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Macroprudential Regulation and the Role of Monetary Policy

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Abstract

We study the macroprudential roles of bank capital regulation and monetary policy in a borrowing cost channel model with endogenous financial frictions, driven by credit risk, bank losses and bank capital costs. These frictions induce financial accelerator mechanisms and motivate the examination of a macroprudential toolkit. Following credit shocks, countercyclical regulation is more effective than monetary policy in promoting price, financial and macroeconomic stability. For supply shocks, combining macroprudential regulation with a stronger anti-inflationary policy stance is optimal. The findings emphasize the importance of the Basel III accords and cast doubt on the desirability of conventional Taylor rules during periods of financial distress.

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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 economy. 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. Subsequently, a growing number of research papers and policy discussions on the role of banking, credit risk and bank capital in the transmission of demand, supply and importantly financial 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). 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 and price 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 nominal rigidities, a borrowing cost channel and endogenous financial frictions. These market imperfections include collateralized lending, financial regulation, risk of default at the firm level, and commercial bank losses.[3] The necessity for bank capital adequacy requirements is to absorb banking sector losses, which guarantees deposits are repaid in full. 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

[1] Meh and Moran (2010) and Gerali, Neri, Sessa and Signoretti (2010) examine the role of bank capital in propagating various shocks. Jermann and Quadrini (2012) and Christiano, Motto and Rostagno (2014), on the other hand, focus on the direct effects financial shocks have on the macroeconomy. These authors find that different types of financial shocks are important for explaining the dynamics of real variables.

[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.

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

regulatory requirements (under Basel II), 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, rate of price inflation and output 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), and De Fiore and Tristani (2013).[6,7] 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 (Basel III) is very effective at fostering financial and price stability, whereas credit spread augmented Taylor rules provide zero welfare gains. From a policy perspective we conclude that: a) If the economy is hit by credit shocks then by setting bank capital requirements responding countercyclically to credit risk, regulatory authorities can achieve the anti-inflation target of monetary policy as well as eliminate welfare losses (comprised of volatilities in price inflation, the output gap and the wage inflation gap). If this state is achieved, Taylor rules become redundant since the optimal monetary policy suggests leaving the refinance rate unchanged; b) Following technology shocks, aggressive macroprudential regulation can restore a more hawkish stance of monetary policy, which in combination yield the lowest central bank losses. Under these conditions, central banks can contribute further to price stability through the standard demand channel of monetary policy without amplifying inflationary pressures via the monetary policy cost channel. 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 also related to the following strands of literature. First, it contributes to Agénor

[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 initially 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] In a recent contribution which abstracts from credit default risk, De Paoli and Paustian (2013) also use the borrowing cost channel (loans for working-capital needs) to study the optimal interaction between macroprudential regulation (defined by a cyclical tax on the borrowing of firms) and monetary policy under discretion and commitment. We instead focus on optimal simple implementable rules, with monetary policy defined by a Taylor rule, and the macroprudential regulation conducted via countercyclical bank capital requirements.

[7] The majority of the literature on financial regulation uses credit lines to finance house purchases and investment in physical capital. We instead pursue a different approach and introduce loans to finance labour costs. This modeling viewpoint is also motivated by recent evidence which suggests that variations in working-capital loans following adverse financial shocks can have persistent negative effects on the economic activity (see Fernandez-Corugedo, McMahon, Millard and Rachel (2011) who estimate the cost channel for the U.K economy). This result, therefore, requires the examination of macroprudential policies when firms rely on external finance to support their production activities.

and Aizenman (1998) and its New Keynesian counterpart framework developed in Agénor, Bratsiotis and Pfajfar (2014), 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 optimal macroprudential and monetary policy rules 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.[8] 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 paper relates to recent contributions which have studied the interaction between macroprudential regulation and monetary policy in macroeconomic models. 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. In some DSGE contributions, Kannan, Rabanal and Scott (2012), Angelini, Neri and Panetta (2014), Rubio and Carrasco-Gallego (2014) 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 welfare losses. 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 and unconventional monetary policy rules.

Third, following financial shocks, driven by uncertainty about the banks ability to recover the collateral of defaulting firms, 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 in an attempt to maintain cash flows, leading to a rise in aggregate inflation and violating the so called 'divine coincidence' of monetary policy.[9] In the borrowing 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 welfare losses and macroeconomic volatility. To the best of our knowledge, this paper 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

[8]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).

[9]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.

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 simple and implementable optimal policy rules which minimize a micro-founded welfare loss function. Section 6 concludes.

2 The Model

The economy consists of five types of agents: households (who are also labour suppliers), a final good (FG) firm, intermediate good (IG) firms, 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.[10] 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.[11] 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 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 capital holders, know the aggregate state of the economy and can calculate ex-ante 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.

[10] 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.

[11] 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.

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,

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

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 invest in (real) bank capital, V_t, which pays a gross interest of R_t^V, and hold (real) bank deposits, D_t, which bear a gross interest rate of R_t^D. Hence, total returns from holding bank capital and deposits in period $t-1$ are respectively given by $(1-\xi_{t-1}^V)R_{t-1}^V V_{t-1}(P_{t-1}/P_t)$ and $R_{t-1}^D D_{t-1}(P_{t-1}/P_t)$, 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 ex-ante 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 $(W_{i,t}/P_t)\,H_{i,t}$, 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 reads as,

$$\begin{aligned} C_t + D_t + V_t \quad \leq \quad & R_{t-1}^D D_{t-1} \frac{P_{t-1}}{P_t} + (1-\xi_{t-1}^V) R_{t-1}^V V_{t-1} \frac{P_{t-1}}{P_t} + \\ & + \frac{W_{i,t}}{P_t} H_{i,t} + \int_0^1 J_{j,t}^{IG} dj + J_t^B + J_t^{FG} - Lump_t. \end{aligned} \tag{2}$$

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,

$$C_t^{-\frac{1}{\varsigma}} = \beta E_t R_t^D \frac{P_t}{P_{t+1}} C_{t+1}^{-\frac{1}{\varsigma}}, \tag{3}$$

$$R_t^V = \frac{R_t^D}{(1-\xi_t^V)}. \tag{4}$$

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 ex-ante default costs in the banking sector (derived later in the text).[12]

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,

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

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 $(W_{i,t+s}/W_{t+s}) = \Pi^s W_{i,t}/W_{t+s}$, 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 $H_{i,t+s} = (\Pi^s W_{i,t}/W_{t+s})^{-\lambda_w} N_{t+s}$.

In equilibrium all re-optimizing households choose the same wage (W_t^*), and the optimal relative wage in a log-linearized form (denoted by hat) is given by $(\widehat{W_t^*/W_t}) = [\omega_w/(1 - \omega_w)] \widehat{\pi_t^W}$, 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 $[\lambda_w / (\lambda_w - 1)]$ multiplied by the marginal rate of substitution between leisure and consumption (MRS_t). Specifically, $(W_t/P_t) = [\lambda_w / (\lambda_w - 1)] MRS_t$, where $MRS_t = N_t^\gamma C_t^{\frac{1}{\varsigma}}$ and $N_t = H_t$.[13]

[12] 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 our 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.

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

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 obtaining implementable optimal policy rules following *supply shocks*, which would otherwise produce abnormally high optimal inflation coefficient weights in the Taylor rule (see Schmitt-Grohé and Uribe (2007)). Given that this paper examines implementable optimal policy rules and their interactions with one another, there is an appeal in having a benchmark optimal inflation coefficient within an unbounded reasonable range.

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,

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

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,

$$Z_{j,t} = A_t \varepsilon^F_{j,t}. \tag{13}$$

The term A_t denotes a common economy wide technology shock which follows the $AR(1)$ process, $A_t = (A_{t-1})^{\varsigma^A} \exp(\alpha^A_t)$, where ς^A is the autoregressive coefficient and α^A_t a normally distributed random shock with zero mean and a constant variance. The expression $\varepsilon^F_{j,t}$ represents an idiosyncratic shock with a constant variance distributed uniformly over the interval $(\underline{\varepsilon}^F, \bar{\varepsilon}^F)$.[14]

Every firm j must borrow from a representative commercial bank in order to pay households wages in advance.[15] Specifically, let $L_{j,t}$ be the amount borrowed by firm j, then the (real) financing constraint must equal to,

$$L_{j,t} = W^R_t N_{j,t}. \tag{14}$$

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, $\chi_t = (\chi_{t-1})^{\varsigma^\chi} \exp(\alpha^\chi_t)$, where ς^χ denotes the degree of persistence while α^χ_t 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,

$$\chi_t Y_{j,t} < R^L_t L_{j,t}, \tag{15}$$

where R^L_t denotes the interest rate on loans granted to IG firms.[16]

[14] We use the uniform distribution in order to generate plausible data-consistent steady state risk of default and loan rate spreads as explained in the parameterization section. This simple distribution also allows for a closed-form expression for credit risk. See also Faia and Monacelli (2007) who adopt a similar approach.

