used to finance loans to IG firms. Furthermore, the bank faces a linear cost function when issuing bank capital, captured by the term cV_t, with $c > 0$. These costs are independent of the state of

[16] The aggregate lending from the banking sector is given by $\int_0^1 L_{k,t} dk$, where each bank k lends to contiumn of firms with identical loan demands. Because loans are identical for all banks the k subscript can be dropped.

[17] Recall that with probability $(1-\chi_t)$ the bank receives no collateral in the bad states of nature and therefore makes a loss.

the economy and reflect steady administrative costs associated with underwriting or issuing brochures for example. By contrast, the rate of return on bank capital is the main driving force of the *total* bank capital costs $(1+i_t^V+c)$, and endogenously rises following increased financial riskiness and lower output levels, as shown later in the simulations section.[18]

Turning now to the derivation of the lending rate note that,

$$\begin{aligned}\int_{\varepsilon_{j,t}^{F,M}}^{\bar{\varepsilon}^F}\left[(1+i_t^L)L_{j,t}\right]f(\varepsilon_{j,t}^F)d\varepsilon_{j,t}^F &\equiv \int_{\underline{\varepsilon}^F}^{\bar{\varepsilon}^F}\left[(1+i_t^L)L_{j,t}\right]f(\varepsilon_{j,t}^F)d\varepsilon_{j,t}^F - \\ &-\int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}}\left[(1+i_t^L)L_{j,t}\right]f(\varepsilon_{j,t}^F)d\varepsilon_{j,t}^F,\end{aligned}$$

where $\int_{\underline{\varepsilon}^F}^{\bar{\varepsilon}^F}\left[(1+i_t^L)L_{j,t}\right]f(\varepsilon_{j,t}^F)d\varepsilon_{j,t}^F \equiv \left[(1+i_t^L)L_{j,t}\right]$. Hence, equation (23) can be written as,

$$\begin{aligned}&\left[(1+i_t^L)L_{j,t}\right]-\int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}}\left[(1+i_t^L)L_{j,t}-(\chi_t Y_{j,t})\right]f(\varepsilon_{j,t}^F)d\varepsilon_{j,t}^F \\ =\;&(1+i_t^V+c)V_t+(1+i_t^D)D_t.\end{aligned} \tag{24}$$

Using the banks balance sheet (equation 22), substituting (16) for $\chi_t\left(A_t\varepsilon_{j,t}^{F,M}\right)N_{j,t}=(1+i_t^L)L_{j,t}$, and employing the value of output from the production function (equation 12) gives,

$$\begin{aligned}&\left[(1+i_t^L)L_{j,t}\right]-\int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}}\left[\varepsilon_{j,t}^{F,M}-\varepsilon_{j,t}^F\right]\chi_t A_t N_{j,t} f(\varepsilon_{j,t}^F)d\varepsilon_{j,t}^F \\ =\;&(1+i_t^V+c)V_t+(1+i_t^D)(L_{j,t}-V_t).\end{aligned} \tag{25}$$

Dividing by $L_{j,t}$, equation (25) can be written as,

$$\begin{aligned}i_t^L &= \left(i_t^V+c\right)\left(\frac{V_t}{L_{j,t}}\right)+\left(i_t^D\right)\left(1-\frac{V_t}{L_{j,t}}\right)+ \\ &+\frac{\int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}}\left[\varepsilon_{j,t}^{F,M}-\varepsilon_{j,t}^F\right]\chi_t A_t N_{j,t} f(\varepsilon_{j,t}^F)d\varepsilon_{j,t}^F}{L_{j,t}}.\end{aligned} \tag{26}$$

Real wages and the amount of labour employed are identical for each firm and therefore the volume of lending by each bank is also the same. Thus, the subscript j is dropped in what follows. Moreover, the threshold value $\varepsilon_{j,t}^{F,M}$ depends on the state of the economy

[18] From the technical point of view, the additional (exogenous) issuance cost per unit of bank capital (c) is also added to control in a more tractable way for the loan rate steady state value. All other variables which determine the loan rate behaviour are endogenous, and cannot be adjusted without altering the long run values of the other economic variables of the model.

(from 17) and hence is identical across all firms. Using the expression for $L_{j,t}$ (equation 14) and defining $\Delta_t = V_t/L_t$ as the total bank capital-loan ratio, equation (26) reduces to,

$$i_t^L = (\Delta_t)\left(i_t^V + c\right) + (1-\Delta_t)\left(i_t^D\right) + \frac{\chi_t A_t \int_{\underline{\varepsilon}^F}^{\varepsilon_t^{F,M}} \left[\varepsilon_t^{F,M} - \varepsilon_t^F\right] f(\varepsilon_t^F) d\varepsilon_t^F}{W_t^R}, \tag{27}$$

with $\frac{\chi_t A_t \int_{\underline{\varepsilon}^F}^{\varepsilon_t^{F,M}} \left[\varepsilon_t^{F,M} - \varepsilon_t^F\right] f(\varepsilon_t^F) d\varepsilon_t^F}{W_t^R}$ denoting the finance premium.

To find an explicit expression for the probability of default, it is assumed that ε_t^F follows a uniform distribution over the interval $(\underline{\varepsilon}^F, \bar{\varepsilon}^F)$. Therefore, its probability density is $1/(\bar{\varepsilon}^F - \underline{\varepsilon}^F)$ and its mean $\mu_\varepsilon = (\bar{\varepsilon}^F + \underline{\varepsilon}^F)/2$. The probability of default is given by,

$$\Phi_t = \int_{\underline{\varepsilon}^F}^{\varepsilon_t^{F,M}} f(\varepsilon_t^F) d\varepsilon_t^F = \frac{\varepsilon_t^{F,M} - \underline{\varepsilon}^F}{\bar{\varepsilon}^F - \underline{\varepsilon}^F}. \tag{28}$$

Thus, the probability of default depends on the range of the uniform distribution and the threshold value of the idiosyncratic shock (determined by equation 17).

2.4.3 The Bank Capital Risk Premium Rate

We now turn to derive the premium on a unit of bank capital (ξ_t^V), which determines the mark-up of the bank capital rate over the risk free deposit rate in the household's no arbitrage condition (equation 4). As explained earlier, the commercial banks set the loan rate in each period to the expected break even level. This implies that the price of loans is determined by the cost of deposits and bank capital, adjusted for the risk premium and the bank capital-loan ratio. Additionally, a fraction $(1-\chi_t)$ of banks make a loss due to their inability to retrieve collateral in the default states.

