

Financial Shocks, Loan Loss Provisions and Macroeconomic Stability*

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Abstract

This paper studies the interactions between loan loss provisioning rules, business cycle fluctuations and monetary policy in a model with nominal price rigidities, a borrowing cost channel and endogenous credit default risk. We show that empirically relevant *specific* provisioning regimes induce financial accelerator mechanisms and result in financial, price and macroeconomic instability. *Dynamic* provisioning systems, set to cover for expected losses over the whole business cycle, significantly reduce welfare losses, and in addition moderate the (otherwise optimal) anti-inflationary stance in the monetary policy rule. The optimal policy response to financial shocks calls for a combination of macroprudential dynamic provisions and standard Taylor rules, which exclude targeting financial indicators.

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1 Introduction

In the aftermath of the financial crisis and the Great Recession, countercyclical bank capital buffers and loan to value (LTV) ratios have attracted most interest among policy makers and academics investigating macroprudential policy. The aim of these macroprudential tools is to enhance bank soundness, to help curb procyclicality in the financial system and to lessen the adverse externalities flowing from the financial sector to the real economy. The new regulatory Basel III accords, set to be fully implemented by 2018, intend to enforce banks to raise the quality of their assets, and to hold countercyclical capital buffers set as a fraction of up to 2.5% of risk-weighted assets. The bank equity buffers should be related to credit growth or the loan to GDP ratio, both viewed as good indicators of systemic risk (see Basel Committee on Banking Supervision (2011)). A number of recent contributions which have studied the performance of countercyclical bank capital regulation and LTV ratios in Dynamic Stochastic General Equilibrium (DSGE) models include Angelini, Neri and Panetta (2014), Angeloni and Faia (2013), Kannan, Rabanal and Scott (2012) and Rubio and Carrasco-Gallego (2014), among others. These papers conclude that a combination of countercyclical regulation and credit-augmented monetary policy rules is optimal from a macroeconomic and financial stabilization perspective.

Notably less attention in the theoretical literature has been given to the macroprudential role of loan loss provisions despite the recent calls of the Basel Committee for the transition from *specific* provisioning systems (incurred-loss approach) towards a more *dynamic* provisioning regime (expected-loss approach).¹ In practice, the provisioning system in most industrialized countries is specific and tied by the International Accounting Standards (IAS) 39, which require banks to set specific provisions related to identified credit losses (such as past due payments (usually 90 days) or other default-like events).²

By contrast, dynamic provisions should be set in a timely manner before credit risk materializes and during upswing phases, and allow the financial sector to better absorb losses by drawing upon these provisions in the wake of a negative credit cycle. Specifically, dynamic provisions ought to smooth out the evolution of total loan loss provisions, thus reducing the need of financial intermediaries to increase costly loan loss reserves during economic downturns. The Bank of Spain has introduced such statistical provisioning for loan loss reserves since 2001 in order to dampen excess procyclicality in credit growth. Under this system, banks must make provisions according to the latent risk over the business cycle, or based on the historical information regarding credit losses for different types of loans. By anticipating better the expected losses lurking in a loan portfolio, statistical provisions should provide additional buffers and mitigate procyclicality. While the dynamic provisioning regime in Spain allowed banks to enter the financial crisis in a more robust shape, it is less clear what kind of effect it had on the real estate bubble this country experienced in the previous decade (see Saurina (2009a,2009b), Caprio (2010) and Jiménez, Ongena, Peydró and Saurina (2012)).³

¹Dynamic (or statistical) loan loss provisions are sometimes also referred to as ‘forward-looking’ provisions, but because this term may be confusing, we have chosen not to use it in this paper. Our terminology used to describe the different provisioning regimes is consistent with Saurina (2009a, 2009b).

²Under the guidelines of the Generally Accepted Accounting Standards (GAAP) in the United States, loan loss provisions should be related to identified nonperforming loans, *and* also set at a sufficient level to cover for associated expected credit losses recognized at the specific time of the balance sheet. Therefore, the GAAP is also primarily ex-post by design.

³As noted in Wezel, Chan-Lau and Columba (2012), and Galindo, Rojas-Suarez and Del Valle (2013), several countries in Latin America have also introduced dynamic provisioning systems in recent years, but their experience

Two theoretical frameworks which examine the effectiveness of loan loss provisioning regimes are Bouvatier and Lepetit (2012a) and Agénor and Zilberman (2015). The former develop an analytical partial equilibrium model, and show that statistical provisions, defined by accounting rules to cover for expected losses, can eliminate procyclicality in lending standards induced largely by specific provisions. The latter use a standard medium-scale calibrated DSGE model and illustrate that dynamic provisions can help mitigate financial and real sector volatility, even more so when implemented together with a credit-augmented monetary policy rule. These results depend on an empirically justified stock-flow formulation for loan loss reserves, and more specifically on the gradual accumulation of loan loss reserves out of loan loss provisions as well as past reserves.

This paper examines the interactions between loan loss provisioning rules, business cycle fluctuations and monetary policy in a DSGE model featuring nominal price rigidities, a borrowing cost channel, collateralized lending and endogenous nonperforming loans (risk of default). Contributing to the theoretical models described above, within our framework we capture endogenously the two main stylized facts characterizing the behaviour of specific loan loss provisions: *i*) the negative correlation between output and provisions (Cavallo and Majnoni (2001), Laeven and Majnoni (2003) and Bikker and Metzmakers (2005); *ii*) the highly countercyclical relationship between the loan loss provisions to loan ratio and the economic activity (Clerc, Drumetz and Jaudoin (2001), De Lis, Pagés and Saurina (2001) and Pain (2003)). Moreover, the bank’s lending rate decision is directly linked to what we refer to as the provisioning cost channel; because provisions are costly and deducted from the bank’s income statement, higher loan loss provisions relative to loans amplify a rise in the loan rate following adverse financial shocks. As the lending rate is endogenously linked to the risk of default through a risk premium channel, raising more provisions during a downturn leads to higher financial risk and to additional procyclicality in borrowing costs (see Jin, Kanagaretnam and Lobo (2011), who document a strong positive relationship between loan loss provisions and the probability of bank failures (associated with higher nonperforming loans) for financially weak banks between 2007-2010).⁴ Specific provisions in this model are therefore shown to exacerbate procyclicality in the financial system, in line with the cross-country analysis performed by Bouvatier and Lepetit (2012b) and the partial equilibrium results of Bouvatier and Lepetit (2012a). Macroprudential regulation in the form of dynamic provisions, on the other hand, considerably attenuate the rise in borrowing costs and default risk inherent in deteriorating economic conditions.

As in Ravenna and Walsh (2006), firms in our model must borrow from a financial intermediary (bank) in order to finance their labour costs. Therefore, monetary policy, nonperforming loans and loan loss provisioning rules, all which dictate the loan rate behaviour, translate into changes in the firms’ marginal cost, price inflation and output through the borrowing cost channel.⁵ Supporting Gilchrist, Schoenle, Sim and Zakrajsek (2014), adverse financial shocks in our model produce inflationary pressures and thus lead to an output-inflation trade-off, which motivates us to examine implementable macroprudential policy tools beyond standard monetary policy rules. Following financial shocks, dynamic provisioning rules prove to be very effective in promoting both price

is still premature to provide robust conclusions.

⁴Contributing to Agénor and Zilberman (2015), in our model the loan rate, the fraction of nonperforming loans and the loan loss provisions to loan ratio are all endogenously related such that the provisioning cost channel has also a meaningful effect on financial risk.

⁵The additional financial frictions present in this model contribute to the standard monetary policy cost channel of Ravenna and Walsh (2006), where the loan rate is simply equal to the risk-free policy rate.

and output stability, thereby significantly improving social welfare.^{6,7} A credit spread-augmented monetary policy rule, on the other hand, increases inflation volatility and therefore adds zero welfare gains once the other standard monetary policy rule coefficients and/or the provisioning rule are optimized. Optimal policy analysis suggests that once dynamic provisions are fully implemented, the central bank can relax its anti-inflation response in the policy rule and in fact follow more conventional and empirically relevant Taylor (1993) rules. Put differently, statistical provisions can restore a normal operation of monetary policy rules and alleviate the standard output-inflation trade-off faced by central banks in the presence of a monetary policy cost channel.

This paper therefore contributes to the existing literature on loan loss provisions, which largely uses empirical and/or partial equilibrium frameworks to examine the role of provisioning practices in shaping the financial cycle. We go a step further and highlight the importance of loan loss provisioning rules in explaining also the behaviour of real business cycles and inflation, as well as their optimal interaction with simple monetary policy rules and welfare implications.

The remainder of the paper is structured as follows. Section 2 describes the model. We keep the presentation relatively brief, given that several ingredients are described in Ravenna and Walsh (2006) and Agénor, Bratsiotis and Pfajfar (2014). Instead, we focus on how our model departs from these papers, especially with respect to the bank’s balance sheet, loan loss provisioning regimes, financial risk shocks, credit spread-augmented monetary policy and optimal policy analysis. Section 3 details the equilibrium properties and parameterization of the model. Section 4 examines simple and implementable optimal policy rules that minimize a micro-founded welfare loss function following a financial shock. Section 5 concludes.

2 The Model

The economy consists of households, a final good (FG) firm, a continuum of intermediate good (IG) firms, a competitive bank, a government, 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 bank receives deposits from households, and sets the loan rate based on the refinance rate, the risk premium and the loan loss provisioning rule. For a given loan rate, monopolistic IG firms decide on the level of employment, prices and loans, with the latter used to partly fund wage payments to households. Using a standard Dixit-Stiglitz (1977) technology, the FG firm combines

⁶In 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 macroprudential regulation conducted via dynamic provisions.

⁷The 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, and Christiano, Eichenbaum, and Trabandt (2014) for the U.S). This result, therefore, requires the examination of macroprudential policies when firms rely on external finance to support their production activities. Moreover, contributing to Agénor and Zilberman (2015), the *output-inflation trade-off* generated by the borrowing cost channel as well as the small scale nature of our model allows us to analyse optimal simple rules which minimize a *micro-founded* welfare loss function.

all intermediate goods to produce a homogeneous final good used only for consumption purposes. At the end of the period, the idiosyncratic shocks are realized and the bank seizes collateral from defaulting firms. We now turn to focus on those aspects of the model that differ from Ravenna and Walsh (2006) and Agénor, Bratsiotis and Pfajfar (2014).

2.1 The Real Economy

Households have identical preferences over consumption (C_t) and labour (H_t). The objective of the representative household is to maximize,

$$U_t = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{1-\varsigma}}{1-\varsigma} - \frac{H_t^{1+\gamma}}{1+\gamma} \right\}, \quad (1)$$

where \mathbb{E}_t is the expectations operator, $\beta \in (0, 1)$ the discount factor, ς the inverse of the intertemporal elasticity of substitution in consumption, and γ the inverse of the Frisch elasticity of labour supply.