[15] For the purpose of this paper we abstract from net worth and firms financing loans via debt and equity (which is the case in Jermann and Quadrini (2012)). Instead, we follow the borrowing cost channel literature, initiated by Ravenna and Walsh (2006), by assuming that firms must borrow from the commercial bank to fund production activity. This modeling framework (which has empirical support as mentioned in the introduction) allows us to highlight the importance of the Basel III accords in a transparent way as shown below.

[16] 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.

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,

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

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

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

Therefore, the threshold value is related to the lending rate, aggregate technology shocks and the real wages and is identical across all firms. 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 (2014)), but *also* on the probability of the bank recovering collateral (credit risk shocks), the total unit costs of 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.

Given the uniform properties of ε_t^F we can write an explicit expression closed-form solution for the probability of default,

$$\Phi_t = \int_{\underline{\varepsilon}^F}^{\varepsilon_t^{F,M}} f(\varepsilon_t^F) d\varepsilon_t^F = \frac{\varepsilon_t^{F,M} - \underline{\varepsilon}^F}{\bar{\varepsilon}^F - \underline{\varepsilon}^F}. \tag{18}$$

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 labour, taking its (real) effective costs ($R_t^L W_t^R$) as given. This minimization problem yields the real marginal cost,[17]

$$mc_{j,t} = \left(R_t^L W_t^R \right) / Z_{j,t}. \tag{19}$$

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,

$$\max_{P_{j,t+s}} E_t \sum_{s=0}^{\infty} \omega_p^s \Delta_{s,t+s} \left[\left(\frac{P_{j,t+s}}{P_{t+s}} \right)^{1-\lambda_p} Y_{t+s} - mc_{t+s} \left(\frac{P_{j,t+s}}{P_{t+s}} \right)^{-\lambda_p} Y_{t+s} \right], \tag{20}$$

where $\Delta_{s,t+s} = \beta^s \left(C_{t+s}/C_t \right)^{\varsigma^{-1}}$ is the total discount factor.[18]

Denoting P_t^* as the optimal price level chosen by each firm at time t, and using the definition of

[17] Below we show that the bank sets the loan rate based on the IG firm's default decision and threshold default value. Therefore, the risk of default has also a direct effect on the IG firms marginal costs through its endogenous impact on the cost of borrowing.

[18] 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,

the total discount factor, the first order condition of the above problem with respect to P_t^* yields the optimal relative price equation,[19]

$$\frac{P_t^*}{P_t} = \left(\frac{\lambda_p}{\lambda_p - 1}\right) \frac{E_t \sum_{s=0}^{\infty} \omega_p^s \beta^s C_{t+s}^{-\frac{1}{\varsigma}} Y_{t+s} mc_{t+s} \left(\frac{P_{t+s}}{P_t}\right)^{\lambda_p}}{E_t \sum_{s=0}^{\infty} \omega_p^s \beta^s C_{t+s}^{-\frac{1}{\varsigma}} Y_{t+s} \left(\frac{P_{t+s}}{P_t}\right)^{\lambda_p - 1}}, \tag{21}$$

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

Finally, using the aggregate price equation (11) with the Calvo sticky price assumption, and log-linearizing equation (21) yields the familiar form of the New Keynesian Phillips Curve (NKPC),

$$\widehat{\pi_t^P} = \beta E_t \widehat{\pi_{t+1}^P} + \frac{(1-\omega_p)(1-\omega_p \beta)}{\omega_p} \widehat{mc_t}. \tag{22}$$

In this model, the marginal cost is determined directly by the cost of borrowing from the commercial bank (from equation 19). Therefore, monetary policy, bank capital and the 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 and output. To fix ideas, we refer to the channel which links between the loan rate, marginal cost, inflation and output 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,[20]

$$L_t = D_t + V_t, \tag{23}$$

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

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$\left(\frac{C_{t+s}}{C_t}\right)^{\varsigma^{-1}}$ is the marginal utility value (in terms of consumption) of a one unit increase of IG firms profits in period t.

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

[20] 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.

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,

$$\begin{aligned} & \int_{\varepsilon_{j,t}^{F,M}}^{\bar{\varepsilon}^F} \left[R_t^L L_{j,t}\right] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F + \int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} \left[\chi_t Y_{j,t}\right] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F \\ = \quad & R_t^V V_t + R_t^D D_t + cV_t, \end{aligned} \tag{24}$$

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).[21] The expression $R_t^V V_t + R_t^D D_t$ is the return to households for investing in 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 the economy and reflect steady administrative costs associated with underwriting or issuing brochures for example. One can also think of these costs as a tax advantage of debt over equity (not explicitly modeled here), which increases the spread between the overall cost of capital $(R_t^V + c)$ and the rate on deposits (R_t^D). Following the derivation of the loan rate and the bank capital risk premia, we discuss in more detail why including these costs are important in this framework.

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

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

where $\int_{\underline{\varepsilon}^F}^{\bar{\varepsilon}^F} \left[R_t^L L_{j,t}\right] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F \equiv R_t^L L_{j,t}$. Hence, equation (24) can be written as,

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

Using the banks balance sheet (equation 23), substituting (16) for $\chi_t \left(A_t \varepsilon_{j,t}^{F,M}\right) N_{j,t} = R_t^L L_{j,t}$, and employing the value of output from the production function (equation 12) gives,

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

[21] Recall that with probability $(1 - \chi_t)$ the bank receives no collateral in the bad states of nature and therefore makes a loss. However, at the aggregate break-even level, the banking sector makes zero profits.

Dividing by $L_{j,t}$, equation (26) can be written as,

$$R_t^L = (R_t^V + c)\left(\frac{V_t}{L_{j,t}}\right) + (R_t^D)\left(1 - \frac{V_t}{L_{j,t}}\right) + \qquad (27)$$
$$+\frac{\int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} \left[\varepsilon_{j,t}^{F,M} - \varepsilon_{j,t}^F\right] \chi_t A_t N_{j,t} f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F}{L_{j,t}}.$$

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. Using the expression for $L_{j,t}$ (equation 14), substituting (17) and defining $\Delta_t = V_t/L_t$ as the total bank capital-loan ratio, then equation (27) reduces to,

$$R_t^L = \nu_t \left[\Delta_t(R_t^V + c) + (1 - \Delta_t)R_t^D\right], \qquad (28)$$

where $\nu_t \equiv \left[1 - \frac{\int_{\underline{\varepsilon}^F}^{\varepsilon_t^{F,M}} \left[\varepsilon_t^{F,M} - \varepsilon_t^F\right] f(\varepsilon_t^F) d\varepsilon_t^F}{\varepsilon_t^{F,M}}\right]^{-1} > 1$ is defined as the finance premium.

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, 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 suffer a loss due to their inability to retrieve collateral from the firms who default.

Households, who invest bank capital in all banks, know the aggregate level of firm default and are able to calculate aggregate ex-ante losses in the banking sector.[22] 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,

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

Identity (29) guarantees that the total losses on bank capital ($\xi_t^V V_t$) are equal to the value of collateral the banks expected to earn if they were able to retrieve $\chi_t Y_{j,t}$ in the default states of nature, weighted by the probability of being a loss-incurring bank $(1 - \chi_t)$.[23] Combining and substituting equations (12), (13), (14) and (17) and using the properties of the uniform distribution

[22]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.

[23]Note that the remaining χ_t proportion of banks make a profit of $\int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} \left[(1 - \chi_t)Y_{j,t}\right] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F$ 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.

in (29) results in the risk premium for holding bank capital,

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

The bank capital premium rate is a function of the cost of default, $(1-\chi_t)\frac{L_t}{V_t}R_t^L\left(\frac{\varepsilon_t^{F,M}+\underline{\varepsilon}^F}{2\varepsilon_t^{F,M}}\right)\Phi_t$, 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 upshot is that the funds raised through the premium on bank capital are necessary to guarantee that all loss-incurring banks are able to honour their commitment towards depositors, whilst households are indifferent between investing in bank capital and deposits.