Households, who invest bank capital in all banks, know the aggregate level of firm default and are able to calculate aggregate losses in the banking sector.[19] Accounting for bank losses, which translate into bank capital default, ensures that deposits are a safe asset. The decision for households therefore involves calculating the bank capital default rate such that the no arbitrage condition (given by equation 4) is satisfied. Specifically,

$$\xi_t^V V_t = (1-\chi_t)\left[\int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} \left[\chi_t Y_{j,t}\right] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F\right]. \tag{29}$$

Identity (29) guarantees that the total losses on bank capital ($\xi_t^V V_t$) are equal to the value of collateral the failing banks expected to earn if they were able to retrieve $\chi_t Y_{j,t}$ in the

[19] Note that neither the bank nor the household are able to distinguish *ex ante* which banks will be unable to claim collateral. Only the proportion χ_t is known.

default states of nature.[20] Substituting equations (12), (13) and (14) in (29) yields,

$$\xi_t^V V_t = (1-\chi_t)\chi_t A_t \frac{L_t}{W_t^R}\left[\int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} \varepsilon_{j,t}^F f(\varepsilon_{j,t}^F) d\varepsilon_t^F\right].$$

Using the properties of the uniform distribution and rearranging, we obtain the risk premium for holding bank capital,

$$\xi_t^V = (1-\chi_t)\frac{L_t}{V_t}\left(\frac{\chi_t A_t}{W_t^R}\right)\left(\frac{\varepsilon_t^{F,M}+\underline{\varepsilon}^F}{2}\right)\Phi_t. \tag{30}$$

The bank capital premium rate is a function of the cost of default, $(1-\chi_t)\left(\frac{\chi_t A_t}{W_t^R}\right)\left(\frac{\varepsilon_t^{F,M}+\underline{\varepsilon}^F}{2}\right)\Phi_t$, which stems from the possibility of banks making a loss in the states of nature where firms default on their credit. The bank capital risk premium also depends negatively on the bank capital-loan ratio, which, in turn, is determined by the regulatory requirements. The role of bank capital regulation is therefore to solve the market failure associated with default costs in the banking system.

2.4.4 Bank Capital Requirements and Countercyclical Regulation

The representative bank is subject to risk sensitive bank capital requirements imposed by the central bank and set according to the Basel accords. At the beginning of each period the bank must issue a certain amount of capital that covers a given percentage of its loans to IG firms. As explained, lending to IG firms is of a risky nature and therefore the risk weight on loans is defined as ϑ_t. The bank capital requirement constraint in real terms is thus,

$$V_t = \rho_t \vartheta_t L_t, \tag{31}$$

with ρ_t denoting the "overall" bank capital-loan ratio (defined below). Under the foundation Internal Ratings Based (IRB) approach of Basel II (which remains essentially the same under Basel III), the risk weight on loans (ϑ_t) can be be related to the default probability of firms estimated by the banks as it is perceived as a measure of credit risk. That is, it is assumed that the default probability of firms is passed to the bank's risk weight on loans according to the following equation,

$$\vartheta_t = \left(\frac{\Phi_t}{\Phi}\right)^q, \tag{32}$$

where $q > 0$ represents the elasticity of the risk weight relative to deviations of the probability of default (Φ_t) from its steady state value (Φ).

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[20] Note that the remaining χ_t proportion of banks make a profit of $\int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} [(1-\chi_t)Y_{j,t}]\, f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F$ such that the aggregate gains from non-defaulting banks would offset exactly the losses outlined in equation (29). Banks are assumed not to be risk sharing and these profits are transferred back to households as a lump sum at the end of the period.

The general consensus in the literature is that risk sensitive bank capital requirements, in the form of Basel II, may amplify the procyclical effects already inherent in the financial system. In this section, a countercyclical regulatory rule is specified, in line with one of the recent proposals of the Basel Committee to reform Basel II and address this issue of procyclicality (see BCBS (2011)).

For this purpose, the "overall" capital ratio (ρ_t) is defined as follows,

$$\rho_t = \rho^D \rho_t^C. \tag{33}$$

The term $\rho^D \in (0,1)$ denotes the minimum capital adequacy requirements, also known as the *Cooke Ratio* (set by legislation), whereas ρ_t^C represents the countercyclical component. Under Basel II, the "overall" capital ratio is simply set at ρ^D with the cyclical element having no effect. Hence, under Basel II, $\rho_t = \rho^D$ and $\rho_t^C = \rho^C = 1$.

However, under the new proposed Basel III, the adjustment of the cyclical component can be related to deviations of the loan-output ratio from its steady state level.[21] Specifically,

$$\rho_t^C = \left(\frac{L_t/Y_t}{L/Y}\right)^{\theta^C}, \tag{34}$$

with $\theta^C > 0$ denoting an adjustment parameter. Hence, in periods of economic booms accompanied with an expansion in lending activities, a macroprudential rule like (34) tightens bank capital requirements such that the cost of credit rises (see equation 35 below). The rise in the loan rate, in turn, can mitigate the procyclical effects of the financial system and real economy.

2.4.5 The Transmission Channels of Risk and Bank Capital on the Loan Rate

Using equations (28), (32), (33), (34) and applying the characteristics of the uniform distribution, the lending rate equation (given by 27) reduces to,

$$i_t^L = i_t^D + \left[\rho^D \left(\frac{L_t/Y_t}{L/Y}\right)^{\theta^C} \left(\frac{\Phi_t}{\Phi}\right)^q\right](i_t^V - i_t^D + c) + \left(\frac{\chi_t A_t}{W_t^R}\right)\frac{\left(\bar{\varepsilon}^F - \underline{\varepsilon}^F\right)}{2}\Phi_t^2, \tag{35}$$

where the term $\left(\frac{\chi_t A_t}{W_t^R}\right)\frac{\left(\bar{\varepsilon}^F - \underline{\varepsilon}^F\right)}{2}\Phi_t^2$ is defined as the finance premium, which itself is also a positive function of the lending rate (from equations 17 and 28).

Equation (35) shows that the lending rate is positively related to the cost of borrowing deposits from households, the finance premium, the bank capital-deposit rate spread and

[21] Other authors who use the loan-output ratio to define a countercyclical regulatory rule include Christensen, Meh and Moran (2011) and Angelini, Neri, and Panetta (2012). These papers emphasize the role of the loan-output ratio as an important indicator of financial risk. Our results would not significantly change if we used loan deviations from steady state or credit growth (as in Kannan, Rabanal and Scott (2012), for example) as indicators to which a countercyclical rule should respond to. In our model, loans and output always move in the same direction, with loans being the more volatile variable. Hence, the effects of changes in credit always dominates the change in output such that the loan-output ratio is mainly driven by credit deviations.

the issuance cost of bank capital. The bank capital-deposit rate spread and the cost of issuing bank capital, in turn, are set as a proportion of the bank capital-loan ratio, which is determined by the Cooke Ratio, and the risk weight on loans. Under Basel III, the lending rate not only depends on the minimum adequacy requirement and the risk weight (the Basel II case) but also on the countercyclical regulatory rule defined by equation (34).

We identify various channels through which the probability of default impacts the loan rate. The first, defined as the *bank capital default channel*, stems from a combination of a positive level of default costs on bank capital and the no arbitrage condition, relating the bank capital rate to the deposit rate and the bank capital risk premium rate (ξ_t^V). The risk premium on bank capital, in turn, depends on the risk of default at the IG firm level and the bank capital-loan ratio (see equations 4 and 30). Second, the *finance premium channel*, arising from the positive correlation between the risk of default and the finance premium, which directly influences the cost of credit. Third, the probability of default affects the lending rate also through the *risk weight channel*, resulting from the positive relationship between the risk weight on loans and the risk of default. The latter channel is evident in the IRB approach of Basel II (and Basel III) while the first two channels prevail regardless of the regulatory regime.