Households enter period t with real cash holdings of M_t . They receive their wage bill $W_t^R H_t$ paid as cash at the start of the period, with W_t^R denoting the real wages. This cash is then used to make deposits D_t at the bank (in real terms). The households remaining cash balances of $M_t + W_t^R H_t - D_t$ become available to purchase consumption goods (C_t) subject to a cash-in-advance constraint, $C_t \leq M_t + W_t^R H_t - D_t$. At the end of the period, households receive all real profit income from financial intermediation (J_t^{FI}), and the IG firms ($\int_0^1 J_{j,t}^{IG} dj$), and also pay a lump-sum tax (T_t).⁸ Furthermore, households earn the gross interest payments on their deposits ($R_t^D D_t$). The real value of cash carried over to period $t + 1$ is,

$$M_{t+1} \frac{P_{t+1}}{P_t} = M_t + W_t^R H_t - D_t - C_t + R_t^D D_t + J_t^{FI} + \int_0^1 J_{j,t}^{IG} dj - T_t. \quad (2)$$

With a positive deposit rate, $R_t^D > 1$, and taking real wages (W_t^R) and prices (P_t) as given, the first order conditions of the household's problem with respect to C_t, D_t and H_t can be summarized as,

$$C_t^{-\varsigma} = \beta \mathbb{E}_t \left(C_{t+1}^{-\varsigma} R_t^D \frac{P_t}{P_{t+1}} \right), \quad (3)$$

$$H_t^\gamma C_t^\varsigma = W_t^R. \quad (4)$$

Each IG firm $j \in (0, 1)$ faces the following linear production function,

$$Y_{j,t} = Z_{j,t} H_{j,t}, \quad Z_{j,t} \equiv \varepsilon_{j,t}^F A_t, \quad (5)$$

where $H_{j,t}$ is employment by firm j in period t , and A_t is a mean one aggregate productivity factor following a standard $AR(1)$ process. The term $\varepsilon_{j,t}^F$ represents an idiosyncratic shock with a constant variance distributed uniformly over the interval $(\underline{\varepsilon}^F, \bar{\varepsilon}^F)$.⁹

⁸Households also receive profits from the final good firm, but these profits are equal to zero in equilibrium.

⁹We 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 enables a closed-form expression for credit risk. See also Faia and Monacelli (2007) who adopt a similar approach.

The IG firm must partly borrow from a representative bank in order to pay households wages in advance. Let $L_{j,t}$ be the amount borrowed by firm j , then the (real) financing constraint is equal to,¹⁰

$$L_{j,t} = \kappa W_t^R H_t. \quad (6)$$

with $\kappa \in (0, 1)$ determining the fraction of wage bill that must be financed at the beginning of the period.¹¹

Financing labour costs bears risk and in case of default the bank expects to seize a fraction χ_t of the firm's output ($Y_{j,t}$). The term χ_t follows the $AR(1)$ shock process, $\chi_t = (\chi)^{1-\zeta^\chi} (\chi_{t-1})^{\zeta^\chi} \exp(\alpha_t^\chi)$, where $\chi \in (0, 1)$ is the steady state value of this fraction, ζ^χ the degree of persistence, and α_t^χ a random shock with a normal distribution and a constant variance.¹² A shock to effective collateral (χ_t) represents a financial (credit) shock in this model, as it directly impacts credit risk at the firm level as well as bank credit spreads as shown below.

In the good states of nature each firm pays back the bank principal plus interest on loans. Consequently, and in line with the willingness to pay approach to debt contracts, default occurs when the expected value of seizable output ($\chi_t Y_{j,t}$), net of state verification and enforcement costs, is less than the amount that needs to be repaid to the lender at the end of the period, i.e., $\chi_t Y_{j,t} < R_t^L L_{j,t}$, where R_t^L denotes the gross lending rate. Using (5) and (6), the threshold value ($\varepsilon_{j,t}^{F,M}$) below which the IG firm defaults is,

$$\varepsilon_{j,t}^{F,M} = \frac{\kappa}{\chi_t A_t} R_t^L W_t^R. \quad (7)$$

Therefore, the cut-off point is related to aggregate credit shocks, the funding costs and 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 and Aizenman (1998), and Agénor, Bratsiotis and Pfajfar (2014)), but *also* on credit risk shocks and the loan loss provisions to loan ratio.¹³ Given the uniform properties of ε_t^F , the closed-form expression for the probability of default (or the fraction of nonperforming loans) is,

$$\Phi_t = \int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} f(\varepsilon_t^F) d\varepsilon_t^F = \frac{\varepsilon_{j,t}^{F,M} - \underline{\varepsilon}^F}{\bar{\varepsilon}^F - \underline{\varepsilon}^F}. \quad (8)$$

Finally, the pricing decision during period t takes place in two stages. In the first stage, each IG producer minimizes the cost of employing labour, taking its effective costs ($R_t^L W_t^R$) as given.

¹⁰For 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)).

¹¹We assume that the remainder of the wage bill to households, $(1 - \kappa)W_t^R H_t$, is financed through lump-sum taxes, T_t .

¹²Steady state values are denoted by dropping the time subscript.

¹³As we solve explicitly for the risk of default using a threshold condition, the collateral constraint in this model, from which we derive the cut-off point, is always binding.

This minimization problem yields the real marginal cost,¹⁴

$$mc_t = \frac{[1 + \kappa (R_t^L - 1)] W_t^R}{Z_{j,t}}. \quad (9)$$

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 firms keep their prices fixed while a portion of $1 - \omega$ firms adjust prices optimally given the going marginal cost and the loan rate. Solving the standard IG firm's problem yields the familiar form of the log-linear New Keynesian Phillips Curve (NKPC): $\hat{\pi}_t = \beta \mathbb{E}_t \hat{\pi}_{t+1} + k_p \widehat{mc}_t$, with $k_p \equiv (1 - \omega)(1 - \omega\beta)/\omega$.

2.2 The Financial Sector

2.2.1 Balance Sheet and Loan Loss Reserves

Consider a perfectly competitive bank, who raises funds through deposits (D_t) and a liquidity injection (X_t) from the central bank in order to supply credit (L_t) to IG firms. Moreover, the bank holds government bonds (B_t), a safe asset, yielding a gross return of R_t^B . As the loan portfolio takes into account expected loan losses, loan loss reserves (LLR_t) are subtracted from total loans, consistent with standard practice (see Walter (1991) and Jiménez, Ongena, Peydró and Saurina (2012)). The bank lends to a continuum of firms and therefore its balance sheet (in real terms) is $L_t - LLR_t + B_t = D_t + X_t$, where $L_t \equiv \int_0^1 L_{j,t} dj$ is the aggregate lending to IG firms.

The bank must also satisfy regulation in the form of setting loan loss provisions (a flow), which are deducted from current earnings. Loan loss reserves (a stock) are assumed to be invested into a safe asset such that $LLR_t = B_t$. This assures that loan loss reserves are a liquid asset and available to face losses (as in Bouvatier and Lepetit (2012a)). Further, it is assumed that in equilibrium government bonds are issued in zero net supply so we do not need to specify the evolution of loan loss reserves in order to examine the direct effects of loan loss provisioning practices on the bank's intra-period intermediation activities.^{15,16} Using these results, the bank's balance sheet boils down to,

$$L_t = D_t + X_t. \quad (10)$$

¹⁴Below 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 cost through its endogenous impact on the cost of borrowing. In other words, firms internalize the possibility of default in their optimal pricing behaviour once they borrow at the going lending rate.

¹⁵In practice, *variations* in loan loss reserves are equal to the flow of provisions plus unanticipated charged-off loans (subtracted from earnings) minus charged-off loans (Walter (1991)). Due to the intra-period nature of loans and rational expectations, we do not model charged-off loans given that there is no distinction between the fraction of nonperforming loans and the fraction of charged-off loans (both of which are equal to the risk of default). To avoid a zero steady state value of provisions and to simplify the analysis, we assume that loan loss reserves are invested in government bonds in each period.

¹⁶In Agénor and Zilberman (2015), government bonds play a role in the determination of the money market equilibrium and the bond rate, which, in turn, affects the transmission process of shocks and linkages between the real and financial sides of the economy. In our simpler model, by contrast, money is a veil, with the bond rate, deposit rate and policy rate all being equal.

2.2.2 Provisioning Rules and Nonperforming Loans

Provisioning rules are set by the central bank. We consider two specifications of loan loss provisions: *i*) a *specific* provisioning system, where loan loss provisions are driven by contemporaneous nonperforming loans and fit identified loan losses; *ii*) a macroprudential *dynamic* provisioning system that requires the bank to make provisions related to both current risk (specific provisions) *and* expected losses over the whole business cycle. Loan loss provisions are defined as,

$$LLP_t^i = l_0 \Phi \left(\frac{\Phi_t}{\Phi} \right)^{1-\mu} L_t, \quad (11)$$

where l_0 is the steady state fraction of nonperforming loans ($\Phi \left(\frac{\Phi_t}{\Phi} \right)^{1-\mu} L_t$), which are covered by loan loss provisions in period t (also referred to as the coverage ratio). The term Φ is the steady state risk of default, and $\mu \in (0, 1)$ is the degree of loan loss provisions smoothing under the macroprudential dynamic regime. With $\mu = 0$ (no smoothing), $LLP_t^S = l_0 \Phi_t L_t$, corresponding to the extreme specific, incurred-loss approach system (superscript \mathbb{S}). In contrast, the dynamic provisioning system (superscript \mathbb{D}), is represented by setting $0 < \mu \leq 1$ such that $LLP_t^D = l_0 \Phi^\mu \Phi_t^{1-\mu} L_t$. A larger μ implies a higher smoothing effect on loan loss provisions. In this way, during an economic expansion, where the short run value of nonperforming loans (Φ_t) is lower than the estimation of the latent risk over the whole cycle (Φ) and lending (L_t) is high, the bank can build up statistical provisions. Taking into account expected losses over the business cycle offsets the short-run impact of problem loans on total provisions, and allows the bank to deduce constant expected losses in each period when $\mu = 1$. The underlying principle is that provisions should be set in line with long-run, or “through-the-cycle” expected losses, which are estimated based on past experience rather than in terms of the current credit risk (“point-in-time” losses). Hence, dynamic provisions make provisioning efforts more stable and less dependent on the cycle (see also Jiménez and Saurina (2006), Saurina (2009a) and Galindo, Rojas-Suarez and Del Valle (2013)).¹⁷

As we show later, the probability of default in this setup moves countercyclically with output (collateral) and therefore a rise in the fraction of nonperforming loans, associated with deteriorating economic conditions, results in an increase in loan loss provisions and the loan loss provisions to loan ratio. These results are consistent with the main stylized facts characterizing the behaviour of specific loan loss provisions governed by the IAS 39 in practice (see references provided in the introduction).