2.4.4 Bank Capital Requirements and Countercyclical Regulation

The representative bank is subject to minimum 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. The bank capital requirement is set equal to a simple exponential function,

$$\frac{V_t}{L_t} \equiv \Delta_t = (\Delta_{t-1})^{\phi_\Delta}\left[\rho\left(\frac{\Phi_t}{\Phi}\right)^{\theta^C}\right]^{1-\phi_\Delta}, \tag{31}$$

with ρ denoting the minimum capital adequacy requirements, also known as the *Cooke Ratio* (set by legislation). The term $\phi_\Delta \in (0,1)$ denotes a persistence parameter capturing the idea of policy makers altering required capital very smoothly. This is in part due to implementations lags, where banks may not be able to raise substantial amount of capital quickly, and because policy makers can be uncertain as to the macroeconomic impact of their actions. The term θ^C is an adjustment parameter which allows for dynamic bank capital requirements responding to deviations in cyclical risk.[24]

Through equation (31), we can examine the differences between Basel I, Basel II and Basel III regulatory regimes. Specifically, $\theta^C = 0$ reproduces the Basel I regime, in which the capital ratio is fixed and set to $\rho = 0.08$. Values of $\theta^C > 0$ mimic the minimum capital requirements under the foundation Internal Ratings Based (IRB) of Basel II, where the regulatory ratio increases with the perceived credit risk in the banks' loan portfolio. Negative values for $\theta^C < 0$ would imply that bank capital requirements increase (decrease) in periods of low (high) credit risk. As the risk of default in our model is endogenously and negatively related to output and lending, imposing $\theta^C < 0$ means that bank capital requirements should be loosened (tightened) during economic recessions

[24] Our specification for bank capital requirements is similar to Angeloni and Faia (2013), who relate bank capital directly to deviations of output from its steady state level. Because risk in our model is endogenously and negatively linked to output and lending, responding directly to the business/financial cycle would produce similar policy implications. Some models, which abstract from an endogenous risk of default, use loans or the loan-output ratio to define a countercyclical regulatory rule. Christensen, Meh and Moran (2011) and Angelini, Neri, and Panetta (2014), for example, emphasize the role of the loan-output ratio as an important indicator of financial risk.

(expansions). This type of countercyclical bank capital requirement rule is consistent with the new proposed Basel III accords (see BCBS (2011)).

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

Applying the characteristics of the uniform distribution and the bank capital requirement (31), the lending rate equation (given by 28) reduces to,

$$R_t^L = \nu_t \left\{ R_t^D + (\Delta_{t-1})^{\phi_\Delta} \left[\rho \left(\frac{\Phi_t}{\Phi} \right)^{\theta^C} \right]^{1-\phi_\Delta} (R_t^V + c - R_t^D) \right\}, \tag{32}$$

where Φ_t is determined by (17) and (18), R_t^V by (4) and (30), and $\nu_t \equiv \left[1 - \frac{(\bar{\varepsilon}^F - \underline{\varepsilon}^F)}{2\varepsilon_t^{F,M}} \Phi_t^2 \right]^{-1} > 1$ is defined as the finance premium. The risk premium (ν_t) is also a positive function of the lending rate (from equations 17 and 18). As a clear analytical solution to the quadratic loan rate equation is unattainable, we resort to numerical solutions which illuminate the channels explained in this section.[25]

Equation (32) 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 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 (ρ), and the cyclical adjustment parameter (θ^C) prevailing under Basel II or Basel III.

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, under Basel II and Basel III, the probability of default affects the lending rate through the *bank capital requirement channel,* in which the sign of θ^C determines the direction of adjustment in bank capital.

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 R_t^L and the positive spread $R_t^V + c - R_t^D$ (set as a fraction of $\Delta_t = V_t/L_t$). 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, there is a higher equity base to absorb losses resulting in an attenuation effect on the bank capital premium rate, the bank capital-deposit rate spread and the cost of credit.

The decline in the bank capital risk premium brought about by the higher capital ratio is consistent with the logic of the Modigliani and Miller (1958) theorem and supported by a large body of empirical evidence (see Barth, Caprio and Levine (2004); Coleman, Esho and Sharpe

[25] However, in the appendix we solve the loan rate equation in steady state using some simplifying assumptions, which helps to better understand the role of bank capital requirements.

(2006); and Kashyap, Stein and Hanson (2010)). Moreover, Admati and Hellwig (2014) argue that bank capital is inexpensive and lowers the risk premium on equity, leading also to fewer distortions in lending decisions and to better performing banks. In our model, the contradicting effects of bank capital regulation on the loan rate largely offset one another in steady state and minimize the role for time-varying regulation in the model dynamics. The effectiveness of dynamic capital requirements is restored when some small additional issuance costs of bank capital (c) are added (see for example Covas and Fujita (2010) and Gerali, Neri, Sessa and Signoretti (2010)).[26] This cost (or tax benefit of debt over equity) puts the increase in the weighted average cost of capital and the loan rate following a rise in capital into a reasonable empirical range (see also Kashyap, Hanson and Stein (2011)).

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 (in the benchmark Basel II case where $\theta^C > 0$). The increase in bank capital costs then translate into a rise in the loan rate, which puts further upward pressure on the risk of default and the bank capital premium rate, ultimately amplifying the initial increase in the loan rate. Therefore, the probability of default, through its relationship with 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, supporting the general consensus in the literature regarding the procyclical nature of banking and more specifically of Basel II. The upshot is that a macroprudential policy (Basel III, $\theta^C < 0$) is warranted in order to reduce these procyclical tendencies of the financial system.

2.5 Monetary Policy

The central bank targets the short term policy rate (R_t^{cb}) according to the following Taylor (1993)-type policy rule,[27]

$$R_t^{cb} = \left[\left(R^{cb}\right) \left(\frac{\pi_t^P}{\pi^{P,T}}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_Y} \left(\frac{R_t^L/R_t^D}{R^L/R^D}\right)^{-\phi_s} \right]^{1-\phi} \left(R_{t-1}^{cb}\right)^{\phi}, \tag{33}$$

where $\phi \in (0,1)$ is 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 state targets, respectively.

The new term added to the standard Taylor rule is given by $\left(\frac{R_t^L/R_t^D}{R^L/R^D}\right)^{-\phi_s}$, where $\phi_s > 0$. Thus, the central bank sets its policy rate also in part to deviations of credit spreads from their steady state level.[28] In this way, following adverse shocks which create an output-inflation trade-off, the probability of default and loan rate increase, both which reduce lending and increase credit spreads.

[26] Through numerical methods we show that in order for the steady state loan rate to increase following a rise in bank capital requirements, $c \geq 0.0014$. In the simulations we use a larger value of c to ensure a plausible steady state loan rate.

[27] 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 ($R_t^{cb} = R_t^D$).

[28] Such type of credit spread augmented Taylor rules have been advocated by Cúrdia and Woodford (2010), among others. Having the Taylor rule responding positively to loans or loan growth in this model would not affect the results materially.

With $\phi_s > 0$, the policy rate falls and mitigates the initial increase in the lending rate, thereby dampening the contraction in credit and output, whilst mitigating the rise in inflation. However, an increase in the output gap caused by the lower policy rate may generate additional inflationary pressures through the standard demand channel of monetary policy.

2.6 Market Clearing Conditions

In a symmetric equilibrium, all firms choose the same level of prices, employment and the volume of lending. Aggregate output is obtained by aggregating the production of the IG firms, with the seizable collateral $\chi_t Y_t$ in case of default distributed to the households at the end of the period. The resource constraint in real terms therefore reads as,[29]

$$Y_t = C_t \tag{34}$$

Definition 1 *The competitive equilibrium is defined as a sequence of private sector decisions* $\left\{C_t, Y_t, N_t, W_t^R, \pi_t^W, L_t, \pi_t^P, mc_t, R_t^D, R_t^V, R_t^L, \Phi_t, \xi_t^V\right\}_{t=0}^{\infty}$ *and macroeconomic policies* $\left\{R_t^{cb}, \Delta_t\right\}_{t=0}^{\infty}$, *which for a given set of exogenous processes* $\left\{A_t, \chi_t, \varepsilon_t^F\right\}_{t=0}^{\infty}$ *solves equations (3), (4), (7), (8), (12), (13), (14), (17), (18), (19),(21),(30),(32) and* $Y_t = Z_t N_t$.

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).[30] The baseline calibration numbers are summarized in the following Table 1,

[29] 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.

[30] The results we present in the next sections are robust to changes in the standard parameters of the model such as the discount factor, wage and price rigidities (within plausible ranges), intertemporal substitution in consumption and the inverse of the Frisch elasticity of labour supply. We focus in this section on the parameters new to this model.

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	8.00	Elasticity of Demand - Labour
ω_w	0.64	Degree of Wage Stickiness
λ_p	6.00	Elasticity of Demand - Intermediate Goods
ω_p	0.60	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
ϕ_Δ	0.00	Degree of Persistence in Regulatory Rule
ρ^D	0.08	Capital Adequacy Ratio
θ^C	0.1,-0.1	Elasticity of Regulatory Rule wrt to Risk
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	0.10	Response of Policy Rate to Output Deviations
ϕ_s	0.00	Response of Policy Rate to Credit Deviations
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; 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%.[31] Moreover, the bank capital adequacy ratio (ρ) is set to 0.08, which represents a floor value under Basel II. These numbers, together with a price mark-up of 20%, generate a steady state credit risk of 3.82%, a long run value of 2.51% for the return on bank capital and a loan rate of 3.16%. All these estimates are consistent with values found for industrialized countries.