The bank capital-loan ratio in our model has an ambiguous impact on the loan rate. On the one hand, tighter bank capital regulation increases the cost of credit through the direct positive relationship between i_t^L and $\frac{V_t}{L_t} = f(\vartheta_t(\Phi_t))$, (the risk weight channel). On the other hand, a rise in the bank capital-loan ratio reduces the risk premium on bank capital, thereby lowering the loan rate via the bank capital default channel (see equation 30). With higher bank capital requirements, bank losses can be spread over more units of bank capital resulting in an attenuation effect on the bank capital premium rate and the cost of credit. This result is consistent with the studies of Barth, Caprio and Levine (2004) and Coleman, Esho and Sharpe (2006), in which holding more bank capital allows banks to charge a lower spread on loans, where the spread depends positively on the risk of default. Intuitively, banks holding bank capital above the regulatory requirements are expected to face lower bankruptcy cost, thus allowing them to expand lending by reducing the interest rate charged on loans. Fonseca, Gonzalez and Pereira da Silva (2010) examine the pricing behaviour of more than 2,300 banks in 92 countries over the period 1990-2007, and show that holding bank capital buffers affect the bank loan rate and thus the risk of default. In our model, we endogenize the negative relationship between bank capital, aggregate losses in the banking sector and the risk of default.

Nevertheless, the risk premium on holding bank capital (ξ_t^V) is also directly positively related to the probability of default at the IG firm level (Φ_t) and this effect dominates the attenuating effect of $\frac{V_t}{L_t} = f(\vartheta_t(\Phi_t))$ on ξ_t^V and consequently on i_t^L. This is due to the elasticity of the risk weight (and thus bank capital requirements) with respect to deviations of the probability of default (q), which is assumed to be less than 1.[22] Hence, both the risk

[22] Having the strength of the risk weight channel (q) higher than unity can alter the results and weaken the effects of countercyclical bank capital requirements. However, most data indicate that the elasticity of bank adequacy requirements with respect to the risk of default (under the Foundation IRB approach of Basel II) is between 0.05 and 0.15 (see Covas and Fujita (2010) and Aguiar and Drumond (2009)).

weight and bank capital default channels amplify a rise in the loan rate following adverse shocks.

A key element in this setup is that the probability of default is a function of the loan rate, while the bank capital rate is a function of the probability of default and commercial bank losses (from the no arbitrage condition). Hence, an adverse shock, associated with falling levels output (collateral), leads to increased risk of default, which raises the bank capital rate and regulatory requirements. The increase in bank capital costs then translate into an amplified rise in the loan rate. Therefore, the probability of default, through its relationship with bank losses, regulatory requirements, the bank capital rate and the borrowing costs, aggravates the impact on the rest of the financial and economic variables. These frictions give rise to significant financial accelerator effects in this model.

2.5 Prudential Monetary Policy

The central bank targets the short term policy rate (i_t^R) according to the following log-linearized Taylor-type policy rule,[23]

$$\widehat{i_t^R} = \phi \widehat{i_{t-1}^R} + (1-\phi)\left[\phi_\pi \widehat{\pi_t^P} + \phi_Y \widehat{Y}_t + \phi_{L/Y}\left(\widehat{L_t} - \widehat{Y}_t\right)\right], \tag{36}$$

where $\widehat{\pi_t^P} \equiv \pi_t^P - \pi^{P,T}$ denotes inflation deviations from its target steady state value ($\pi^{P,T}$), $\widehat{Y}_t$ output deviations from its steady state value, $\phi \in (0,1)$ the degree of interest rate smoothing and $\phi_\pi, \phi_Y > 0$ coefficients measuring the relative weights on inflation and output deviations from their steady states, respectively.[24]

The new term added to the standard Taylor rule is given by $\phi_{L/Y}\left(\widehat{L_t} - \widehat{Y}_t\right)$, where $\phi_{L/Y} > 0$. Thus, the central bank sets its policy rate also in part to "lean against the credit cycle", and specifically to deviations of the loan-output ratio from its steady state level (as in Benes and Kumhof (2011), for example).[25] In this way, during an expansionary period, the probability of default and loan rate fall, both which further stimulate lending to IG firms and raise the loan-output ratio. Consequently, the policy rate rises and mitigates the initial decline in the lending rate, thereby dampening the expansion in credit and output. At the same time, an increase in the policy rate can also result in higher price inflation given the presence of the borrowing cost channel in this model.

[23] Using the no arbitrage condition and the fact that the commercial bank does not borrow from the central bank, the deposit rate is equal to the policy rate.

[24] Note that we include output in terms of deviations from its steady state value rather than Walsh's (2003) measure of output gap. Our specification is consistent with Faia and Monacelli (2007) and Meh and Moran (2010) among others.

[25] Benes and Kumhof (2011) also use credit deviations as a variable to which a prudential monetary policy responds to. Nevertheless, as explained earlier and as shown in the simulations below, loans are more volatile than output, with the two variables moving always in the same direction. Hence, using the loan-output ratio or just loans (both as deviations from steady state) in the Taylor rule produces very similar results.

2.6 Market Clearing Conditions

Equilibrium conditions must ensure that markets for goods, labour, loans, deposits and bank capital clear. The supply of loans by the commercial bank, the supply of deposits by households and bank capital issued in accordance with regulation, are all assumed to be perfectly elastic at the prevailing interest rates and therefore these markets always clear.

The seizable collateral $\chi_t Y_{j,t}$ in case of default is distributed to the households at the end of the period. Thus, the goods market equilibrium satisfies the condition that realized aggregate output is equal to aggregate consumption,[26]

$$Y_t = C_t. \tag{37}$$

3 Calibration

The model is calibrated, where applicable, within the range of the parameters proposed by Smets and Wouters (2003,2007) and Christiano, Eichenbaum and Evans (2005). The baseline calibration numbers are summarized in the following Table 1,

[26] The lost output in case of default is already incorporated in the goods market clearing condition. This is because households insure themselves against bank losses by requiring a higher premium on bank capital. Moreover, collateral in this model is given by the level of output (and thus consumption), which already is endogenously related to the probability of default.

Table 1: Calibrated Parameter Values

Parameter	Value	Description
β	0.99	Discount Factor
ς	1.00	Intertemporal Substitution in Consumption
γ	2.50	Inverse of the Frisch Elasticity of Labour Supply
λ_w	11.0	Elasticity of Demand - Labour
wm	1.10	Wage Mark-up
ω_w	0.80	Degree of Wage Stickiness
λ_p	6.00	Elasticity of Demand - Intermediate Goods
pm	1.20	Price Mark-up
ω_p	0.75	Degree of Price Stickiness
A	1.00	Average Productivity Parameter
$\bar{\varepsilon}^F$	1.36	Idiosyncratic Productivity Shock Upper Range
$\underline{\varepsilon}^F$	1.00	Idiosyncratic Productivity Shock Lower Range
χ	0.97	SS Probability of Banks Recovering Collateral
ρ	0.08	Capital Adequacy Ratio
θ^C	10.0	Adjustment Parameter in Countercyclical Rule
q	0.05	Elasticity of Risk Weight wrt Default Probability
c	0.10	Administrative Cost of Issuing Bank Capital
ϕ	0.80	Degree of Persistence in Interest Rate Rule
ϕ_π	1.50	Response of Policy Rate to Inflation Deviations
ϕ_Y	0.20	Response of Policy Rate to Output Deviations
$\phi_{L/Y}$	0.01	Response of Policy Rate to Credit Spreads
ξ^A	0.80	Degree of Persistence - Supply Shock
ξ^χ	0.80	Degree of Persistence - Credit Shock

Elaborating now on some parameters unique to this model; First, although the values for θ^C and $\phi_{L/Y}$ are determined optimally within a grid search in the policy experiments section, for illustrative purposes in the first simulation section, these values are set to 10.0 and 0.01, respectively. We conduct these initial counterfactual experiments under the assumption that the central bank places standard weights on output and inflation in the Taylor rule in order to highlight the transmission channels of these rules in isolation (later in the text we compute the optimal policy combination of countercyclical regulation together with standard and augmented Taylor rules).