2.2.3 Lending Rate Decision

At the beginning of period t , the bank breaks even from its intermediation activity, such that the expected income from lending to a continuum of IG firms minus the flow expense of loan loss provisions for the given period, is equal to the total costs of borrowing deposits from households

¹⁷Put differently, provisions in the dynamic system do not explicitly depend on the statistical prediction of nonperforming loans in period $t + 1$. Rules are specified in order to smooth provisions made by the bank over a whole business cycle (see also Bouvatier and Lepetit (2012a)). Note also that regardless of the provisioning regime, the steady state value of loan loss provisions with our specification is always $LLP = l_0 \Phi L$.

and receiving liquidity from the central bank,¹⁸

$$\int_{\underline{\varepsilon}_{j,t}^F}^{\bar{\varepsilon}^F} [R_t^L L_{j,t}] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F + \int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} [\chi_t Y_{j,t}] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F - LLP_t^i = R_t^D (D_t + X_t), \quad (12)$$

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.

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

$$\int_{\underline{\varepsilon}_{j,t}^F}^{\bar{\varepsilon}^F} [R_t^L L_{j,t}] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F \equiv \int_{\underline{\varepsilon}^F}^{\bar{\varepsilon}^F} [R_t^L L_{j,t}] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F - \int_{\underline{\varepsilon}^F}^{\varepsilon_{j,t}^{F,M}} [R_t^L L_{j,t}] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F,$$

where $\int_{\underline{\varepsilon}^F}^{\bar{\varepsilon}^F} [R_t^L L_{j,t}] f(\varepsilon_{j,t}^F) d\varepsilon_{j,t}^F \equiv R_t^L L_{j,t}$. Hence, using equations (10), (7) for $\chi_t (A_t \varepsilon_{j,t}^{F,M}) N_{j,t} = R_t^L L_{j,t}$, (5), dividing by $L_{j,t}$ and applying the characteristics of the uniform distribution yields,¹⁹

$$R_t^L = R_t^D + \frac{LLP_t^i}{L_t} + \left(\frac{\chi_t A_t}{\kappa W_t^R} \right) \frac{(\bar{\varepsilon}^F - \underline{\varepsilon}^F)}{2} \Phi_t^2. \quad (13)$$

Finally, substituting (7) and (8) in (13) gives the final loan rate equation,

$$R_t^L = \nu_t \left(R_t^D + \frac{LLP_t^i}{L_t} \right), \quad (14)$$

where the term $\nu_t \equiv \left[1 - \frac{(\bar{\varepsilon}^F - \underline{\varepsilon}^F)}{2\varepsilon_{j,t}^{F,M}} \Phi_t^2 \right]^{-1} > 1$ is defined as the finance premium, which itself is also a positive function of the lending rate.

From equation (14), the loan rate is affected by various components: *i*) the direct *monetary policy cost channel* associated with changes in the deposit rate, equal to the refinance rate in the absence of required reserves policies; *ii*) the *finance premium channel*, which is related to the fact that the bank expects to receive back only a fraction of its loans and seize collateral in case of default. The bank internalizes the positive risk of default and consequently charges a higher loan rate.

The contribution of this model is the additional effects loan loss provisioning rules have on the cost of borrowing and financial risk; what is referred to as: *iii*) the *provisioning cost channel*. A higher loan loss provisions to loan ratio (LLP_t^i/L_t), associated with a rise in identified credit losses, lowers the profitability of the bank and therefore requires an increase in the loan rate for the break-even condition to be satisfied. This can explain procyclicality in the credit markets generated by specific provisioning systems (see also Bouvatier and Lepetit (2012a, 2012b)). Moreover, through an internal propagation mechanism, the higher borrowing costs amplify the rise in nonperforming loans and produce further procyclicality in financial variables (see equations 7, 8 and 14). More precisely, specific provisions result in higher financial risk, supporting empirical findings by Jin, Kanagaretnam and Lobo (2011).

¹⁸The extra central bank liquidity is paid back at the risk-free deposit rate.

¹⁹The subscript j is dropped given that the amount of labour and loans are the same for all firms.

2.3 Monetary Policy

The central bank sets the loan loss provisioning rules (as explained above), and in addition targets the short term policy rate (R_t^{cb}) according to a Taylor (1993)-type policy rule,

$$R_t^{cb} = \left[\left(R^{cb} \right) \left(\frac{\pi_t}{\pi^T} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_t^n} \right)^{\phi_Y} \left(\frac{R_t^L/R_t^D}{R^L/R^D} \right)^{-\phi_s} \right]^{1-\phi} \left(R_{t-1}^{cb} \right)^\phi, \quad (15)$$

where $\phi \in (0, 1)$, and $\phi_\pi, \phi_Y > 0$ coefficients measuring the relative weights on inflation deviations from its target (π^T) and the ‘natural’ output gap, respectively. The output gap is defined as deviations of output from its flexible price equilibrium (natural) level given by $Y_t^n = \left[\frac{Z_t^{1+\gamma}}{pm(1+\kappa(R_t^L-1))} \right]^{\frac{1}{(\varsigma+\gamma)}}$, where pm denotes the price mark-up resulting from the monopolistic competition in the intermediate goods market. The new term added to the conventional Taylor rule is $\left(\frac{R_t^L/R_t^D}{R^L/R^D} \right)^{\phi_s}$, where $\phi_s \geq 0$ measures the response of the policy rule to deviations in credit spreads. These types of augmented monetary policy rules (‘leaning against the credit cycle’) have been advocated by Taylor (2008) and Cúrdia and Woodford (2010), among others, and may be effective so long inflation and output are not above their potential levels.²⁰

3 Equilibrium and Parameterization

In line with the cost channel literature, we assume the size of the liquidity injection from the central bank (also the financial regulator in this model) is $X_t = M_{t+1} \frac{P_{t+1}}{P_t} - M_t$. Following the financial intermediation process, the central bank receives $R_t^D X_t + LLP_t = J_t^{FI}$, which is paid back to the household in a lump-sum fashion.²¹ In a symmetric equilibrium, we substitute the IG firms profits, total profits from the financial intermediation process, the equilibrium condition in the market for loans ($\kappa W_t^R H_t = D_t + X_t$), lump-sum taxes ($T_t = (1 - \kappa) W_t^R H_t$), and the size of the liquidity injection in identity (2) to obtain the market clearing condition, $Y_t = C_t$.²²

To solve the model, we log-linearize the behavioral equations and the resource constraint around the non-stochastic, zero inflation ($\pi^T = 1$) steady state and take the percentage deviation from their counterparts under flexible prices. The log-linearized versions of (3), (4), (9) and Y_t^n can be used to express the model in terms of the following two equations involving the (natural) output gap ($\hat{Y}_t - \hat{Y}_t^n$), inflation ($\hat{\pi}_t$), the loan rate (\hat{R}_t^L) and the loan rate gap ($\hat{R}_t^L - \hat{R}_t^{L,n}$),

$$\hat{Y}_t - \hat{Y}_t^n = \mathbb{E}_t \left(\hat{Y}_{t+1} - \hat{Y}_{t+1}^n \right) - \varsigma^{-1} \left(\hat{R}_t^D - \mathbb{E}_t \hat{\pi}_{t+1} \right) + v (\varsigma + \gamma)^{-1} \left(\hat{R}_t^L - \mathbb{E}_t \hat{R}_{t+1}^L \right) + \hat{u}_t, \quad (16)$$

$$\hat{\pi}_t = \beta \mathbb{E}_t \hat{\pi}_{t+1} + k_p (\varsigma + \gamma) (\hat{Y}_t - \hat{Y}_t^n) + k_p v \left(\hat{R}_t^L - \hat{R}_t^{L,n} \right), \quad (17)$$

where $\hat{u}_t \equiv ((1 + \gamma)/(\varsigma + \gamma)) \left(\mathbb{E}_t \hat{Z}_{t+1} - \hat{Z}_t \right)$, and $v \equiv \kappa R^L / (1 + \kappa(R^L - 1))$. Equation (16) is the

²⁰ Having the Taylor rule responding negatively to the loan rate and risk of default, or positively to credit would not affect the results materially.

²¹ Recall the commercial bank breaks-even and therefore earns zero profits.

²² By receiving all profits from the financial intermediation process, households deposits are safe and output equals consumption at all times.

Euler equation describing the determinants of the output gap.²³ The gap is affected positively by its expected future value, negatively by the policy rate and positively by the loan rate, which itself increases with the refinance rate. Hence, the policy rate has an ambiguous impact on the output gap and inflation, stemming from the standard demand channel of monetary policy on the one hand, and the monetary policy cost channel on the other. Equation (17) is the NKPC relating current inflation to future inflation, and to the output gap and loan rate gap, both of which comprise of the marginal cost. Higher external financing costs experienced by firms lead to a rise in inflation and the output gap, and exert a downward pressure on the economic activity. Compared to Ravenna and Walsh (2006), the loan rate term in both equations (the borrowing cost channel) is driven mainly by credit risk and provisioning rules rather than the refinance rate. Therefore, this general equilibrium framework allows us to study how different accounting and regulatory rules for loan loss provisions translate into real macroeconomic effects.²⁴

The baseline parameterization used to simulate the model is summarized in Table 1. Parameters that characterize tastes, preferences, technology and the standard Taylor rule, are all standard in the literature. We therefore focus on in what follows on the parameters that are unique to this model.

Table 1: Benchmark Parameterization - Parameter Values

Parameter	Value	Description
β	0.997	Discount Factor
ς	1.00	Inverse of Elasticity of Intertemporal Substitution
γ	1.00	Inverse of the Frisch Elasticity of Labour Supply
λ	6.00	Elasticity of Demand for Intermediate Goods
ω	0.65	Degree of Price Stickiness
A	1.00	Average Productivity Parameter
κ	0.50	Strength of the Borrowing Cost Channel
$\bar{\varepsilon}^F$	1.90	Idiosyncratic Productivity Shock Upper Range
$\underline{\varepsilon}^F$	0.50	Idiosyncratic Productivity Shock Lower Range
χ	0.98	Average Fraction of Collateral Seized in Default States
μ	0.00	Smoothing Coefficient in Dynamic LLP Rule
ϕ	0.70	Degree of Persistence in Taylor rule
ϕ_π	1.50	Response of Policy Rate to Inflation Deviations
ϕ_Y	0.10	Response of Policy Rate to Output Gap
ϕ_s	0.00	Response of Policy Rate to Credit Spreads
$s.d(\alpha_t^X)$	0.14	Standard Deviation - Financial Shock
ς^X	0.90	Degree of Persistence - Financial Shock

The loan loss provisions coverage ratio (l_0) is parametrized at 1, meaning that loan loss provisions fully cover for nonperforming loans. This value, together with $\chi = 0.98$, $\kappa = 0.5$ and an

²³Equations (16) and (17) can also be written in terms of the welfare relevant (efficient) output gap ($\widehat{Y}_t - \widehat{Y}_t^e$) by applying $\widehat{Y}_t^e - \widehat{Y}_t^n = (\gamma + \varsigma)^{-1} v \widehat{R}_t^{L,n}$.