For illustrative purposes in the initial model dynamics section we examine the case where $\theta^C = 0.1$ (Basel II), $\theta^C = -0.1$ (Basel III) and $\phi_s = 0.2$.[32] We conduct these initial counterfactual experiments with standard Taylor rule parameters ($\phi_\pi = 1.5$ and $\phi_Y = 0.1$) in order to highlight the transmission channels of the new policy rules in isolation (below we compute the optimal policy combination of bank capital regulation together with standard and augmented Taylor rules). Finally, the degree of persistence in the regulatory rule (ϕ_Δ) is set to 0, as we find that including this parameter increases welfare losses when the regulatory rule (θ^C) is set optimally.

[31] Reducing the steady state value of the probability χ, which is a key financial friction in this model, raises the cost of borrowing in the long run as well as amplifies the response of both financial and real variables following various shocks.

[32] Under the foundation internal ratings based (IRB) approach of Basel II, the equivalent to θ^C lies between 0.05 and 0.15 (see Covas and Fujita (2010) and Aguiar and Drumond (2009)).

4 Model Dynamics

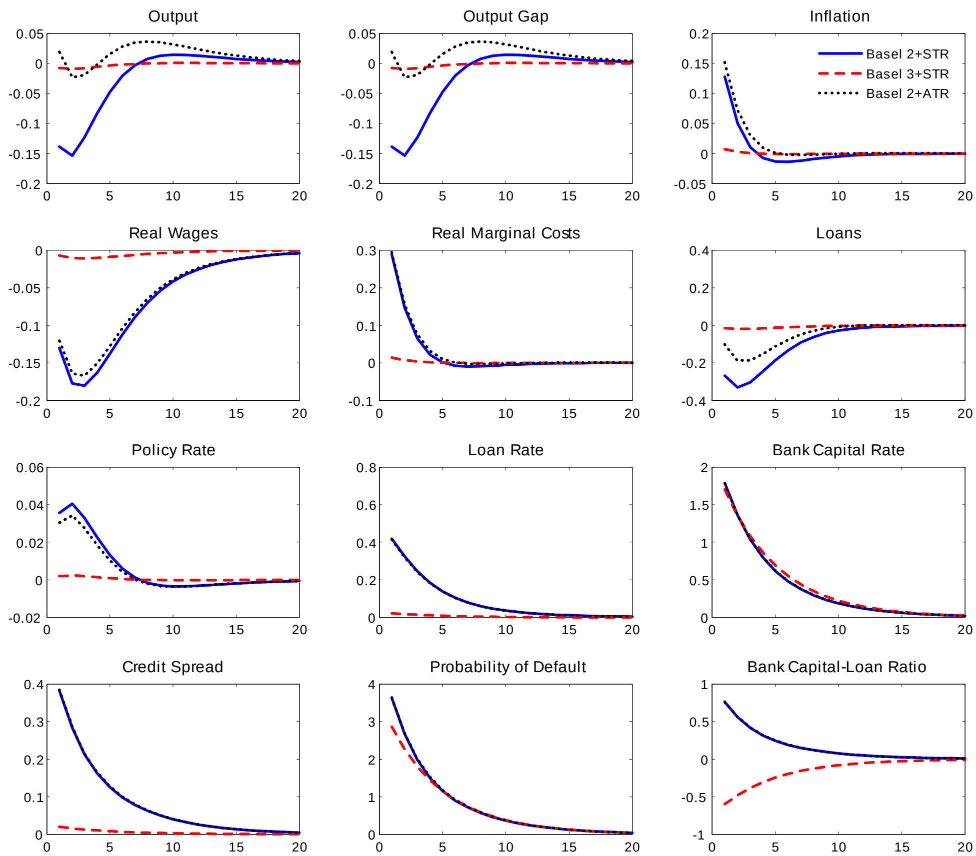
This section examines the cyclical behaviour of the macroeconomic and financial variables following both an adverse financial shock to χ_t and a negative supply shock to A_t. Under each shock a comparison is made between the following three regimes:

- *The first* baseline policy regime examines a Basel II type rule and a standard Taylor rule (STR) ($\theta^C = 0.1, \phi_s = 0$, solid blue line).
- *The second* regime combines a Basel III type rule and a standard Taylor rule (STR) ($\theta^C = -0.1, \phi_s = 0$, dashed red line).
- *The third* regime combines a Basel II type rule and an credit spread augmented Taylor rule (ATR) ($\theta^C = 0.1, \phi_s = 0.2$, dotted black line).

4.1 Financial Shock

Figure 1 shows the impulse response functions of the main variables of the model following a 1 standard deviation 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-loan ratio are measured in percentage point deviations from steady state. The rest of the variables are measured in terms of percentage deviations.

The direct effect of a negative shock to collateral recovery (risk shock) is a rise in probability of default and consequently the loan rate through the bank capital default and finance premium channels. Furthermore, with a Basel II regime ($\theta^C = 0.1 > 0$), bank capital requirements increase, inducing an amplification effect on the borrowing costs. It can be shown that both the bank capital default and the bank capital requirement channels lead to an exacerbation in the loan rate and risk of default behaviour compared to the Basel I case ($\theta^C = 0$) and to the case where banks are not subject to capital regulation.[33]

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

[33] These simulations are available upon request.

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, consistent with the empirical findings of 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 fall in real wages, as a result of lower output and higher price inflation, attenuates the rise in the marginal costs following financial shocks. Nevertheless, this mitigation effect is relatively small given the nature of the financial shock which directly impacts the loan rate.

Because the bank capital default channel and Basel II regulation result in a further rise in the loan rate and probability of default, these channels produce 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.

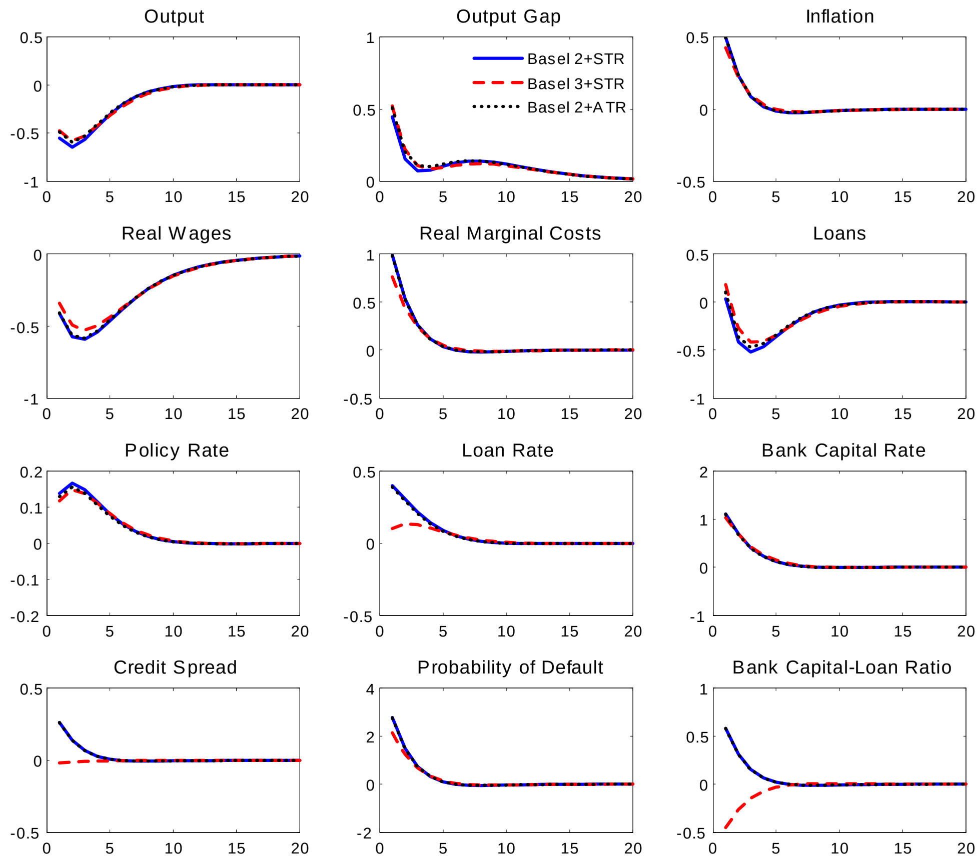
Turning now to discuss the implications of a countercyclical regulatory rule ($\theta^C = -0.1 < 0$). Because the risk of default rises following adverse credit shocks, the required ratio of bank capital to loans falls. Following the loosening of bank capital requirements, the loan rate response is considerably mitigated. At the same time, lower bank capital requirements can also increase the loan rate via the bank capital default channel as explained earlier. However, given our calibration with a small positive c, 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 much more moderate rise due to the imposition of a countercyclical regulatory rule. Consequently, risk rises by less, and the rise in the marginal costs and inflation are less pronounced. All these effects moderate substantially the fall in output and loans.

A credit spread augmented Taylor rule ($\phi_s = 0.2$) affects directly the policy rate, which through intertemporal substitution, increases significantly the level of output. Furthermore, the fall 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, the rise in output and therefore the output gap, brought about by the lower refinance rate, results in an increase in price inflation through the standard demand channel of monetary policy. Given our standard calibration numbers, the latter channel dominates such that a fall in the policy rate is indeed inflationary. This result highlights the possible welfare detrimental aspects of responding to financial variables in the central bank's policy rule.