Furthermore, the bank capital adequacy ratio (ρ) is set to 0.08, which represents a floor value under Basel II, while the elasticity of the risk weight with respect to the default probability (q) is calibrated at 0.05 (as estimated by Covas and Fujita (2010)).

Finally, we set the idiosyncratic productivity shock's range to $(1, 1.36)$, and the steady state probability of the bank recovering collateral (χ) to 97%. These values, together with a price mark-up of 20%, generate a steady state credit risk of 3.82%, a long run value of 2.54% for the return on bank capital and a loan rate of 5.16%.

4 Simulations

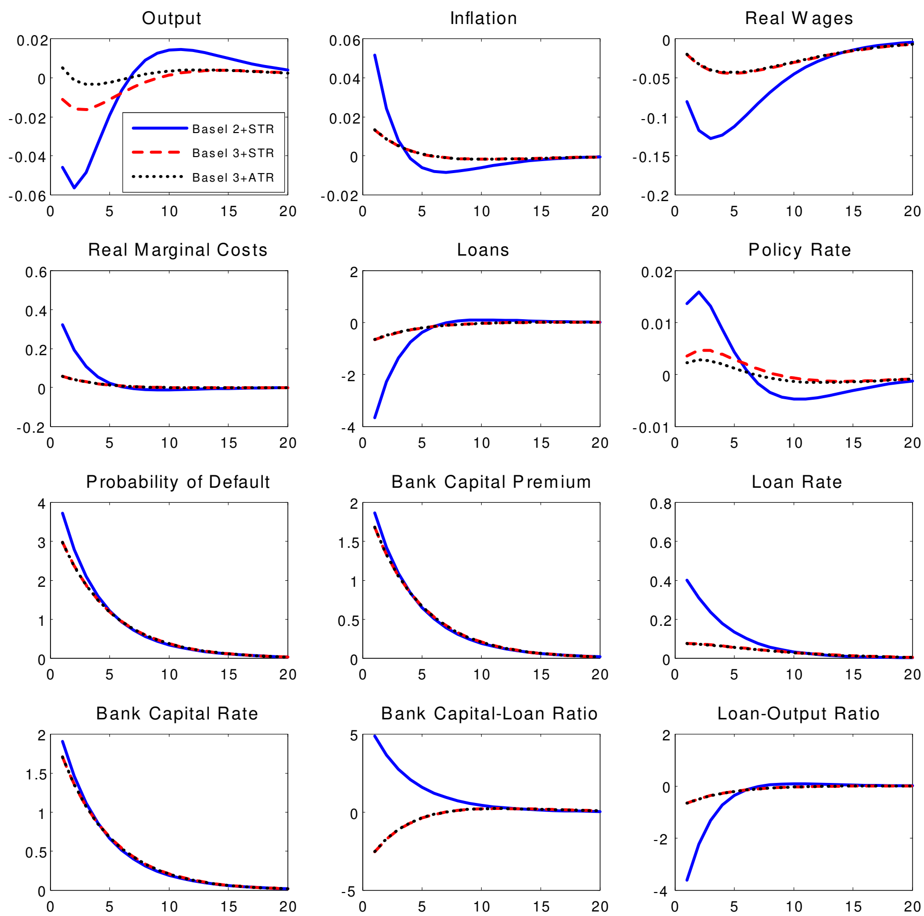
This section examines the cyclical behaviour of the macroeconomic and financial variables following both an adverse financial shock to χ_t and a negative supply shock to A_t. Under each shock a comparison is made between the following three regimes:

- *The first* baseline policy regime examines the case in which commercial banks are subject to a Basel II type rule, and the central bank following a standard Taylor rule (STR) ($q = 0.05, \theta^C = 0, \phi_{L/Y} = 0$, solid blue line).
- *The second* regime combines a Basel III type rule and a standard Taylor rule (STR) ($q = 0.05, \theta^C = 10.0, \phi_{L/Y} = 0$, dashed red line).
- *The third* regime combines a Basel III type rule and an augmented Taylor rule (ATR) ($q = 0.05, \theta^C = 10.0, \phi_{L/Y} = 0.01$, dotted black line).

4.1 Financial Shock

Figure 1 shows the impulse response functions of the main variables of the model following a 1% adverse financial shock under the three regimes mentioned above.

Figure 1 - Adverse Financial Shock



Note: Interest rates, inflation rate, the probability of default and the bank capital premium are measured in percentage point deviations from steady state. The rest of the variables are measured in terms of log-deviations from steady state.

The direct effect of a negative shock to collateral recovery (risk shock) is a rise in bank losses, probability of default and consequently the loan rate through the bank capital default and finance premium channels. Furthermore, as the bank is subject to risk sensitive bank capital regulation (Basel II), the risk weight on loans increases with the rise in the probability of default, inducing an amplification effect on the borrowing costs. It can be shown that both the bank capital default and risk weight channels lead to an exacerbation in the loan rate and risk of default behaviour compared to the case where the bank is not subjected to bank capital regulation or when there is no role for bank capital (which is the case in Agénor, Bratsiotis and Pfajfar (2013)).

The increase in the loan rate, coupled with the rise in risk, raises the marginal costs and price inflation through the borrowing cost channel. Moreover, the policy rate rises in response to the increase in prices, generating an additional upward shift in the bank capital and loan rates, and to a decline in aggregate demand. This result captures the trade-off between price inflation and output following financial shocks, as indicated by Gilchrist, Schoenle, Sim and Zakrajsek (2014). The rise in borrowing costs reduces also the demand for employment, which exerts a downward pressure on output and the demand for loans. The slight fall in real wages attenuates the rise in the marginal costs following financial shocks, although this mitigation effect is relatively small given that these shocks do not directly impact the marginal costs, inflation and thus the real wages.

Because the bank capital default and risk weight channels result in a further rise in the loan rate and probability of default, these channels have an additional procyclical effect on the key economic variables. Indeed, the loan rate and the various credit frictions link between the financial system and real economy through the borrowing cost channel, as explained above.