²⁴Unlike De Fiore and Tristani (2013), who also have a cost channel affected by financial frictions, the focus of our model is to study optimal simple regulatory and monetary policy rules rather than optimal monetary policy under commitment.

idiosyncratic productivity range of (0.50, 1.90), gives a loan loss provisions-loan ratio (matching the fraction of nonperforming loans) of 3.84% per annum and a loan rate of 5.08% per annum.²⁵ These values are well within the range observed for advanced economies. Furthermore, the Taylor rule parameters in our benchmark case are set to $\phi_\pi = 1.5$ and $\phi_Y = 0.1$, values typically employed in the literature. We calibrate the persistence parameters (ζ^i) and standard deviations ($s.d(\alpha_t^i)$) associated with financial ($i = \chi$) and technology ($i = A$) shocks to approximately match the standard deviations of loan rates, output and inflation in the U.S. data, over the period 2000:Q1-2015:Q2. For financial shocks we obtain $\zeta^\chi = 0.90$ and $s.d(\alpha_t^\chi) = 0.14$, while for supply supply shocks the results imply $\zeta^A = 0.98$ and $s.d(\alpha_t^A) = 0.08$.

4 Optimal Simple Policy Rules and Welfare

In this section, we calculate optimal policy rules in response to financial shocks, and examine the interaction between monetary policy and loan loss provisioning rules. The central bank's objective function is given by a second order approximation of the household's ex-ante expected utility written in 'gap' form (see Appendix D for details),

$$\sum_{t=0}^{\infty} \beta^t U_t \approx U - \frac{1}{2} U_C C \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{\lambda}{\kappa_p} \right) \text{var}(\hat{\pi}_t) + (\zeta + \gamma) \text{var}(\hat{Y}_t^g) \right], \quad (18)$$

where $\hat{Y}_t^g = \hat{Y}_t - \hat{Y}_t^e$ is the *welfare relevant* output gap, and $\hat{Y}_t^e = [(1 + \gamma) / (\zeta + \gamma)] \hat{Z}_t$ is the efficient level of output chosen by a social planner who can overcome all the nominal and financial frictions in this economy.²⁶ As supply shocks are not considered for the purpose of the main paper, the welfare relevant output gap is simply equal to cyclical output, $\hat{Y}_t^g = \hat{Y}_t$.²⁷

The policy rules examined are: Policy I (benchmark case) - specific provisions ($\mu = 0$) and a standard Taylor rule policy where the central bank sets exogenously $\phi_\pi = 1.5$, $\phi_Y = 0.1$ and $\phi_s = 0$. Policy II - central bank responding optimally to inflation in the Taylor rule (solving for ϕ_π and setting $\phi_s = \mu = 0$). Policy III - central bank reacting optimally to inflation and credit spreads (solving for ϕ_π and ϕ_s , and setting $\mu = 0$). Policy IV - an optimal response to inflation and a dynamic provisioning system (solving for ϕ_π and μ , and setting $\phi_s = 0$). Policy V - a credit spread-augmented Taylor rule and a dynamic provisioning system (solving for ϕ_π , ϕ_s and μ). The optimal parameters that maximize welfare are grid-searched within the following implementable ranges: $\phi_\pi = [1 : 10]$, $\phi_s = [0 : 1]$ and $\mu = [0 : 1]$ with step of 0.01. In all policies we keep $\phi_Y = 0.1$ as we find that optimally altering this parameter once ϕ_π is set optimally adds only negligible welfare gains.

In considering Policies $j = II, III, IV, V$, we measure the welfare gain of a particular policy j as a fraction of the consumption path under the benchmark case (Policy I) that must be given up in order to obtain the benefits of welfare associated with the various optimal policy rules;

²⁵See Appendix A for a sensitivity analysis conducted with respect to χ and κ .

²⁶The richer borrowing cost channel, featuring default risk and loan loss provisions, therefore does not change the *structure* of the loss function compared to standard New Keynesian models with just a monetary policy cost channel (see also Ravenna and Walsh (2006) and Appendix D of this paper).

²⁷We also do not examine the ex-post effects of the actual idiosyncratic productivity shock ($\varepsilon_{j,t}^F$), but only consider its uniform properties and how its threshold ($\varepsilon_t^{F,M}$) value moves in response to aggregate shocks hitting the economy at the beginning of the period. Therefore, $\hat{Y}_t^g = \hat{Y}_t$ in the absence of beginning of period supply and end of period idiosyncratic shocks still holds. Results for supply shocks are presented in Appendix C.

$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U_t (C_t^j, H_t^j) = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U_t ((1 - \Lambda) C_t^I, H_t^I)$, where Λ is a measure of welfare gain in units of steady state consumption. Given the utility function adopted and with $\varsigma = 1$, the expression for the consumption equivalent (Λ) in percentage terms is,

$$\Lambda = \left\{ 1 - \exp \left[(1 - \beta) \left(\mathbb{W}_t^j - \mathbb{W}_t^I \right) \right] \right\} \times 100,$$

with $\mathbb{W}_t^j = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U_t (C_t^j, H_t^j)$ representing the unconditional expectation of lifetime utility under

policy $j = II, III, IV, V$, and $\mathbb{W}_t^I = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U_t (C_t^I, H_t^I)$ the welfare associated with the benchmark

Policy I. A higher positive Λ implies a larger welfare gain and hence indicates that the policy is more desirable from a welfare perspective. The steady state of our model is independent of the monetary policy rule $(\phi_\pi, \phi_Y, \phi_s)$ and the type of the loan loss provisioning rule (μ) so our computation of social welfare is comparable across all policy rules.²⁸

Table 2 shows the welfare gains associated with the optimal simple policy rules, and how the value of each policy rule changes with the introduction of additional policy instruments following a 0.14 standard deviation shock to χ_t .

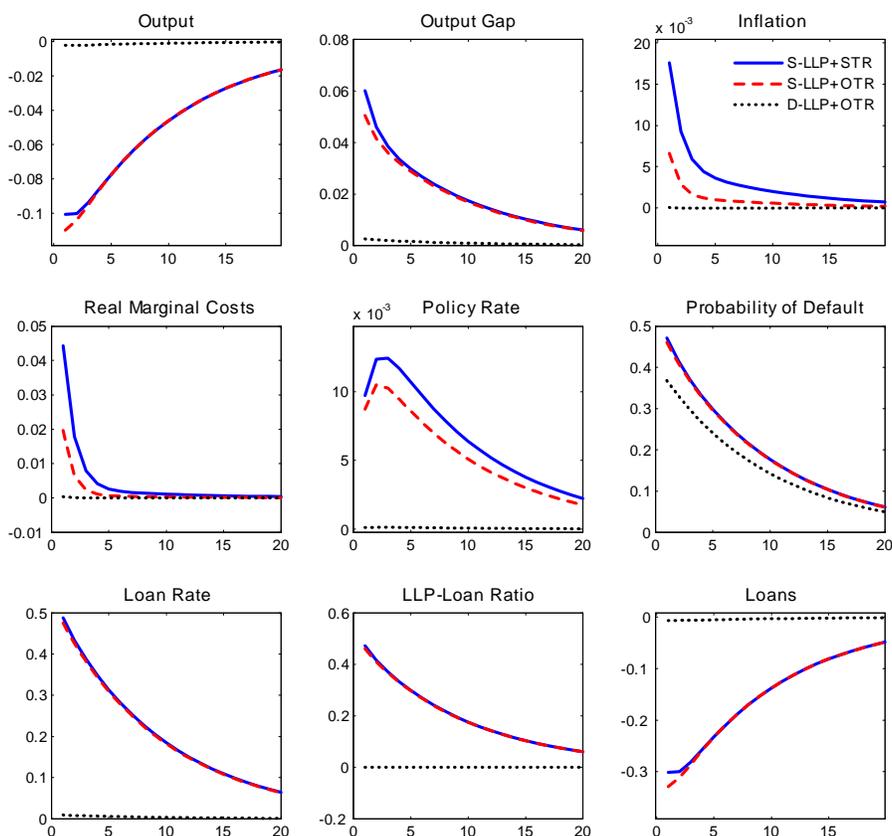
Table 2: Optimal Simple Policy Rules - Financial Shock

	Policy I	Policy II	Policy III	Policy IV	Policy V
	$\phi_\pi = 1.50$	$\phi_\pi = 3.63$	$\phi_\pi = 3.63$	$\phi_\pi = 1.66$	$\phi_\pi = 1.66$
	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$
	$\phi_s = -$	$\phi_s = -$	$\phi_s = 0.00$	$\phi_s = -$	$\phi_s = 0.00$
	$\mu = -$	$\mu = -$	$\mu = -$	$\mu = 1$	$\mu = 1$
	$\Lambda = -$	$\Lambda = 8.08 \times 10^{-3}$	$\Lambda = 8.08 \times 10^{-3}$	$\Lambda = 0.15$	$\Lambda = 0.15$

Figure 1 depicts the impulse response functions associated with the optimal policy parameters as calculated in Table 2 following a 1 percent adverse financial shock. More specifically, we compare benchmark Policy I (specific provisions+standard Taylor rule ('S-LLP+STR')) to Policy II (identical to Policy III - both labelled as specific provisions + optimal Taylor rule ('S-LLP+OTR')), and Policy IV (identical to Policy V, both labelled as dynamic provisions+optimal Taylor rule ('D-LLP+OTR')). The impulse response functions illuminate the discussion below.

²⁸Including loan loss provisions *does alter* the steady state of the model compared to a setup featuring no provisions (see steady state equations for (11) and (14)). Therefore, to make our welfare analysis comparable and tractable, our benchmark case (Policy I) features a specific provisioning rule (as implemented in most industrialized countries), and a conventional Taylor rule. In Appendix B, we show that the inclusion of specific provisions improves the model's ability to capture more data-consistent steady state interest rate margins, as well as considerably amplifies economic fluctuations compared to a model economy without provisions. However, using a full macroprudential dynamic provisioning system ($\mu = 1$) stabilizes the economy closer towards a model absent of the additional steady state and dynamic frictions caused by specific loan loss provisions. In line with Angelini, Neri and Panetta (2014), for example, our approach towards loan loss provisions (regulatory and accounting tool) is *positive*. That is, empirically relevant specific provisions initially exist because government regulation requires it (see IAS 39 in practice). The question we ask therefore is: with the presence of regulatory loan loss provisions, which macroprudential type rules can achieve the highest welfare? Unlike their model, nevertheless, our focus is on dynamic provisions (rather than bank capital requirements), with the welfare criterion being micro-founded and based on the underlying economic and financial distortions.

Figure 1: Adverse Financial Shock with Optimal Policy Rules



Note: Interest rates, inflation rate, the probability of default and the LLP-loan ratio are measured in percentage point deviations from steady state. The rest of the variables are measured in terms of percentage deviations.