4.2 Supply Shock

Figure 2 shows the impulse response functions of the main variables of the model following a 1 standard deviation 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-loan ratio are measured in percentage point deviations from steady state. The rest of the variables are measured in terms of percentage deviations.

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 Basel II ($\theta^C = 0.1 > 0$) channels behave similarly to adverse credit shocks and result in a further amplification in the reaction of the loan rate and risk of default. Note also that the output gap rises as this variable is measured in terms of the deviations of output from its efficient level ($\widehat{Y_t^g} = \widehat{Y}_t - \widehat{Y_t^e}$, where $\widehat{Y_t^g}$ is the output gap and $\widehat{Y_t^e} = \left[(1+\gamma)/\left(\frac{1}{\varsigma}+\gamma\right)\right]\widehat{Z_t}$ is the efficient level of output in the absence of any nominal rigidities and financial frictions).

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, thereby reducing the impact of the borrowing cost channel. However, given the nature of the supply shock and the various financial accelerator channels of bank capital, the loan rate and credit spreads increase, output falls, inflation rises and the demand for loans decrease. Finally, the policy rate rises in response to the hike in inflation, thereby adding to further downward pressure on output.

A countercyclical rule ($\theta^C = -0.1 < 0$) leads to similar results to the case of credit shocks. However, the deviations in price inflation, output 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. As a result, a countercyclical regulatory rule has a smaller relative effect on the real economy when compared to financial shocks, despite having a similar quantitative impact on the bank capital-loan ratio.[34] This implies that a much stronger countercyclical rule is needed in order to promote macroeconomic stability following supply shocks.

A macroprudential Taylor rule ($\phi_s = 0.2$) results in a slightly more muted rise in the policy rate due to the hike in credit spreads. Hence, and similar to the case of credit shocks, households increase their current consumption through an intertemporal substitution effect, leading to a rise in output and output gap, but at the cost of higher inflationary pressures.

We now turn to examine how the inclusion of the above macroprudential policies alters the transmission of standard monetary policy and their effect on welfare and central bank losses.

5 Optimal Simple Policy Rules

This section provides an analysis of the optimal mix of conventional and macroprudential policy instruments outlined above. For this purpose, unless otherwise mentioned, we use the parameter values used in the previous sections, with the central bank aiming to minimize a period average welfare loss function approximated by,

$$Loss_t = \frac{\lambda_p}{k_p} var(\widehat{\pi_t^P}) + \left(\frac{1}{\varsigma} + \gamma\right) var(\widehat{Y_t^g}) + \frac{\lambda_w}{k_w} var(\widehat{\pi_t^W}), \tag{35}$$

where $k_p = (1-\omega_p)(1-\omega_p\beta)/\omega_p$, $k_w = \frac{(1-\omega_w)(1-\beta\omega_w)}{\omega_w(1+\gamma\lambda_w)}$ and $\widehat{Y_t^g} = \widehat{Y}_t - \widehat{Y_t^e}$ is the welfare relevant output gap. The term $\widehat{Y_t^e} = \left[(1+\gamma)/\left(\frac{1}{\varsigma}+\gamma\right)\right]\widehat{Z_t}$ is the efficient level of output chosen by the social planner who can overcome all the nominal and financial frictions in this economy. This loss function is derived using a second order approximation of the household's utility function, just as in Erceg, Henderson and Levine (2000) who introduce wage rigidities, and Ravenna and Walsh (2006) who incorporate the monetary policy cost channel. Similar to Ravenna and Walsh (2006), the presence of the borrowing cost channel creates a wedge between the natural and efficient level of output. Specifically, $\widehat{Y_t^e} - \widehat{Y_t^n} = \left[1/\left(\varsigma^{-1}+\gamma\right)\right]\widehat{R_t^{L,n}}$, where $\widehat{Y_t^n}$ and $\widehat{R_t^{L,n}}$ denote the natural level

[34] 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.

(indexed by superscript n) of output and loan rate prevailing under flexible prices and wages.[35]

We study various optimal policy rules aimed at minimizing the above loss function. For the purpose of this exercise we set $\phi_Y = 0$ in all experiments as we find that responding to output (or the output gap) in the Taylor rule generates negligible welfare gains for both credit and supply shocks. Abstracting from ϕ_Y also allows us to clearly establish and understand the interaction between the response to inflation in the standard Taylor rules and the new macroprudential instruments.

The policy rules examined are: Policy I - Central bank following a standard Taylor rule (setting exogenously $\phi_\pi = 1.5$ and $\phi_s = \theta^C = 0$).[36] Policy II - Central bank responding only to inflation in the Taylor rule (solving for ϕ_π only and setting $\phi_s = \theta^C = 0$). Policy III - Central bank responding to inflation and credit spreads (solving for ϕ_π and ϕ_s and setting $\theta^C = 0$). Policy IV - an inflation targeting Taylor rule and countercyclical bank capital regulation (solving for ϕ_π and θ^C and setting $\phi_s = 0$). Policy V - a credit spread augmented Taylor rule and a countercyclical rule (solving for ϕ_π,θ^C and ϕ_s). The optimal parameters which minimize the above loss function are searched within the following ranges: $\phi_\pi = [1 : 10]$, $\phi_s = [0 : 1]$ and $\theta^C = [-50 : 0]$ with step of 0.01.[37]

Table 2 shows the optimal simple policy rules and how the value of each policy rule changes with the introduction of additional policy instruments following credit and supply shocks.

[35] The richer borrowing cost channel therefore does not change the structure of the loss function compared to standard new Keynesian models with staggered wages. However, unlike Ravenna and Walsh (2006), where $\widehat{R_t^{L,n}} = 0$, in our model the presence of the various financial frictions also lead to deviations in $\widehat{R_t^{L,n}}$ and hence generate the wedge between $\widehat{Y_t^n}$ and $\widehat{Y_t^e}$ (see also Airaudo and Olivero (2013)).

[36] The benchmark case in this section is the Basel I case as we set θ^C optimally in policies III and IV.

[37] As is clear from the simulations above, having $\theta^C > 0$ as in Basel II is welfare detrimental.

Table 2: Optimal Simple Policy Rules

	Credit Shock	Supply Shock
Policy I	$\phi_\pi = 1.50$ $Loss_t = 0.2863$	$\phi_\pi = 1.50$ $Loss_t = 13.2098$
Policy II	$\phi_\pi = 1.01$ $\phi_s = -$ $\theta^C = -$ $Loss_t = 0.2294$	$\phi_\pi = 1.90$ $\phi_s = -$ $\theta^C = -$ $Loss_t = 12.6039$
Policy III	$\phi_\pi = 1.01$ $\phi_s = 0.00$ $\theta^C = -$ $Loss_t = 0.2294$	$\phi_\pi = 1.90$ $\phi_s = 0.00$ $\theta^C = -$ $Loss_t = 12.6039$
Policy IV	$\phi_\pi = ANY$ $\phi_s = -$ $\theta^C = -0.114$ $Loss_t = 0.00$	$\phi_\pi = 9.00$ $\phi_s = -$ $\theta^C = -35$ $Loss_t = 1.2543$
Policy V	$\phi_\pi = ANY$ $\phi_s = ANY$ $\theta^C = -0.114$ $Loss_t = 0.00$	$\phi_\pi = 9.00$ $\phi_s = 0.00$ $\theta^C = -35$ $Loss_t = 1.2543$

Note: The value of the loss function is calculated following a 1 s.d credit shock and a 1 s.d supply shock

Figures 3 and 4 depict the impulse response functions associated with the optimal policy parameters obtained in Table 2 for credit and supply shocks, respectively.