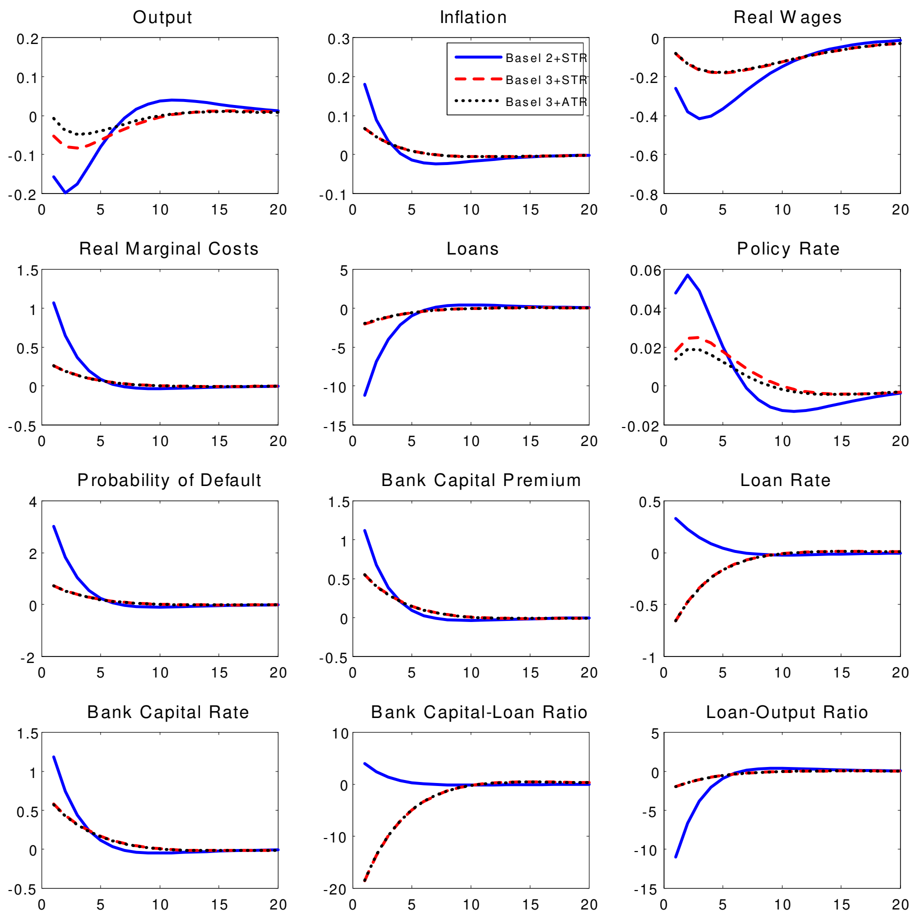
Turning now to discuss the implications of a countercyclical regulatory rule. Because the loan-output ratio declines following adverse credit shocks, the required ratio of bank capital to loans falls. As a result, bank capital requirements are loosened such that the loan rate response is mitigated. At the same time, lower bank capital requirements can also increase the loan rate via the bank capital default channel as shown earlier. However, given our calibration, the direct positive relationship between bank capital requirements and the loan rate dominates the negative link between the bank capital-loan ratio and the bank capital premium rate, which positively impacts the lending rate. The focus is therefore on the positive interaction between bank capital requirements and the borrowing costs, which exhibit a more moderate rise due to the imposition of a countercyclical regulatory rule. Consequently, risk rises by less, the demand for loans increases, and the rise in the marginal costs and inflation are less pronounced. All these effects lead to a mitigation effect on output as well.

With an augmented Taylor rule imposed in addition to a countercyclical regulatory rule, the impact of financial shocks on output and the policy rate is further dampened, while its effect on the rest of the variables is hardly noticeable compared to a standard Taylor rule. As the loan-output ratio falls, the central bank acts to raise the policy rate by less, which mitigates the fall in current consumption and output. Furthermore, the moderated rise in the policy rate attenuates slightly the increase in the loan rate, which acts initially to mitigate the response of inflation via the borrowing cost channel. However, as inflation falls, real wages and output increase, which create upward pressure on the marginal costs and inflation. Hence, the rise in real wages largely offset the fall in borrowing costs, which can also explain why the financial variables, marginal costs and inflation are largely unaffected by an augmented Taylor rule. Output, on the other hand, is directly related to the policy rate and therefore exhibits a much stronger reaction to a "lean against the credit cycle" type of monetary policy.

4.2 Supply Shock

Figure 2 shows the impulse response functions of the main variables of the model following a 1% negative supply shock under the three policy regimes considered,

Figure 2 - Negative Supply Shock



Note: Interest rates, inflation rate, the probability of default and the bank capital premium are measured in percentage point deviations from steady state. The rest of the variables are measured in terms of log-deviations from steady state.

A negative supply shock directly lowers the level of GDP and raises price inflation via the NKPC equation. As output falls, collateral declines as well, which through the finance premium channel, increases both the probability of default and the loan rate. The bank capital default and risk weight channels behave similarly to adverse credit shocks and result in a further amplification in the reaction of the loan rate and risk of default.

Beyond the direct impact of the productivity shock, the higher loan rate amplifies the response of price inflation through the borrowing cost channel. A rise in inflation lowers real wages, which in turn has an attenuating effect on the probability of default and the loan rate. Note that compared to adverse financial shocks, the drop in real wages is much stronger following technology shocks, which reduces the impact of the borrowing cost channel. However, given the nature of the supply shock and the various transmission channels of bank capital, which exacerbate the response of the loan rate, output falls, inflation rises and the demand for loans decrease. Finally, the policy rate rises in response to the hike in inflation, thereby creating an additional downward pressure on current consumption and output, and to a further increase in borrowing costs.

A countercyclical rule leads to similar results to the case of credit shocks although its effect on the bank capital-loan ratio and the loan rate is stronger. Intuitively, the demand for loans fall due to both the direct effect of a negative supply shock, and the borrowing cost channel. Moreover, the deviations in price inflation and wages stem mainly from the direct effect of the productivity shock rather than the secondary impact resulting from the loan rate behaviour. Risk shocks, nonetheless, impact wages and inflation through their effect on the lending rate, which then feeds into the rest of the economy via the borrowing cost channel. In other words, the borrowing cost channel following technology shocks is weaker compared to the case where the economy is hit by financial shocks. This implies that countercyclical regulation, which directly affects the loan rate, has a smaller effect on the real economy when compared to financial shocks, despite having a strong impact on the bank capital-loan ratio and the loan rate. As a result, the rise in the risk of default and bank capital losses is mitigated, leading to a muted response of the rest of the key variables in the economy via the borrowing cost, bank capital default, finance premium and risk weight channels, as illustrated above.[27] Overall, employment, loans and output, all exhibit a more volatile response as a result of the direct effect of the productivity shock on the marginal costs.

Adding a macroprudential Taylor rule results in a moderated rise in the policy rate due to the fall in the loan-output ratio. Hence, and similar to the case of credit shocks, households increase their current consumption through intertemporal substitution. As a result, the output response is mitigated, while the rest of the key variables are mostly unaffected.