In benchmark Policy I, a negative financial shock translates into an immediate rise in nonperforming loans and consequently the loan rate through the finance premium effect. The hike in the lending rate, coupled with the rise in risk, raises the marginal cost, increases price inflation and lowers the level of output (collateral) via the borrowing cost channel. The decreasing levels of available collateral exacerbates the rise in risk and propagates the worsening credit market conditions into the real economy. Furthermore, with standard Taylor rule parameters, higher prices prompt the central bank to raise the policy rate, thus inducing a more pronounced effect on the lending rate through the monetary policy cost channel. However, by raising the policy rate, output deteriorates further, which, in turn, mitigates the rise in the natural output gap and inflation via the standard demand channel of monetary policy. Given the nature of the adverse financial shock hitting directly credit risk, the rise in the loan rate raises inflation and the output gap, and lowers both output and

credit.²⁹ Finally, as raising specific provisions is costly for the bank, this incurred-loss approach system magnifies volatility in the loan rate and nonperforming loans compared to the case where provisions are absent.³⁰ Hence, inflationary pressures increase while the drop in output and loans is intensified.

Policy II prescribes a relatively high, yet contained, weight on inflation in the monetary policy rule such that the refinance rate initially increases following adverse credit shocks. In this case, the natural output gap is lowered (compared to a standard Taylor rule), which mitigates the inflationary pressures resulting from the rise in the cost of borrowing. At the same time, the higher policy rate amplifies welfare output and loan losses, but this has a smaller impact on overall welfare given that the policy maker places a much higher weight on inflation variance relative to output volatility in the micro-founded loss function.³¹ The upshot is that the fall in the natural output gap and inflation moderate the rise in the policy rate, which as a result contributes further to price stability and welfare through the monetary policy cost channel.

In Policy III, and still in the presence of inflationary specific provisions, we observe that a credit spread-augmented Taylor rule does not promote overall welfare once the other Taylor rule coefficients are optimized as it exerts higher volatility in inflation.³² By calculating the theoretical moments, adjusted for the size of the shock, we find that even a small response to credit spreads ($\phi_s = 0.01$), with the other Taylor rule parameters optimized ($\phi_\pi = 3.63$), increases the standard deviation in inflation from 0.0078 to 0.0114, and reduces the standard deviation in output from 0.2665 to 0.2662. Intuitively, a credit spread-augmented monetary policy rule initially mitigates the rise in the policy rate following a rise in spreads, thereby moderating the decline in output but at the cost of raising the output gap and inflation via an intertemporal substitution effect. These inflationary outcomes, in turn, trigger a hike in the policy rate. Given our standard parameterization, the demand channel dominates the monetary policy cost channel, with the overall increase in the refinance rate fuelling additional upward pressures on the loan rate and accordingly on inflation. Therefore, with a well-defined micro-founded welfare loss function, the welfare contribution of monetary policy leaning against financial instability (measured in terms of variations in credit spreads, loan rate or default risk) is null.

The role of macroprudential dynamic provisions is emphasized in Policy IV. The optimal provisioning policy calls for a full smoothing of loan loss provisions relative to loans such that the bank needs not to raise as much provisions in response to adverse credit shocks. Expected credit losses (statistical, latent risk) are fully taken into account, and offset the immediate procyclical impact of current nonperforming loans on loan loss provisions and the loan rate instigated by the specific provisioning system. The fall in the lending rate attributed to the weaker provisioning cost channel reduces procyclicality in nominal, real and financial variables through the borrowing cost channel, and leads to considerable welfare gains compared to Policies I, II and III. More precisely, relative to the non-optimized benchmark Policy I, macroprudential dynamic provisions provide a welfare gain of about 0.15 percent of permanent consumption, a value not inconsistent with the relatively

²⁹See also Gilchrist, Schoenle, Sim and Zakrajsek (2014), who show that *aggregate* inflation rises following adverse financial shocks.

³⁰In Appendix A we perform a full volatility analysis which confirms the impulse response analysis of this section. Also, see Appendix B for the additional simulation of a model without provisions.

³¹Specifically, $\lambda/\kappa_p = 31.66$ and $\varsigma + \gamma = 2.00$.

³²We find that this sub-optimal result for credit spread-augmented Taylor rules also holds when: *i*) the other monetary policy rule coefficients are *not* optimized ($\phi_\pi = 1.5$ and $\phi_Y = 0.1$); *ii*) there are *no* specific loan loss provisions.

large welfare improvement obtained in Benes and Kumhof (2015) following an implementation of a countercyclical bank capital buffer rule. This result highlights the importance of flattening the loan loss provisions to loan ratio based on the expected loss approach as observed in the Spanish system (see also Jiménez and Saurina (2006)). Furthermore, in Policy IV, inflation and output fluctuations are contained by the dynamic provisioning system, which also alleviates considerably the standard output-inflation trade-off faced by the central bank in the presence of a monetary policy cost channel. Consequently, a dynamic provisioning regime allows the central bank to relax its response to inflation, and follow more conventional and data-consistent Taylor (1993) rules ($\phi_\pi = 1.66$). To complete our analysis we also examine Policy V and show that once the standard monetary policy *and* loan loss provisioning rules are optimized, there is still no welfare benefit from monetary policy leaning against the credit cycle.

These results support the ‘conventional’ view that financial stability concerns should be primarily attributed to regulatory instruments (Svensson (2012)), whereas the best a central bank can do is focus on price and output gap stability (Bernanke and Gertler (2001)). With this in mind, macroprudential regulation can be very potent in achieving the primary mandates of central banks when financial markets and the real economy are intertwined.

5 Concluding Remarks

This paper sheds new insights on how macroprudential policy in the form of dynamic provisions impacts the financial system, real economy and welfare, as well as alters the optimal conduct of monetary policy. The main results are summarized in the introduction. The conclusions drawn from this paper support the recent calls by the Basel committee to re-design accounting principles such that banks set discretionary provisions in a timely manner based on the expected-loss approach (see Basel Committee on Banking Supervision (2011,2012)). Indeed, the Basel Committee continues to work with the International Accounting Standards Board (IASB) on the expected-loss approach to loan loss provisions in order to reform the IAS 39, the incurred-loss framework and procyclicality issues instigated by specific provisions. Coordinating between these boards and central banks, by increasing transparency regarding the effective roles of each institutional body, should promote even further financial and macroeconomic stability.

A natural extension to this model would be to simultaneously account for countercyclical capital requirements and dynamic provisioning systems, and understand how such policy tools interact with one another. In this setup featuring a borrowing cost channel, both dynamic provisions and countercyclical capital buffers would impact the real economy through their effect on the lending rate. Assuming that bank capital is more costly than deposits (due to a tax advantage of debt over equity for example), a regulatory rule which relaxes (tightens) equity requirements during bad (good) times can also lead to significant welfare improvements and therefore act as a substitute to dynamic provisions. However, in the presence of an effective dynamic provisioning system, as already implemented in some countries, the countercyclical weight on a Basel III type equity rule would not need to be too aggressive in order to mitigate welfare losses. Put differently, a small adjustment in bank capital requirements, based on the nature of the business cycle and unexpected losses, would suffice to promote even further macroeconomic stability when dynamic provisions (covering for expected losses) are set. In this case, bank capital and loan loss provisions would be complementary to one another. We leave the formal analysis of this important issue for future research.

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6 Appendices

6.1 Appendix A - Robustness

To assess the robustness of the results presented in the main analysis, we consider several additional independent experiments: a higher value on the weight given to the borrowing cost channel (κ), and then a lower fraction of output seized by the bank in the default states of nature (χ). Specifically, by adjusting κ and χ , we calculate the new optimal policy parameters and welfare gains/losses following a 0.14 standard deviation shock to χ_t .

The weight on the borrowing cost channel (κ) - for the first experiment we consider an increase in the weight attached to the borrowing cost channel from $\kappa = 0.50$ to $\kappa = 0.55$. An alteration in this value, all else equal, affects directly the steady state risk of default and loan rate which increase to $\Phi = 21.76\%$ (from 3.84%) per annum, and $R^L = 24.48\%$ (from 5.08%) per annum, respectively. These values are significantly higher than the average estimates for advanced economics, and in the model also result in an annual drop of 5.34% in the long-run level of output (Y). We allow for these extremely large variations in steady state risk and cost of borrowing to highlight that our policy implications as presented in the main text prevail.³³

Based on the various policies defined in the main text, we calculate the optimal policy parameters under the different regimes and with $\kappa = 0.55$ (keeping χ fixed at 0.98 as in the original parameterization). The results are presented in the following Table A1,

Table A1: Optimal Simple Policy Rules with $\kappa=0.55$ - Financial Shock

	Policy I	Policy II	Policy III	Policy IV	Policy V
	$\phi_\pi = 1.50$	$\phi_\pi = 5.40$	$\phi_\pi = 5.40$	$\phi_\pi = 1.36$	$\phi_\pi = 1.36$
	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$
	$\phi_s = -$	$\phi_s = -$	$\phi_s = 0.00$	$\phi_s = -$	$\phi_s = 0.00$
	$\mu = -$	$\mu = -$	$\mu = -$	$\mu = 1$	$\mu = 1$
	$\Lambda = -$	$\Lambda = 0.0369$	$\Lambda = 0.0369$	$\Lambda = 0.2912$	$\Lambda = 0.2912$

Compared to Table 2 in the main text, Table A1 shows that the policy implications of the model remain qualitatively unchanged. The differences are quantitative with stronger optimal responses in the Taylor rule coefficients, and higher welfare gains from following the various optimal rules, both of which are attributed to the increased financial distortions caused by a higher κ . A central bank optimizing a standard Taylor rule attaches a relatively high but contained weight on inflation (Policy II) compared to a non-optimized conventional Taylor rule (Policy I). A credit spread-augmented monetary policy rule does not contribute to welfare once the standard monetary policy and provisioning rules are optimized (Policies III and V). Furthermore, applying statistical provisions is very effective in reducing welfare losses and allows the central bank to follow a more lax monetary policy regime (Policies IV and V). The impulse response functions with $\kappa = 0.55$ based on the optimized rules of Table A1 are qualitatively identical to a model with $\kappa = 0.50$

³³The steady state values of our model are highly sensitive to changes in κ . The values for κ and $(\underline{\varepsilon}^F, \bar{\varepsilon}^F)$ chosen in the main text ensure data-consistent steady state interest rate margins and default risk. Nevertheless, by adjusting the range of the idiosyncratic shock, we can pin down a plausible steady state risk and loan rate, for any level of $1 \geq \kappa \gg 0$. To analyze the effects of changing κ in this appendix section, we keep the idiosyncratic shock range between (0.50, 1.90), as in the main text.

and are not shown here to save space. The difference is only quantitative as a higher weight on the borrowing cost channel amplifies standard deviations ($s.d$) in the loan rate and risk of default, which, in turn, exacerbate the response of the rest of the economic variables. By calculating the theoretical moments, Table A2 shows the standard deviations in the key variables of the model in the stochastic economy for $\kappa = 0.50$ and $\kappa = 0.55$ and under the different optimal policy regimes defined in the main text. Examining the differences between the rows under each column, these results also complement and confirm the impulse response analysis presented in the main text.