Figure 3 - Adverse Financial Shock with Optimal Policy Rules

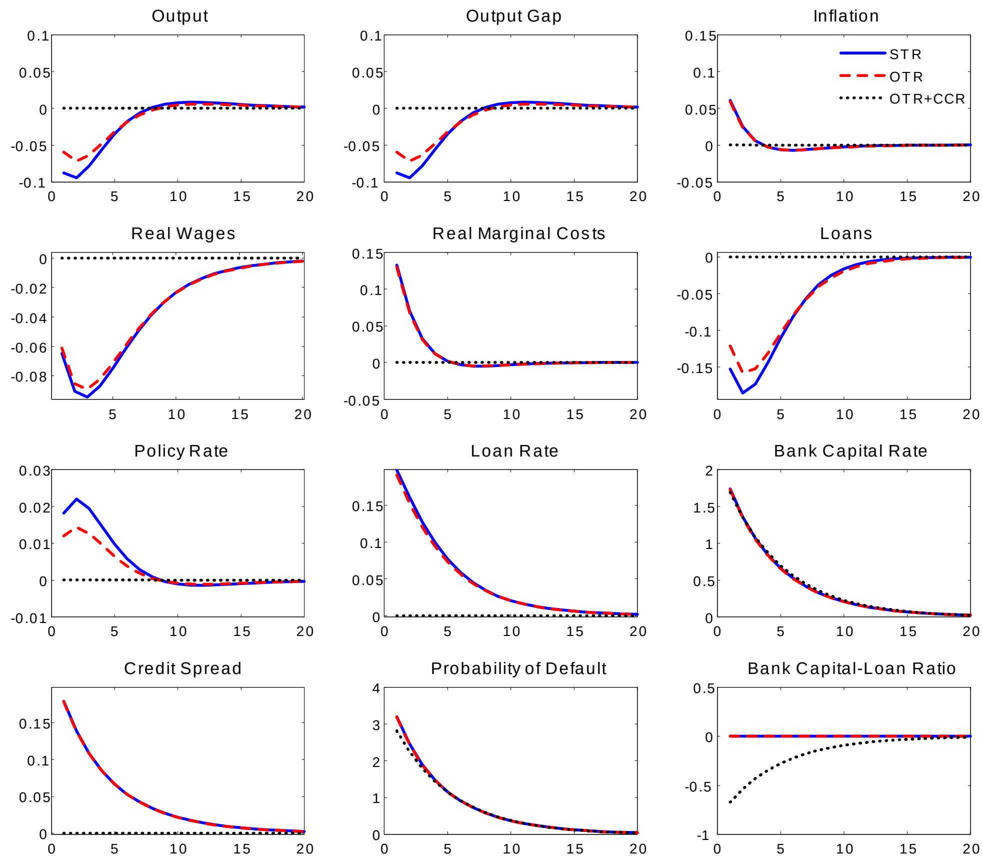


Figure 3 compares between Policy I (Standard Taylor Rule (STR)), Policy II (identical to Policy III - Optimal Taylor Rule (OTR)) and Policy IV (identical to Policy V - Optimal Taylor Rule + Countercyclical Rule (OTR+CCR)). See also notes to Figures 1 and 2.

Figure 4 - Negative Supply Shock with Optimal Policy Rules

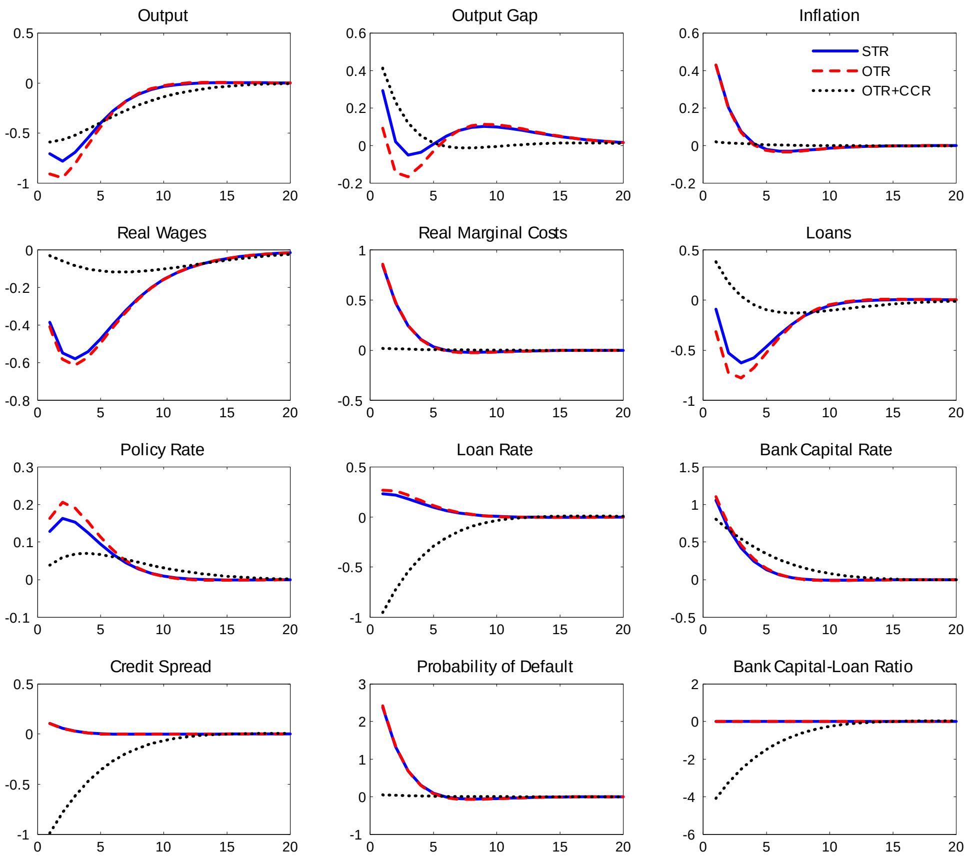


Figure 4 compares between Policy I (Standard Taylor Rule (STR)), Policy II (identical to Policy III - Optimal Taylor Rule (OTR)) and Policy IV (identical to Policy V - Optimal Taylor Rule + Countercyclical Rule (OTR+CCR)). See also notes to Figures 1 and 2.

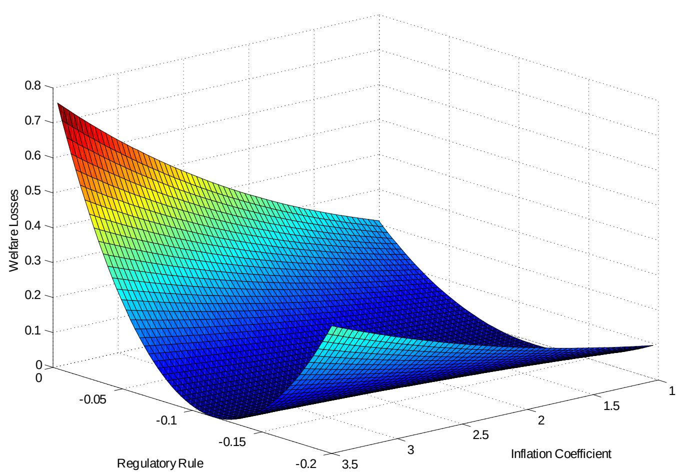
Financial (Credit) Shock

Following credit shocks, a lower response to inflation in the Taylor rule (Policy II) provides non-negligible welfare gains compared to a standard Taylor rule (Policy I). Intuitively, for economies where credit plays a key role for firms financing, responding too aggressively to price inflation may prompt higher borrowing costs and increased procyclicality in output, prices, wages and financial variables. By mitigating the rise in the policy rate, the inflationary impact of the borrowing cost channel is dampened, which leads to a relative improvement in output and wages. At the same time, the relative drop in the refinance rate can also result in higher inflationary pressures through the standard demand channel of monetary policy. Compared to Policy I, Policy II has a limited impact on inflation due to the conflicting channels described above. However, given the moderated fall in output and wage inflation, both of which comprise of the welfare loss function, it is optimal to respond only mildly to inflation in the Taylor rule ($\phi_\pi = 1.01$).

In Policy III, we observe that a credit augmented Taylor rule does not promote overall welfare as it creates demand driven inflation, despite mitigating output losses and wage inflation (see the simulations in previous section).

A mildly optimal countercyclical policy tool ($\theta^C = -0.114$) provides the most targeted approach as it directly suppresses the inflationary effect of the borrowing cost channel as well as shuts down all output and wage inflation fluctuations (see Policies IV and V). Put differently, following credit shocks which directly impact the cost of borrowing, an optimal macroprudential rule eliminates the standard output-inflation trade-off faced by monetary policy. Moreover, once the countercyclical rule is set optimally, it does not matter the extent to which the monetary policy rule reacts to inflation and/or to credit spreads since all gaps are closed and the policy rate remains unchanged. An overreaction in the countercyclical rule can generate excessive easing in bank capital requirements, which overly reduce total bank funding costs and create an unwarranted economic expansion. Figure 5 illustrates the effectiveness of macroprudential regulation, the welfare detrimental aspects of a strict inflation targeting rule, and the point at which welfare losses are eliminated and monetary policy rules become futile.

Figure 5 - Relationship Between ϕ_π, θ^C - Credit Shocks



Supply Shock

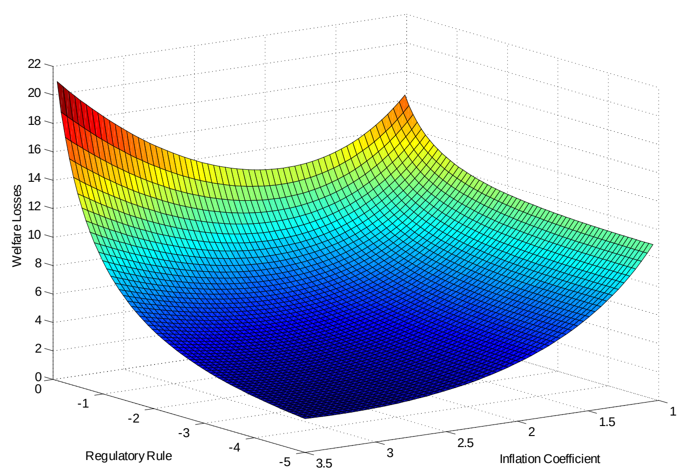
Following adverse supply shocks, optimal monetary policy suggests a slightly stronger, yet contained, response to inflation in the Taylor rule as it mitigates the rise in the output gap (Policy II). However, excessively high inflation coefficient weights are avoided since they would lead to an intensified fall in the output gap, thereby creating additional volatility in this variable. The slightly higher weight on inflation ($\phi_\pi = 1.90$) exagerates the inflationary impact of the monetary policy cost channel, although this rise is largely offset by the fall in the output gap (the standard demand channel of monetary policy). Furthermore, augmented monetary policy rules act to increase output gap inefficiencies, leading to higher volatility in price inflation (Policy III).