In conclusion, following both financial and supply shocks, the effect of a countercyclical Basel III type rule on the real economy is similar such that the procyclicality effects are subdued, though at different magnitudes due to the nature of the shocks. Nevertheless, adding an augmented Taylor rule to a countercyclical regulatory rule acts mainly to stabilize

[27] As in the case of financial shocks, the direct positive link between the loan rate and bank capital requirements dominates the negative relationship between the bank capital-loan ratio and the loan rate arising from the bank capital default channel. Hence, the loan rate response is mitigated as a result of the lower bank capital requirements.

the response of output (with standard Taylor rule parameters and a low value for $\phi_{L/Y}$), while its impact on the other variables is relatively small. This result implies that a countercyclical rule may be a more effective tool in stabilizing the financial variables and inflation whereas output can be further stabilized using a policy rate tool reacting modestly also to deviations in the loan-output ratio.

However, given that loans in this setup are relatively volatile, using a higher value for $\phi_{L/Y}$ results in a further drop in the policy rate, which can *increase* output beyond its steady state level following adverse shocks, but at the expense of *higher* volatility in this variable. Moreover, the rising levels of GDP translate to a higher inflation rate through a standard demand channel linking positively the output gap to inflation. At the same time, the lower policy rate induces a further mitigation effect on the loan rate, which then attenuates the volatility of inflation via the borrowing cost channel. Therefore, we now turn to investigate the potential trade-off between maintaining output, price and financial stability, and find the optimal coefficients in the Taylor rule and countercyclical rule which minimize central bank losses.

5 Policy Experiments and The Role of Monetary Policy

This section provides an analysis of the optimal mix of the conventional and unconventional policy instruments outlined in the previous sections. For this purpose, unless otherwise mentioned, we use the parameter values used in the previous sections with the central bank aiming to minimize the following exogenous loss function,

$$Loss_t = \left(\widehat{\pi_t^P}\right)^2 + \lambda_y \left(\widehat{Y_t^G}\right)^2. \tag{38}$$

with $\widehat{Y_t^G} = \widehat{Y}_t - \widehat{Y_t^E}$ defined as the welfare relevant output gap, and $\widehat{Y_t^E} = \frac{(1+\gamma)}{(\frac{1}{\varsigma}+\gamma)} \widehat{Z_t}$ denoting the efficient level of output chosen by the social planner in a flexible price and wage economy, and without financial frictions. We assume the central bank aims to minimize a standard loss function consisting only of inflation and output gap volatilities, with a relatively strong weight on the latter. Microfounded versions of (38), obtained from taking a second order approximation of the utility function, tend to yield an extremely low value for the relative weight on the output gap (see Schmitt-Grohe and Uribe (2007) for example). However, in practice, central banks are also concerned about stabilizing the output gap. Moreover, it is not clear whether central banks try to maximize household's welfare, despite its appealing micro foundations. In general, central banks receive a mandate from the government which they have to fulfill. Therefore, and following the reasoning of Glocker and Towbin (2012), we use an ad-hoc loss function and acknowledge that in order to assess central bank losses, one must employ relative weights which come from outside the model. The relative weight on output gap volatility is assumed to be fixed at 0.5.[28]

We now compare between different policy rules (defined below) and examine which one performs best in terms of minimizing the loss function described above following 1%

[28] Our robustness checks showed that changing this parameter within plausible values (between 0.1 and 1) made little difference to our results presented below.

financial and supply shocks. Moreover, we investigate how the standard parameters in the Taylor rule adjust with the introduction of the various macroprudential instruments. The policy rules examined are: Policy I - Central bank responding only to inflation in the Taylor rule (solving for ϕ_π only and setting $\phi_Y = \phi_{L/Y} = \theta^C = 0$). Policy II - Central bank responding to inflation and output deviations in the Taylor rule (solving for ϕ_π and ϕ_Y and setting $\phi_{L/Y} = \theta^C = 0$). Policy III - Central bank responding to inflation, output deviations and the loan to GDP ratio (solving for ϕ_π, ϕ_Y and $\phi_{L/Y}$ and setting $\theta^C = 0$). Policy IV - A credit augmented Taylor rule and countercyclical bank capital regulation (solving for $\phi_\pi, \phi_Y, \phi_{L/Y}$ and θ^C). The optimal parameters which minimize the above loss function are searched within the following ranges: $\phi_\pi = [0 : 20]$, $\phi_Y = [0 : 20]$, $\phi_{L/Y} = [0 : 0.02]$ and $\theta^C = [0 : 10]$.[29]

Tables 2A and 2B show how the value of each policy rule changes with the introduction of additional policy instruments following credit and supply shocks, respectively.

Table 2A - Optimal Policy for Credit Shocks

	ϕ_π	ϕ_Y	$\phi_{L/Y}$	θ^C	Welfare Loss
Policy I	1.01	-	-	-	0.0119
Policy II	0.00	14.4	-	-	0.0035
Policy III	0.00	17.9	0.01	-	0.0035
Policy IV	0.80	20.0	0.00	10	0.0003

Table 2B - Optimal Policy for Supply Shocks

	ϕ_π	ϕ_Y	$\phi_{L/Y}$	θ^C	Welfare Loss
Policy I	3.30	-	-	-	0.7581
Policy II	4.80	0.20	-	-	0.6581
Policy III	4.80	0.20	0.00	-	0.6581
Policy IV	6.33	0.00	0.00	10	0.2030

Table 2A shows that when central banks follow an interest rate rule which only responds to inflation then the Taylor principle must hold ($\phi_\pi > 1$) for the real interest rate to increase. However, if the central bank chooses an interest rate rule that weighs both inflation and output, $\phi_\pi > 1$ is neither a necessary nor an optimal condition following credit shocks. The central bank in this case can harness expectations of output stabilization without the need for a large increase in the real interest rate. Thus, it becomes optimal to target output stabilization at a relatively high weight without responding to inflation fluctuations ($\phi_\pi = 0$).

Intuitively, for economies where credit plays a key role for firms financing, responding too aggressively to price inflation may result in higher borrowing costs and increased procyclicality in both prices and financial variables. In contrast, lowering the policy rate by

[29] We do not consider extreme values of the countercyclical rule weight ($\theta^C > 10$) as they deliver insignificant welfare gains, and could potentially produce large welfare losses should the policy maker misinterpret the source of the shock. Our upper limit of $\theta^C = 10$ is consistent with Agénor, Alper and Pereira da Silva (2013).

responding to output (following adverse credit shocks) reduces the inflationary impact of the borrowing cost channel, which leads to a rise in the level of GDP. At the same time, the higher output level and the lower policy rate have an inflationary impact through the demand channel, meaning that ϕ_y cannot be exceptionally high. Note that in this model output and loans move in the same direction, with the latter variable being more volatile. Therefore, targeting mildly the loan to GDP ratio or strongly the level of output in the Taylor rule yields very similar outcomes. Although not shown in the Table 2A, restricting the response to output to a lower range results in a higher, yet contained, response to the loan to GDP ratio. Nevertheless, as explained earlier, the central bank cannot react too strongly to the loan to GDP ratio (or to output) given its inflationary impact arising from the standard demand channel of monetary policy.