Table A2 - Standard Deviations in key variables - Financial Shock

	$\kappa = 0.50$ (benchmark)	$\kappa = 0.55$
Policy I	$s.d(\widehat{\pi}_t) = 0.0032$	$s.d(\widehat{\pi}_t) = 0.0058$
	$s.d(\widehat{Y}_t^g) = 0.0365$	$s.d(\widehat{Y}_t^g) = 0.0491$
	$s.d(\widehat{R}_t^L) = 0.1542$	$s.d(\widehat{R}_t^L) = 0.1879$
	$s.d(\widehat{\Phi}_t) = 0.1476$	$s.d(\widehat{\Phi}_t) = 0.1692$
	$s.d(\widehat{L}_t) = 0.1096$	$s.d(\widehat{L}_t) = 0.1474$
Policy II (III)	$s.d(\widehat{\pi}_t) = 0.0011$	$s.d(\widehat{\pi}_t) = 0.0012$
	$s.d(\widehat{Y}_t^g) = 0.0373$	$s.d(\widehat{Y}_t^g) = 0.0505$
	$s.d(\widehat{R}_t^L) = 0.1519$	$s.d(\widehat{R}_t^L) = 0.1821$
	$s.d(\widehat{\Phi}_t) = 0.1461$	$s.d(\widehat{\Phi}_t) = 0.1656$
	$s.d(\widehat{L}_t) = 0.1119$	$s.d(\widehat{L}_t) = 0.1514$
Policy IV (V)	$s.d(\widehat{\pi}_t) = 1 \times 10^{-5}$	$s.d(\widehat{\pi}_t) = 2 \times 10^{-4}$
	$s.d(\widehat{Y}_t^g) = 8 \times 10^{-4}$	$s.d(\widehat{Y}_t^g) = 0.0047$
	$s.d(\widehat{R}_t^L) = 0.0031$	$s.d(\widehat{R}_t^L) = 0.0172$
	$s.d(\widehat{\Phi}_t) = 0.1184$	$s.d(\widehat{\Phi}_t) = 0.1354$
	$s.d(\widehat{L}_t) = 0.0023$	$s.d(\widehat{L}_t) = 0.0140$

The fraction of output seized in case of default (χ) - a fall in χ from 0.98 to 0.90 (restoring to $\kappa = 0.50$ and all else equal) raises the steady state risk of default and loan rate, in annual terms, to 20.28% and 22.80%, respectively, and results in an annual drop of 4.32% in the long-run level of output (Y).³⁴ Table A3 shows the optimal policy parameters under the different policy regimes defined in the text following a 0.14 standard deviation shock to χ_t ,

Table A3: Optimal Simple Policy Rules with $\chi=0.90$ - Financial Shock

	Policy I	Policy II	Policy III	Policy IV	Policy V
$\phi_\pi = 1.50$	$\phi_\pi = 4.50$	$\phi_\pi = 4.50$	$\phi_\pi = 1.16$	$\phi_\pi = 1.16$	
$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$	
$\phi_s = -$	$\phi_s = -$	$\phi_s = 0.00$	$\phi_s = -$	$\phi_s = 0.00$	
$\mu = -$	$\mu = -$	$\mu = -$	$\mu = 1$	$\mu = 1$	
$\Lambda = -$	$\Lambda = 0.0217$	$\Lambda = 0.0217$	$\Lambda = 0.2363$	$\Lambda = 0.2363$	

³⁴ Again, by adjusting appropriately the range of the idiosyncratic shock, we can pin down plausible steady state values for credit risk and credit spreads for any reasonable level of χ .

Similar to the first sensitivity analysis exercise, reducing the fraction of output that can be seized by the bank in case of default does not change the qualitative policy implications of the model. The main differences come from: *i*) the quantitative change in the values of the optimal policy weights and the higher welfare gain from following optimal policy rules; *ii*) the amplified volatility in key economic and financial variables. These quantitative changes compared to the benchmark parameterization arise due to the higher long run default risk and loan rate, both of which are the source of the financial frictions in this model. Table A4 confirms the higher standard deviations (theoretical moments) in key variables in the stochastic economy with $\chi = 0.90$ compared to $\chi = 0.98$.

Table A4 - Standard Deviations in key variables - Financial Shock

	$\chi = 0.98$ (benchmark)	$\chi = 0.90$
Policy I	$s.d(\widehat{\pi}_t) = 0.0032$ $s.d(\widehat{Y}_t^g) = 0.0365$ $s.d(\widehat{R}_t^L) = 0.1542$ $s.d(\widehat{\Phi}_t) = 0.1476$ $s.d(\widehat{L}_t) = 0.1096$	$s.d(\widehat{\pi}_t) = 0.0047$ $s.d(\widehat{Y}_t^g) = 0.0451$ $s.d(\widehat{R}_t^L) = 0.1883$ $s.d(\widehat{\Phi}_t) = 0.1711$ $s.d(\widehat{L}_t) = 0.1354$
Policy II (III)	$s.d(\widehat{\pi}_t) = 0.0011$ $s.d(\widehat{Y}_t^g) = 0.0373$ $s.d(\widehat{R}_t^L) = 0.1519$ $s.d(\widehat{\Phi}_t) = 0.1461$ $s.d(\widehat{L}_t) = 0.1119$	$s.d(\widehat{\pi}_t) = 0.0012$ $s.d(\widehat{Y}_t^g) = 0.0463$ $s.d(\widehat{R}_t^L) = 0.1840$ $s.d(\widehat{\Phi}_t) = 0.1683$ $s.d(\widehat{L}_t) = 0.1388$
Policy IV (V)	$s.d(\widehat{\pi}_t) = 1 \times 10^{-5}$ $s.d(\widehat{Y}_t^g) = 8 \times 10^{-4}$ $s.d(\widehat{R}_t^L) = 0.0031$ $s.d(\widehat{\Phi}_t) = 0.1184$ $s.d(\widehat{L}_t) = 0.0023$	$s.d(\widehat{\pi}_t) = 1 \times 10^{-4}$ $s.d(\widehat{Y}_t^g) = 0.0040$ $s.d(\widehat{R}_t^L) = 0.0160$ $s.d(\widehat{\Phi}_t) = 0.1342$ $s.d(\widehat{L}_t) = 0.0120$

Finally, we also experimented with adjusting the range of the uniform distribution ($\underline{\varepsilon}^F, \bar{\varepsilon}^F$) within reasonable levels and found that the optimal policy implications and interactions continued to persist.

6.2 Appendix B - A Model without Loan Loss Provisions

In this appendix section we perform a volatility analysis in order to show how a model with specific loan loss provisions exacerbates the standard deviations of key variables compared to a model economy without provisions. We also demonstrate that a dynamic provisioning system (macroprudential policy) can mitigate considerably the variation in key variables and result in strikingly similar variances to a model without the additional expense friction entailed by specific provisions. The first effect of introducing loan loss provisions to a DSGE model with financial risk is on the steady state values of the model. Specifically, incorporating loan loss provisions increases the steady state loan rate from 1.24% to 5.08% (per annum), long run risk from 3.16% to 3.84% (per annum), and reduces the annual level of long run output by 0.95%. Generally, specific provisions improve the model's ability to capture more data-consistent steady state interest rate margins. In

this way, loan loss provisions also lead to increased financial distortions in the steady state, which, in turn, have a direct impact on the long run values of real variables. The second effect of loan loss provisions comes through its impact on the standard deviations of the key variables of the model. Table B1 compares the standard deviations of the key variables of the model in three cases: *i*) a model without loan loss provisions ('NO LLP'); *ii*) a model with specific provisions ('S-LLP', $\mu = 0$); and; *iii*) a model with a full dynamic provisioning regime ('D-LLP', $\mu = 1$).³⁵ In all policies we assume a standard Taylor rule (STR) with $\phi_\pi = 1.5$, $\phi_Y = 0.1$ and $\phi_s = 0$, and a 0.14 percent shock to χ_t with an $AR(1)$ parameter of 0.90.

Table B1 - Standard Deviations in key variables - Financial Shock

NO LLP	S-LLP	D-LLP
$s.d(\widehat{\pi}_t) = 1 \times 10^{-5}$	$s.d(\widehat{\pi}_t) = 0.0032$	$s.d(\widehat{\pi}_t) = 1 \times 10^{-5}$
$s.d(\widehat{Y}_t^g) = 6 \times 10^{-4}$	$s.d(\widehat{Y}_t^g) = 0.0365$	$s.d(\widehat{Y}_t^g) = 8 \times 10^{-4}$
$s.d(\widehat{R}_t^L) = 0.0025$	$s.d(\widehat{R}_t^L) = 0.1542$	$s.d(\widehat{R}_t^L) = 0.0031$
$s.d(\widehat{\Phi}_t) = 0.1177$	$s.d(\widehat{\Phi}_t) = 0.1476$	$s.d(\widehat{\Phi}_t) = 0.1184$
$s.d(\widehat{L}_t) = 0.0019$	$s.d(\widehat{L}_t) = 0.1096$	$s.d(\widehat{L}_t) = 0.0023$

These results highlight the importance of dynamic provisioning in attenuating economic fluctuations closer towards an economy without the additional frictions caused by specific provisions (despite the provisions friction still affecting the steady state and the dynamics of the loan rate and real variables).³⁶

6.3 Appendix C - Alternative Shocks; Supply and Demand

Supply Shocks - As mentioned in the 'Equilibrium and Parameterization' section in the main text, we calibrate the $AR(1)$ shock process for A_t with a persistence parameter of $\varsigma^A = 0.98$ and a standard deviation of $s.d(\alpha_t^A) = 0.08$. We perform a *constrained* grid-search for optimal policy rules within the following implementable ranges: $\phi_\pi = [1 : 10]$, $\phi_Y = 0.1$, $\phi_s = [0 : 1]$ and $\mu = [0 : 1]$ with step of 0.01.³⁷

Based on Policies I-V as defined in the main text, Table C1 shows the optimal policy parameters and welfare gains following the calibrated supply shock,

Table C1: Optimal Simple Policy Rules (Constrained) - Supply Shock

	Policy I	Policy II	Policy III	Policy IV	Policy V
	$\phi_\pi = 1.50$	$\phi_\pi = 10.0$	$\phi_\pi = 10.0$	$\phi_\pi = 10.0$	$\phi_\pi = 10.0$
	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$	$\phi_Y = 0.10$
	$\phi_s = -$	$\phi_s = -$	$\phi_s = 0.00$	$\phi_s = -$	$\phi_s = 0.00$
	$\mu = -$	$\mu = -$	$\mu = -$	$\mu = 1$	$\mu = 1$
	$\Lambda = -$	$\Lambda = 0.32734$	$\Lambda = 0.32734$	$\Lambda = 0.32763$	$\Lambda = 0.32763$

³⁵We find that is always optimal to fully smooth out the evolution of loan loss provisions (relative to loans) regardless of the values attached to the monetary policy rule. We do, however, find that the inclusion of dynamic provisions alters the transmission mechanism of monetary policy, as explained in the main text.