Similar to credit shocks, countercyclical bank capital regulation has an important role in reducing central bank losses. Nevertheless, unlike credit shocks, a very aggressive countercyclical regulatory rule ($\theta^C = -35$) is also welfare improving. The significant fall in bank capital requirements (around 4 percentage points) reduces bank funding costs to the extent that it generates a fall in the credit spread. This helps to further offset some of the increase in the marginal cost and price inflation, although does not eliminate completely the standard effects of the supply shock and specifically the output gap - inflation trade-off.

In Policy IV we also observe a complementary effect between the use of the countercyclical rule and the inflation coefficient in the Taylor rule. Increasing (in absolute value) the weight on the countercyclical rule reduces the cost of credit, thus creating dis-inflationary pressures. This prompts the central bank to weigh inflation more heavily ($\phi_\pi = 9.00$) to effectively adjust the real interest rate in the Euler Equation and avoid a further escalation in the output gap. Overly high inflation coefficients ($\phi_\pi > 9$) are avoided as they suppress the relative rise in output, which would exaggerate further the fall in real wages and losses associated with wage inflation in the central bank's objective function.[38] Finally, with a countercyclical rule and consequently a higher response to inflation in the Taylor rule, there is no welfare gain from a monetary authority reacting to credit spreads (Policy V).

Figure 6 illustrates this complementarity between the weight on inflation and the countercyclical rule. Macroprudential regulation can restore the strong anti-inflation stance in the Taylor rule, and the combination of both these rules yields the lowest welfare losses.[39]

Figure 6 - Relationship Between ϕ_π, θ^C - Supply Shocks



The general conclusion from these experiments is that Basel III type rules, which directly impact the financial market conditions, can effectively promote overall macroeconomic and price stability for both credit and supply shocks. Credit spread augmented Taylor rules, on the other hand, are shown to be welfare detrimental, regardless if used in conjunction with a countercyclical regulatory rule.

[38] Indeed, if the central bank's objective function consisted only of inflation and output gap volatilities, the optimal weights on ϕ_π and θ^C, when determined jointly, tend towards ∞ and $-\infty$, respectively.

[39] In Figure 6, we limit the ranges of ϕ_π and θ^C to $(1, 4)$ and $(-5, 0)$ respectively. This enables us to illustrate the complementarity between these two policy rules in a transparent way, without compromising our main conclusions.

6 Conclusion

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 nominal rigidities, endogenous credit frictions and a borrowing cost channel, which links the financial sector to the macroeconomy.

Bank capital adequacy requirements in this model cover for bank losses. All else equal, an increase in capital requirements result 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 Basel II type regulation amplify the movements in borrowing costs despite their role in reducing the bank capital risk premia during economic downturns.

The policy lessons arising from our model imply that central banks should reduce their inflation response in the Taylor rule in the face of higher inflationary pressures and in the presence of a borrowing cost channel driven mainly by financial frictions. However, following standard supply shocks, introducing countercyclical regulation as proposed by Basel III allows central banks to be more stringent on inflation and control for price volatility via the standard demand channel of monetary policy. For these shocks, an aggressive countercyclical regulatory response to credit risk enables the policy maker to counter (but not eliminate) the standard effects of supply shocks.

For credit shocks, which directly affect default risk and the loan rate spread, Basel III type rules can eliminate macroeconomic gaps and therefore the need for conventional monetary policy rules. In this framework, the financial shock is completely offset by a mild countercyclical response to credit risk, which effectively restores the equilibrium price of credit. However, an over-estimate of the optimal degree in the macroprudential tool can lead to a credit fuelled economic boom.

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)). With a note of caution, we do not attempt to fit the model to the data given some of the stylized and simplifying assumptions in our model such as a full borrowing cost channel and no role for investments and physical capital. However, with standard parametrization, this framework captures the behaviour of financial and real variables following economic and financial disturbances, as well as provides meaningful policy implications when the borrowing cost channel and financial frictions matter.

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.

References

[1] Admati, Anat, and Martin Hellwig. (2014). "The Bankers' New Clothes: What's Wrong with Banking and What to Do about It", Princeton, NJ: Princeton University Press.

[2] Agénor, Pierre-Richard, and Joshua Aizenman. (1998). "Contagion and Volatility with Imperfect Credit Markets", IMF Staff Papers, 45, 207-235.

[3] Agénor, Pierre-Richard, George J. Bratsiotis, and Damjan Pfaifer. (2014). "Credit Frictions, Collateral and the Cyclical Behaviour of the Finance Premium", Macroeconomic Dynamics, 18, 985-997.

[4] Aguiar, Alvaro, and Ines Drumond. (2009). "Business Cycle and Bank Capital: Monetary Policy Transmission under the Basel Accords", FEP Working paper No. 242, University of Porto.

[5] Airaudo, Marco, and María P. Olivero. (2014). "Optimal Monetary Policy with Counter-Cyclical Credit Spreads", Working Paper No. 2014-1, LeBow College of Business, Drexel University.

[6] Angelini, Paolo, Stefano Neri, and Fabio Panetta. (2014). "The Interaction between Capital Requirements and Monetary Policy", Journal of Money, Credit and Banking, 46(6), 1074-1112.

[7] Angeloni, Ignazio, and Ester Faia. (2013). "Capital Regulation and Monetary Policy with Fragile Banks", Journal of Monetary Economics, 60, 311-324.

[8] Barth, James R., Gerard Caprio Jr., and Ross Levine. (2004). "Bank Regulation and Supervision: What Works Best", Journal of Financial Intermediation, 12, 205–248

[9] Basel Committee on Banking Supervision. (1988). "International Convergence of Capital Measurement and Capital Standards", Bank for International Settlements – Basle Committee on Banking Supervision Publications.

[10] Basel Committee on Banking Supervision. (2004). "International Convergence of Capital Measurement and Capital Standards – A Revised Framework", Bank for International Settlements – Basle Committee on Banking Supervision Publications.

[11] Basel Committee on Banking Supervision. (2011). "Basel III: A Global Regulatory Framework for more Resilient Banks and Banking Systems", Report No. 189.

[12] Basel Committee on Banking Supervision. (2012). "Models and Tools for Macroprudential Analysis", Working Paper No. 21, Bank for International Settlements.

[13] Benes, Jaromir, and Michael Kumhof. (2011). "Risky Bank Lending and Optimal Capital Adequacy Regulation", IMF Working Paper 11/130, International Monetary Fund.

[14] Bernanke, Ben, Mark Gertler, and Simon Gilchrist. (1999). "The Financial Accelerator in a Quantitative Business Cycle Framework", In John B. Taylor and Michael Woodford (Eds), Handbook of Macroeconomics, Vol. 1C, 1341-1393, Amsterdam, North Holland (Elsevier).

[15] Bratsiotis, George J., William J. Tayler and Roy Zilberman. (2014). "Financial Regulation, Credit and Liquidity Policy and the Business Cycle", work in progress.

[16] Calvo, Guillermo A. (1983). "Staggered Prices in a Utility-Maximizing Framework", Journal of Monetary Economics, 12, 383-398.

[17] Chowdhury, Ibrahim, Mathias Hoffmann, and Andreas Schabert. (2006). "Inflation Dynamics and the Cost Channel of Monetary Transmission", European Economic Review, 50(4), 995–1016.

[18] Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans. (2005). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy", Journal of Political Economy, 113, 1-45.

[19] Christiano, Lawrence J., Roberto Motto and, Massimo Rostagno. (2013). "Risk Shocks", American Economic Review, 104(1), 27-65.

[20] Christensen, Ian, Césaire A. Meh, and Kevin Moran. (2011). “Bank Leverage Regulation and Macroeconomic Dynamics”, Bank of Canada Working Paper No. 2011-32, Bank of Canada.

[21] Coleman, Anthony D.F., Neil Esho and Ian G. Sharpe. (2006). "Does Bank Monitoring Influence Loan Contract Terms?", Journal of Financial Services Research, 30(2), 177-198.

[22] Covas, Francisco, and Shigeru Fujita .(2010). "Procyclicality of Capital Requirements in a General Equilibrium Model of Liquidity Dependence", International Journal of Central Banking, 6(4), 137-173.