A macroprudential policy tool reacting to the loan to GDP ratio (θ^C) provides a more targeted approach as it directly contains the inflationary impact arising from the borrowing cost channel (see policy IV). A countercyclical rule reduces significantly central bank losses, and together with a strong response to output in the Taylor rule (or a mild reaction to the loan to GDP ratio if the weight on output were to be more restricted) provides the best policy outcome. Hence, what our results indicate is that for credit shocks, inflation targeting is not the correct approach to mitigate inflation and output volatility, as opposed to macroprudential regulation which can perform better.

As shown in Table 2B, supply shocks exhibit more standard results of inflation targeting given that the output gap (affected directly by the efficient level of output) and inflation fluctuate in the same direction, such that the trade-off between these variables is mitigated. Note however that the presence of the borrowing cost channel yields a lower optimal weight on inflation compared to values found in other studies (see Kannan, Rabanal and Scott (2012) for instance).[30] Moreover, as the loan to GDP ratio moves countercyclically with the output gap following supply shocks, a credit augmented Taylor rule amplifies the output gap which exacerbates central bank losses. In fact, the optimal weight on inflation increases with a mild response to output in the Taylor rule, as both act to mitigate the volatility of the output gap and inflation. Finally, increasing the weight on the countercyclical rule reduces losses due to its attenuating impact on the loan rate and therefore inflation. This also allows the central bank to weigh inflation more heavily and target the real interest rate in the Euler Equation (the standard demand channel of monetary policy). With a countercyclical rule and consequently a higher response to inflation in the Taylor rule, there is no gain from the monetary authority reacting to GDP fluctuations or the loan to GDP ratio.

We now turn to ask a slightly different question: assuming that the weight on output in the Taylor rule is fixed at $\phi_Y = 0.2$, how does inflation weight change with a countercyclical regulatory rule and a credit augmented interest rate rule, and what is the impact on welfare losses? Figures 3A (for credit shocks) and 3B (for supply shocks) show how switching on each macroprudential tool alters the optimal inflation weight parameters of a standard Taylor Rule and central bank losses.

[30] Values of $\lambda_y < 0.1$ in the central bank loss function produce a much smaller optimal ϕ_π, though not as low as in the case for financial shocks.

Figure 3A: Relationship Between ϕ_π, Macroprudential Policies and CB Losses - Credit Shocks

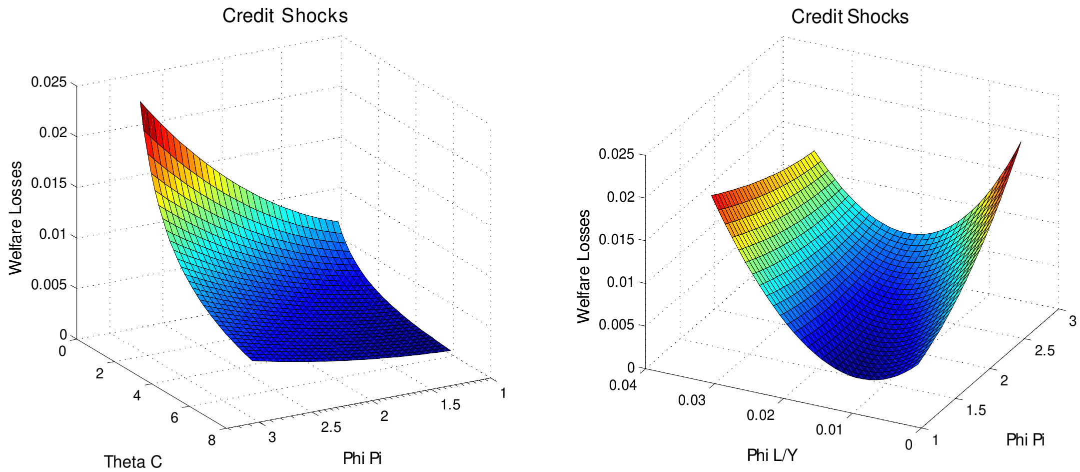
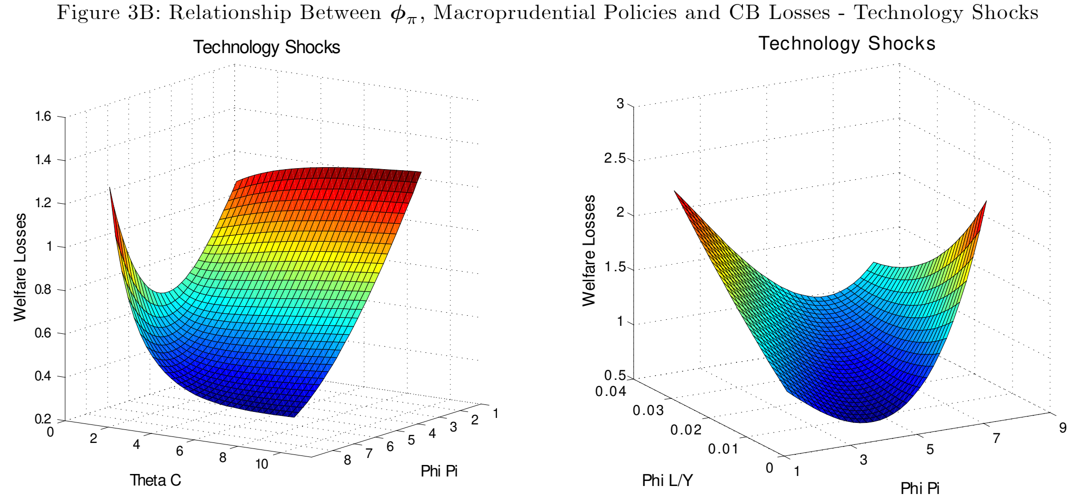


Figure 3B: Relationship Between ϕ_π, Macroprudential Policies and CB Losses - Technology Shocks



Similar to the implications described above for credit shocks, Figure 3A shows that a standard monetary policy (with a fixed normal weight on output) can be welfare detrimental. The lowest welfare losses is achieved when ϕ_π is at the lower bound, whereas a strong countercyclical rule (θ^C) or alternatively a low response to the loan to GDP ratio ($\phi_{L/Y}$) is welfare enhancing.

For supply shocks, Figure 3B illustrates that the optimal weight on inflation indeed increases with the introduction of a countercyclical rule. In this case, central banks can afford to react more strongly to the demand side of the economy and increase output further towards the efficient level, without exacerbating price fluctuations arising from the monetary policy cost channel. In other words, countercyclical regulation restores the strong anti-inflation stance in the Taylor rule, and the combination of both these rules yields the lowest welfare losses. Significantly, countercyclical regulation is only beneficial when combined with strong monetary policy (higher ϕ_π) and vice versa. For example, consider a positive supply shock where output increases by less than the efficient level. If monetary policy is too passive, the fall in the policy rate leaves the output gap at a suboptimally low level. Countercyclical regulation exacerbates this inefficiency by increasing the cost of borrowing, causing output to move even further below its efficient level. Finally, because the loan to GDP ratio is procyclical with respect to output, a credit augmented Taylor rule is not optimal unless the weight on inflation is suboptimally high.