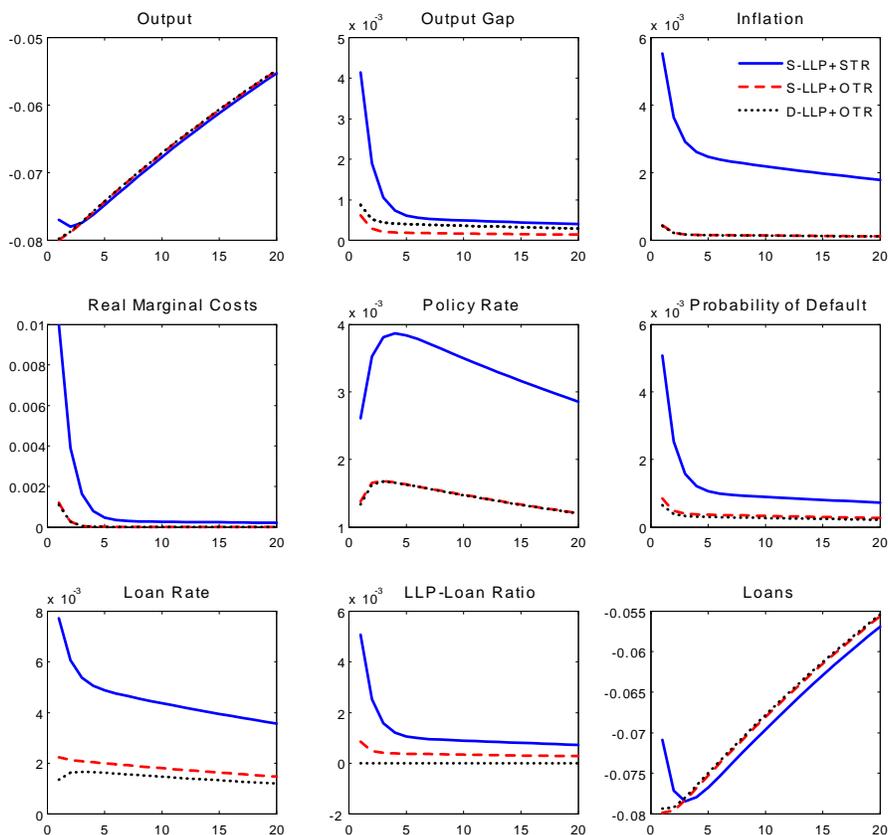
³⁶Because loan loss provisions produce an additional friction in steady state, the standard deviations of key variables under a dynamic provisioning system (combined with a conventional Taylor rule) are still marginally higher than a model absent of specific provisions.

³⁷As in the case of financial shocks, we find that adjusting ϕ_Y optimally once ϕ_π is optimal adds only infinitesimal welfare gains.

Following adverse supply shocks, associated with higher inflation and output gap, it is always optimal to respond firmly to inflation in the Taylor rule in order to mitigate inflationary pressures and welfare output gap fluctuations (equal to $\widehat{Y}_t^g = \widehat{Y}_t - [(1 + \gamma) / (\varsigma + \gamma)] \widehat{Z}_t$) via the standard demand channel of monetary policy. As in the case of negative financial shocks, credit spread-augmented monetary policy rules produce demand driven inflation and are therefore never optimal from a welfare point of view. A policy featuring dynamic loan loss provisions still provides the highest welfare gain although does not enhance welfare as much as in the case of financial shocks once the other standard Taylor rule parameters are optimized (see Table C1, Policies II (identical to III) and IV (identical to V) relative to Policy I). Beyond the optimal Taylor rule policy, dynamic provisions lead only to a marginal decline in inflation at the cost of a slightly higher output gap (due to the moderated fall in output), resulting only in a mild welfare gain. Note also that compared to financial shocks, deviations in inflation and output stem mainly from the direct effect of the supply shock rather than the secondary impact resulting from the borrowing cost channel. The effects of dynamic provisions via the provisioning cost channel are thus weaker under technology shocks, implying that additional financial macroprudential tools, beyond dynamic provisions, may be needed in order to promote further macroeconomic stability when monetary policy rules are restricted.

We have also performed an unconstrained grid-search without limiting the upper bound for ϕ_π . As in Schmitt-Grohé and Uribe (2007), allowing ϕ_π to vary to extremely high implausible (yet more optimal) levels, produces only marginal welfare gains compared to the case where the response to inflation in the monetary policy rule is constrained at 10. At these large levels of ϕ_π , we found that applying $\mu = 1$ relaxes the monetary policy response to inflation due to the mitigating effect dynamic provisions have on price inflation. This is qualitatively similar to the optimal policy interactions obtained for financial shocks, but quantitatively very different due to the huge magnitude in the reaction to inflation in the monetary policy rule. Nevertheless, and as in the constrained optimal policy, the major improvement in welfare is attributed to the strong anti-inflationary stance in the Taylor rule. Overall, optimal policy following supply shocks calls for an overly hawkish response to inflation combined with dynamic provisions (Policies IV and V). Figure C1 below summarizes the above discussion for Table C1 following the calibrated negative technology shock.

Figure C1: Adverse Supply Shock with Optimal Policy Rules



Note: Interest rates, inflation rate, the probability of default and the LLP-loan ratio are measured in percentage point deviations from steady state. The rest of the variables are measured in terms of percentage deviations.

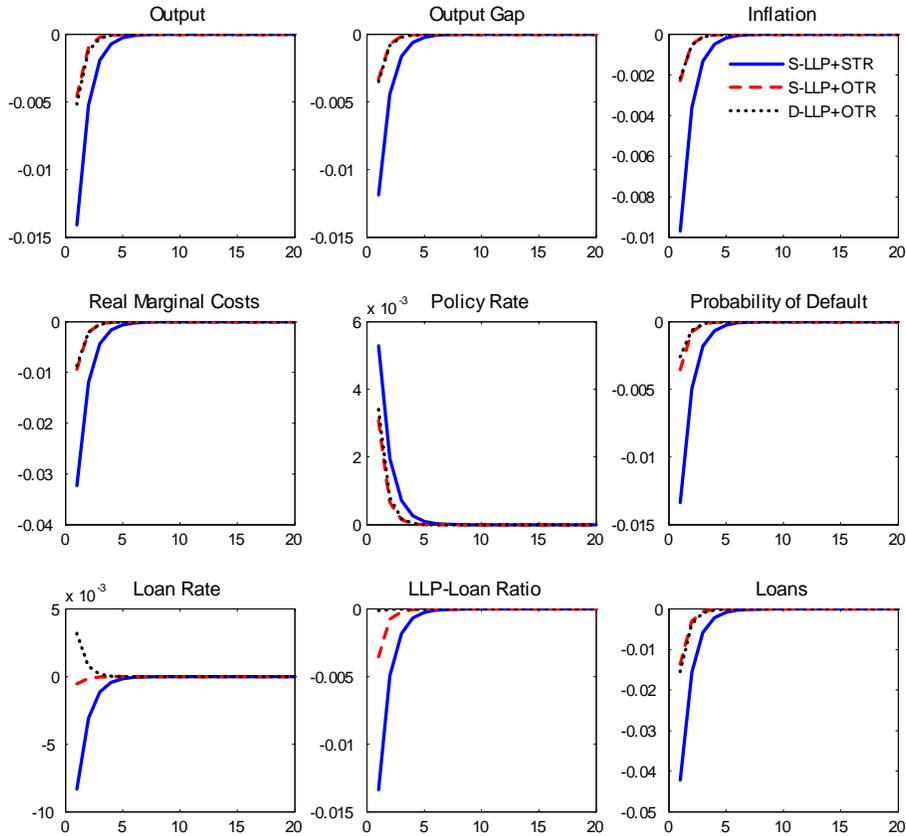
Monetary Policy (Demand) Shocks - to examine the policy implication of a monetary policy shock, we adjust the Taylor rule by including a normally distributed i.i.d shock with zero mean and a standard deviation of 0.005. Based on the various policies defined in the main text, Table C3 shows the optimal policy combinations following a positive shock to the policy rule. We perform a constrained grid-search within the following implementable ranges: $\phi_\pi = [1 : 10]$, $\phi_Y = 0.1$, $\phi_s = [0 : 1]$ and $\mu = [0 : 1]$ with step of 0.01.

Table C3: Optimal Simple Policy Rules (Constrained) - Policy Shock

	Policy I	Policy II	Policy III	Policy IV	Policy V
$\phi_\pi =$	1.50	10.0	10.0	10.0	10.0
$\phi_Y =$	0.10	0.10	0.10	0.10	0.10
$\phi_s =$	-	-	0.00	-	0.00
$\mu =$	-	-	-	0.96	0.96
$\Lambda =$	-	0.04612	0.04612	0.04615	0.04615

Figure C2 depicts the impulse response functions associated with the optimal policy parameters as calculated in Table C3 following a positive 0.01 percent shock to the policy rate,

Figure C2: Positive Policy Shock with Optimal Policy Rules



Note: Interest rates, inflation rate, the probability of default and the LLP-loan ratio are measured in percentage point deviations from steady state. The rest of the variables are measured in terms of percentage deviations.

Starting with Policy I, a rise in the policy rate reduces output and inflation and leads to a fall in real wages and the demand for loans. The decline in real wages puts downward pressure on the marginal cost and consequently on the risk of default and price inflation. With a specific provisioning system, the fall in default risk lowers the loan loss provisions to loan ratio, which, in turn, magnifies the decline in the loan rate.³⁸ Hence, the lending rate and risk of default following positive policy shocks are procyclical with respect to output, unlike financial and supply shocks.³⁹

Examining Policies II and III, an optimized Taylor rule calls for a rigid response to inflation and the natural output gap with no reaction against financial instability (as measured by credit spreads, loan rate and default risk in this model). As the central bank follows a tougher stance against the dis-inflationary pressures, the rise in the policy rate is mitigated, resulting in a moderated fall in the output gap and inflation and hence reduced volatility in these variables. With a restriction on the optimal Taylor rule parameters, dynamic provisions add mild welfare gains by increasing the loan rate and putting upward pressure on the price level at the cost of a slightly larger fall in the output gap (Policies IV and V). We have also tested optimal policies with unrestricted monetary policy rules and have found that allowing ϕ_π to tend towards extremely high (yet optimal) levels erodes the effectiveness of dynamic provisions. However, by limiting the response to inflation to plausible values, the best stabilization policy following a monetary policy shock is a combination of a strong policy stance against price fluctuations complemented with dynamic provisions.

These state contingent optimal policy 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)).

6.4 Appendix D - Welfare Function Derivation

The derivation of the loss function as presented in the paper strictly follows Woodford (2003) and Ravenna and Walsh (2006, online appendix). Our calculations are slightly simplified by ignoring government expenditures and taste shocks, which are present in Ravenna and Walsh (2006) but absent from this paper.