[23] Cúrdia, Vasco, and Michael Woodford. (2010). "Credit Spreads and Monetary Policy", Journal of Money, Credit and Banking, 42 (s1), 3-35.

[24] De Paoli, Bianca, and Matthias Paustian. (2013). "Coordinating Monetary and Macroprudential Policies", Staff Report No. 653, Federal Reserve Bank of New York.

[25] DiCecio, Riccardo. (2009). "Sticky Wages and Sectoral Labor Comovement", Journal of Economic Dynamics and Control, 33(3), 538-553.

[26] Dixit, Avinash K., and Joseph E. Stiglitz. (1977). "Monopolistic Competition and Optimum Product Diversity", American Economic Review, 67, 297-308.

[27] Erceg, Christopher J., Dale W. Henderson, and Andrew T. Levin. (2000). "Optimal Monetary Policy with Staggered Wage and Price Contracts", Journal of Monetary Economics, 46, 281–313.

[28] Faia, Ester, and Tommaso Monacelli. (2007). "Optimal Interest Rate Rules, Asset Prices, and Credit Frictions", Journal of Economic Dynamics and Control, 31(10), 3228-3254.

[29] Fernandez-Corugedo, Emilio, Michael F. McMahon, Stephen Millard, and Lukasz Rachel. (2011). “Understanding the Macroeconomic Effects of Working Capital in the United Kingdom”, Bank of England Working Paper No. 422, Bank of England.

[30] Fiore, Fiorella De., and Oreste Tristani. (2013). "Optimal Monetary Policy in a Model of the Credit Channel", The Economic Journal, 123(571), 906–931.

[31] Gerali, Andrea, Stefano Neri, Luca Sessa, and Federico M. Signoretti. (2010). "Credit and Banking in a DSGE model of the Euro Area", Journal of Money, Credit and Banking, 42(s1), 107-141.

[32] Gilchrist, Simon, Raphael Schoenle, Jae Sim, and Egon Zakrajsek. (2014). "Inflation Dynamics During the Financial Crisis", Unpublished Manuscript, Brandeis University.

[33] Hanson, Samuel G., Anil K. Kashyap, and Jeremy C. Stein. (2011). "A Macroprudential Approach to Financial Regulation", The Journal of Economic Perspectives, 25(1), 3-28.

[34] Jermann, Urban, and Vincenzo Quadrini. (2012). "Macroeconomic Effects of Financial Shocks", American Economic Review, 102(1), 238-271.

[35] Kannan, Prakash, Pau Rabanal, and Alasdair M. Scott. (2012). "Monetary and Macroprudential Policy Rules in a Model with House Price Booms", The B.E. Journal of Macroeconomics, 12(1), Article 16.

[36] Kashyap, Anil K., Jeremy. C. Stein, and Samuel Hanson. (2010). "An Analysis of the Impact of Substantially Heightened' Capital Requirements on Large Financial Institutions", Unpublished Manuscript, University of Chicago.

[37] Liu, Guangling Dave, and Nkhahle E. Seeiso. (2012). "Basel II Procyclicality: The Case of South Africa", Economic Modelling, 29(3), 848-857.

[38] Markovic, Bojan. (2006). "Bank Capital Channels in the Monetary Transmission Mechanism", Bank of England Working Paper No. 313.

[39] Meh, Césaire A., and Kevin Moran. (2010). "The Role of Bank Capital in the Propagation of Shocks", Journal of Economic Dynamics and Control, 34(3), 555-576.

[40] Modigliani, Franco, and Merton H. Miller. (1958). "The Cost of Capital, Corporation Finance and the Theory of Investment", American Economic Review, 48(3), 261-297.

[41] N'Diaye, Papa. (2009). "Countercyclical Macroprudential Policies in a Supporting Role to Monetary Policy", IMF Working Paper No. 257, International Monetary Fund.

[42] Nolan, Charles, and Christoph Thoenissen. (2009). "Financial Shocks and the US Business Cycle", Journal of Monetary Economics, 56(4), 596-604.

[43] Ravenna, Federico, and Carl E. Walsh. (2006). "Optimal Monetary Policy with the Cost Channel", Journal of Monetary Economics, 53, 199-216.

[44] Rubio, Margarita, and José A. Carrasco-Gallego. (2014). "Macroprudential and Monetary Policies: Implications for Financial Stability and Welfare", Journal of Banking and Finance, 49, 326-336.

[45] Schmitt-Grohé, Stephanie, and Martın Uribe. (2007). "Optimal Simple and implementable Monetary and Fiscal Rules", Journal of Monetary Economics, 54(6), 1702–1725.

[46] Smets, Frank, and Raf Wouters. (2003). "An Estimated Stochastic General Equilibrium Model of the Euro area", Journal of the European Economic Association, 1(5), 1123-1175.

[47] Smets, Frank, and Raf Wouters. (2007). "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach", American Economic Review, 97(3), 586-606.

[48] Suh, Hyunduk. (2014). "Dichotomy between Macroprudential Policy and Monetary Policy on Credit and Inflation", Economics Letters, 122(2), 144-149.

[49] Taylor, John B. (1993). "Discretion versus Policy Rules in Practice", Carnegie-Rochester Conference Series on Public Policy, 39, 195-214.

[50] Tillmann, Peter. (2008). "Do Interest Rates Drive Inflation Dynamics? An Analysis of the Cost Channel of Monetary Transmission", Journal of Economic Dynamics and Control, 32, 2723-2744.

[51] Woodford, Michael. (2003). "Interest and Prices: Foundations of a Theory of Monetary Policy", Princeton, NJ: Princeton University Press.

7 Appendix

7.1 Appendix A - The Simplified Loan Rate Equation in Steady State

To provide an analytical solution for the loan rate equation in steady state, we make two simplifying assumptions: (a) A constant unit labour cost W/A, set equal to unity for convenience; (b) An idiosyncratic IG firm risk distribution $U(0,2)$. Under these assumptions, firms default if $\chi\varepsilon^F < R^L$, where χ is the probability of recovering collateral in the default state. The greatest lower band for the idiosyncratic shock at solvent firms is $\varepsilon^{F,M}$. Since the threshold depends on the loan rate, the probability of default is $\Phi = Pr(\varepsilon^F < \varepsilon^{F,M}) = \frac{\varepsilon^{F,M}}{2} = \frac{1}{2}\frac{R^L}{\chi}$. Note however that with constant unit labour cost, $mc = R^L = (pm)^{-1}$, where pm denotes the price mark-up. Hence, the probability of default in steady state can be written as $\Phi = \frac{(pm)^{-1}}{\chi}$, which depends only on the structural parameters of the model. Using the above conditions in the steady state loan rate equation derived from (27) yields,

$$R^L = \nu\left\{R^D + \Delta(R^V + c - R^D)\right\}, \tag{A1}$$

with $\nu \equiv \left[1 - \frac{(pm)^{-1}}{\chi}\right]^{-1} > 1$ denoting the constant risk premium under the above assumptions.

We rewrite equations (4) and (30) in their steady state form employing the above simplifying assumptions,

$$R^V = \frac{R_t^D}{(1-\xi^V)} \tag{A2}$$

$$\xi^V = \frac{1}{2}(1-\chi)\frac{1}{\Delta}\frac{(pm)^{-2}}{\chi} \tag{A3}$$

Dividing (A1) by R^D gives,

$$\frac{R^L}{R^D} = \nu\left\{1 + \Delta\left[\frac{R^V}{R^D} - 1\right] + \frac{c}{R^D}\Delta\right\} \tag{A4}$$

Substituting (A2) and (A3) in (A4) results in,

$$\frac{R^L}{R^D} = \nu\left\{1 + \Delta\left(\frac{1}{1-(1-\chi)\frac{1}{2\Delta}\frac{(pm)^{-2}}{\chi}} - 1\right) + \frac{c}{R^D}\Delta\right\}$$

or,

$$R^L = \nu\left\{R^D + \Delta\left(\frac{(1-\chi)\frac{1}{2\Delta}\frac{(pm)^{-2}}{\chi}}{1-(1-\chi)\frac{1}{2\Delta}\frac{(pm)^{-2}}{\chi}}\right)R^D + c\Delta\right\} \tag{A5}$$

The following partial effects are immediate:

- A higher deposit rate (R^D) raises the loan rate.
- A higher cost of issuing bank capital c raises the loan rate.
- A lower recovery rate (χ) raises the loan rate.

- A higher capital ratio (Δ) has an ambiguous effect on the cost of borrowing: as c is very low, then the loan rate is decreasing in the capital ratio; for 'large enough' c it is increasing. As mentioned in a footnote within the text, we find that for $c \geq 0.0014$ the loan rate is indeed increasing with the regulatory ratio. The value of c chosen in our calibration puts the increase in the weighted average cost of capital and the cost of credit following an increase in bank capital into a reasonable empirical range, as well as fixes the long run loan rate at a plausible level.