6 Conclusion

In the aftermath of the great recession, it is clear that financial volatility and distortions in credit markets have severe macroeconomic implications, and that the role of the macroprudential toolkit ought to be investigated. We develop an important framework for identifying the interactions between the credit markets and the real business cycle, as well as evaluating the macroprudential roles of bank capital regulation and monetary policy in promoting economic and financial stability. Key features of this DSGE setup include endogenous credit frictions, all which impact the behaviour of the loan rate through various transmission channels. Changes in the cost of borrowing, in turn, have meaningful macroeconomic effects through the borrowing cost channel, linking between the lending rate, marginal costs and price inflation.

Bank capital adequacy requirements in this model cover for unexpected bank losses, resulting in a lower premium charged on bank capital, and hence reduced procyclicality in the financial system. At the same time, an increase in the firms risk of default leads to a rise in bank capital requirements, which through a direct cost effect, may aggravate loan rate volatility. We show that the latter effect in this model dominates such that risk sensitive bank capital requirements (Basel II regulation) amplify the movements in borrowing costs despite their role in attenuating bank losses. Numerical analyses confirm that countercyclical bank capital regulation (as proposed by Basel III) contribute to financial and economic stability. This policy instrument is shown to be particularly effective following credit shocks. Credit augmented monetary policy, on the other hand, is shown to be powerful in moderating output fluctuations but at the expense of inflationary pressures arising from the demand side of the economy.

Our results imply that central banks should reduce their inflation response in the Taylor rule in face of higher inflationary pressures and in the presence of a borrowing cost channel driven mainly by financial frictions. However, weakening the impact of the borrowing cost channel, by introducing countercyclical regulation, allows central banks to be more stringent on inflation and control for price volatility via the standard demand channel of monetary policy, especially following supply shocks. As for credit shocks which directly affect default risk, bank losses and the loan rate spread, Basel III type rules are extremely beneficial in terms of mitigating economic volatility. In this case, 'inflation targeting' through a typical Taylor rule is always welfare detrimental. These state contingent results indicate the importance of identifying the source of economic disturbances for the design of macroprudential regulation and monetary policy (in line with Kannan, Rabanal and Scott (2012)).

A key practical issue in the context of our paper and more generally in the macroprudential literature is how macroprudential policies can be implemented without adversely affecting the credibility of central banks and regulatory authorities? The common tradition in central banks is to target inflation in an aggressive manner, but if financial regulation can perform better in terms of achieving price stability, how would this impact the anti-inflation credibility of central banks? Hence, these macroprudential tools must be calibrated jointly with a transparent communication of the specific roles of central banks and the regulatory authorities, which in essence may achieve the objectives of traditional monetary policy in periods of financial distress.

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7 Appendix

Log Linearized System

The Euler Equation (with $\widehat{Y}_t = \widehat{C_t}$),

$$\widehat{Y}_t = E_t\widehat{Y_{t+1}} - \varsigma\left[\widehat{i_t^D} - E_t\widehat{\pi_{t+1}^P}\right].$$

Marginal Costs,

$$\widehat{mc_t} = \widehat{i_t^L} + \widehat{W_t^R} - \widehat{Z_t}.$$

Employment Demand,

$$\widehat{N_t} = -\lambda_w\left[\widehat{W_t^R} + \widehat{i_t^L}\right] + \widehat{Y}_t + (\lambda_w - 1)\widehat{Z_t}.$$

Marginal Rate of Substitution (with $\widehat{Y}_t = \widehat{C_t}$),

$$\widehat{MRS_t} = \frac{1}{\varsigma}\widehat{Y}_t + \gamma\widehat{N_t}.$$

Total Productivity Shock,

$$\widehat{Z_t} = \widehat{A_t} + \widehat{\varepsilon_t^F}.$$

Probability of Default,

$$\widehat{\Phi_t} = \left(\frac{\varepsilon^{F,M}}{\varepsilon^{F,M} - \underline{\varepsilon}}\right)\left(\widehat{i_t^L} + \widehat{W_t^R} - \widehat{A_t} - \widehat{\chi_t}\right).$$

Wage Inflation,

$$\widehat{\pi_t^W} = \beta E_t\widehat{\pi_{t+1}^W} + \frac{(1-\omega_w)(1-\beta\omega_w)}{(\omega_w)(1+\gamma\lambda_w)}\left[\widehat{MRS_t} - \widehat{W_t^R}\right].$$

Real Wages,

$$\widehat{W_t^R} = \widehat{W_{t-1}^R} + \widehat{\pi_t^W} - \widehat{\pi_t^P}.$$

Loans,

$$\widehat{L_t} = \widehat{W_t^R} + \widehat{N_t}.$$

Lending Rate,

$$\widehat{i_t^L} = \frac{1}{(1+i^L)}\left\{\begin{array}{c} \rho\left(1+i^V\right)\widehat{i_t^V} + (1-\rho)(1+i^D)\widehat{i_t^D} + \rho\left(i^V + c - i^D\right)\left[\widehat{\vartheta}_t + \widehat{\rho_t}\right] + \\ +\chi A\frac{\Phi^2}{W^R}\frac{(\bar{\varepsilon}-\underline{\varepsilon})}{2}\left[2\widehat{\Phi_t} - \widehat{W_t^R} + \widehat{A_t} + \widehat{\chi_t}\right] \end{array}\right\}.$$

Bank Capital Rate,

$$\widehat{i_t^V} = \widehat{i_t^D} + \frac{\xi^V}{(1-\xi^V)}\widehat{\xi_t^V}.$$

Bank Capital Premium Rate (Aggregate Bank Losses),

$$\widehat{\xi_t^V} = -\frac{\chi}{(1-\chi)}\widehat{\chi}_t + \widehat{L_t} - \widehat{V}_t + \widehat{\chi}_t + \widehat{A_t} - \widehat{W_t^R} + \widehat{\Phi}_t + \frac{(\varepsilon^{F,M})}{(\varepsilon^{F,M} + \underline{\varepsilon}^F)}\widehat{\varepsilon_t^{F,M}}.$$

Regulatory Bank Capital,

$$\widehat{V}_t = \widehat{\rho}_t + \widehat{\vartheta}_t + \widehat{L_t}.$$

with,

$$\widehat{\vartheta}_t = q\widehat{\Phi_t}.$$

$$\widehat{\rho}_t = \theta^C\left(\widehat{L_t} - \widehat{Y}_t\right).$$

Taylor Rule,

$$\widehat{i_t^R} = \phi\widehat{i_{t-1}^R} + (1-\phi)\left[\phi_Y\widehat{Y}_t + \phi_\pi\widehat{\pi_t^P} + \phi_{L/Y}\left(\widehat{L_t} - \widehat{Y}_t\right)\right] + \epsilon_t^{mp}.$$

The New Keynesian Phillips Curve (NKPC),

$$\widehat{\pi_t^P} = \beta E_t\widehat{\pi_{t+1}^P} + \frac{(1-\omega_p)(1-\omega_p\beta)}{\omega_p}\widehat{mc_t}.$$

Output Gap,

$$\widehat{Y_t^G} = \widehat{Y}_t - \widehat{Y_t^E}\ .$$

where $\widehat{Y_t^E} = \frac{(1+\gamma)}{(\frac{1}{\varsigma}+\gamma)}\widehat{Z_t}$.