To derive a second-order approximation of the representative utility function, it is first necessary to clarify some additional notation. For any variable \mathbb{X}_t , let \mathbb{X} be its steady state value, \mathbb{X}_t^e be its efficient level, $\tilde{\mathbb{X}}_t = \mathbb{X}_t - \mathbb{X}$ be the deviation of \mathbb{X}_t around its steady state, and finally $\hat{\mathbb{X}}_t = \log(\mathbb{X}_t/\mathbb{X})$ be the log-deviation of \mathbb{X}_t around its correspondent steady state. Using a second order Taylor approximation, the variables $\tilde{\mathbb{X}}_t$ and $\hat{\mathbb{X}}_t$ can be related using the following equation,

$$\frac{\mathbb{X}_t}{\mathbb{X}} = 1 + \log\left(\frac{\mathbb{X}_t}{\mathbb{X}}\right) + \frac{1}{2} \left[\log\left(\frac{\mathbb{X}_t}{\mathbb{X}}\right) \right]^2 = 1 + \hat{\mathbb{X}}_t + \frac{1}{2} \hat{\mathbb{X}}_t^2. \quad (19)$$

As we can write $\tilde{\mathbb{X}}_t = \mathbb{X} \left(\frac{\mathbb{X}_t}{\mathbb{X}} - 1 \right)$, it follows that $\tilde{\mathbb{X}}_t \approx \mathbb{X} \left(\hat{\mathbb{X}}_t + \frac{1}{2} \hat{\mathbb{X}}_t^2 \right)$.

³⁸Without specific loan loss provisions, the loan rate slightly increases upon impact. Nevertheless, with wages falling by more than the increase in the lending rate, the marginal cost and risk of default decline, thereby fuelling downward pressure on the cost of borrowing and inflation.

³⁹Introducing wage stickiness as in Agénor, Bratsiotis and Pfajfar (2014) would make the loan rate and risk of default countercyclical with respect to output following policy shocks.

Utility is assumed to be separable in consumption and leisure,

$$U_t = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{1-\varsigma}}{1-\varsigma} - \frac{H_t^{1+\gamma}}{1+\gamma} \right\}. \quad (20)$$

We start by approximating the utility from consumption. The second order expansion for $U(C_t)$ yields,

$$U(C_t) \approx U(C) + U_C(C)\tilde{C}_t + \frac{1}{2}U_{CC}(C)\tilde{C}_t^2, \quad (21)$$

which according to our utility function (20) and using the market clearing condition $Y_t = C_t$ results in,

$$U(C_t) \approx U(C) + U_C Y \left(\hat{Y}_t + \frac{1}{2}(1-\varsigma)\hat{Y}_t^2 \right). \quad (22)$$

We next derive an expression for the disutility from labour. The Taylor expansion for $V(H_t)$ gives,

$$V(H_t) \approx V(H) + V_H(H)\tilde{H}_t + \frac{1}{2}V_{HH}(H)\tilde{H}_t^2, \quad (23)$$

where aggregate employment is,

$$\tilde{H}_t = \int_0^1 \tilde{H}_{j,t} dj,$$

and employment at firm j ,

$$\tilde{H}_{j,t} \approx H \left[\hat{H}_{j,t} + \frac{1}{2}\hat{H}_{j,t}^2 \right].$$

Each firm faces the following technology function,

$$\hat{H}_{j,t} = \hat{Y}_{j,t} - \hat{Z}_t.$$

Thus, we can define employment as,

$$\hat{H}_t = H \left[\int_0^1 \hat{Y}_{j,t} dj - \hat{Z}_t + \frac{1}{2} \int_0^1 (\hat{Y}_{j,t} - \hat{Z}_t)^2 dj \right]. \quad (24)$$

Substituting (24) into (23) and ignoring terms of X^3 and higher powers yields,

$$\begin{aligned} V(H_t) \approx & V(H) + V_H(H)H \left[\int_0^1 (\hat{Y}_{j,t} - \hat{Z}_t) dj + \frac{1}{2} \int_0^1 (\hat{Y}_{j,t} - \hat{Z}_t)^2 dj \right] \\ & + \frac{1}{2}V_{HH}(H)H^2 \left[\int_0^1 (\hat{Y}_{j,t} - \hat{Z}_t) dj \right]^2. \end{aligned} \quad (25)$$

Given the demand function of each firm j , aggregate output is approximated by,

$$\hat{Y}_t = \int_0^1 \hat{Y}_{j,t} dj + \frac{1}{2} \left(\frac{\lambda - 1}{\lambda} \right) var_j \hat{Y}_{j,t}, \quad (26)$$

hence,

$$\left[\int_0^1 \hat{Y}_{j,t} dj \right]^2 = \left[\hat{Y}_t - \frac{1}{2} \left(\frac{\lambda - 1}{\lambda} \right) var_j \hat{Y}_{j,t} \right]^2 \approx \hat{Y}_t^2,$$

and,

$$\int_0^1 \hat{Y}_{j,t}^2 dj = \left[\int_0^1 \hat{Y}_{j,t} dj \right]^2 + var_j \hat{Y}_{j,t}.$$

Therefore,

$$\int_0^1 \hat{Y}_{j,t}^2 dj \approx \hat{Y}_t^2 + var_j \hat{Y}_{j,t},$$

and,

$$\hat{Z}_t \int_0^1 \hat{Y}_{j,t} dj \approx \hat{Z}_t \int_0^1 \hat{Y}_{j,t} dj - \frac{1}{2} \hat{Z}_t \left(\frac{\lambda - 1}{\lambda} \right) var_j \hat{Y}_{j,t} \approx \hat{Y}_t \hat{Z}_t. \quad (27)$$

Using these results, (25) becomes,

$$\begin{aligned} V(H_t) &\approx V(H) + V_H(H)H \left[\hat{Y}_t - \frac{1}{2} \left(\frac{\lambda - 1}{\lambda} \right) var_j \hat{Y}_{j,t} - \hat{Z}_t \right. \\ &\quad \left. + \frac{1}{2} \left(\hat{Y}_t^2 + var_j \hat{Y}_{j,t} \right) - \hat{Z}_t \hat{Y}_t + \frac{1}{2} \hat{Z}_t^2 \right] \\ &\quad + \frac{1}{2} V_{HH}(H)H^2 \left[\hat{Y}_t - \hat{Z}_t \right]^2. \end{aligned} \quad (28)$$

Combining terms and using the utility function (20) yields,

$$V(H_t) \approx V(H) + V_H(H)H \left[\hat{Y}_t - \hat{Z}_t + \frac{1}{2} \left(\frac{1}{\lambda} \right) var_j \hat{Y}_{j,t} + \frac{1}{2} (1 + \gamma) \left(\hat{Y}_t - \hat{Z}_t \right)^2 \right]. \quad (29)$$

To determine total utility we subtract (29) from (22) to obtain,

$$\begin{aligned} U(C_t) - V(H_t) &= U(C) - V(H) + U_C(C)Y \left(\hat{Y}_t + \frac{1}{2} (1 - \varsigma) \hat{Y}_t^2 \right) \\ &\quad - V_H(H)H \left[\hat{Y}_t - \hat{Z}_t + \frac{1}{2} \left(\frac{1}{\lambda} \right) var_j \hat{Y}_{j,t} + \frac{1}{2} (1 + \gamma) \left(\hat{Y}_t - \hat{Z}_t \right)^2 \right]. \end{aligned} \quad (30)$$

Note that the steady state labour market equilibrium condition is $\frac{V_H}{U_C} = W^R = \frac{Z}{\frac{(\lambda-1)}{\lambda}(1+\kappa(R^L-1))}$.

We define Ξ such that,

$$1 - \Xi \equiv \frac{\lambda}{(\lambda - 1)} \frac{1}{(1 + \kappa(R^L - 1))}.$$

Then $V_H(H)H$ can be written as $U_C(C)Y(1 - \Xi)$. As in Ravenna and Walsh (2006), given that the Ξ is small, terms such as $(1 - \Xi)\hat{Y}_t^2$ simply boil down to \hat{Y}_t^2 .⁴⁰ With this assumption we can now rewrite equation (30) as,

$$\begin{aligned} U(C_t) - V(H_t) &= U(C) - V(H) + U_C(C)Y \left(\hat{Y}_t + \frac{1}{2}(1 - \varsigma)\hat{Y}_t^2 \right) \\ &- U_C(C)Y(1 - \Xi) \left[\hat{Y}_t - \hat{Z}_t + \frac{1}{2} \left(\frac{1}{\lambda} \right) \text{var}_j \hat{Y}_{j,t} + \frac{1}{2}(1 + \gamma) \left(\hat{Y}_t - \hat{Z}_t \right)^2 \right], \end{aligned} \quad (31)$$

or alternatively,

$$\begin{aligned} U(C_t) - V(H_t) &= U(C) - V(H) + U_C(C)Y \left[\Xi \hat{Y}_t + (1 - \Xi)\hat{Z}_t + \frac{1}{2}(1 - \varsigma)\hat{Y}_t^2 \right] \\ &- U_C(C)Y \left[\frac{1}{2}(1 + \gamma) \left(\hat{Y}_t - \hat{Z}_t \right)^2 + \frac{1}{2} \left(\frac{1}{\lambda} \right) \text{var}_j \hat{Y}_{j,t} \right]. \end{aligned}$$

Using the efficient level of output $\hat{Y}_t^e = \left(\frac{1+\gamma}{\varsigma+\gamma} \right) \hat{Z}_t$ and defining $d^* \equiv \frac{\Xi}{\varsigma+\gamma}$, the utility approximation is,

$$U(C_t) - V(H_t) = U(C) - V(H) - U_C(C)Y \frac{1}{2} \left[(\varsigma + \gamma) \left(\hat{Y}_t - \hat{Y}_t^e - d^* \right)^2 - \left(\frac{1}{\lambda} \right) \text{var}_j \hat{Y}_{j,t} \right] + \text{tip}, \quad (32)$$

where *tip* defines the terms independent of policy. The log-linearised flexible price equilibrium (natural level) is,

$$\hat{Y}_t^n = \left(\frac{1 + \gamma}{\gamma + \varsigma} \right) \hat{Z}_t - \left(\frac{1}{\gamma + \varsigma} \right) \left[\frac{\kappa R^L}{(1 + \kappa(R^L - 1))} \right] \hat{R}_t^{L,n}.$$

As such, \hat{Y}_t^e can be rewritten as,

$$\hat{Y}_t^e = \hat{Y}_t^n + \left(\frac{1}{\gamma + \varsigma} \right) \left[\frac{\kappa R^L}{(1 + \kappa(R^L - 1))} \right] \hat{R}_t^{L,n}.$$

Similar to Ravenna and Walsh (2006), the borrowing cost channel creates a wedge between the natural and efficient level of output, $\hat{Y}_t^e - \hat{Y}_t^n = \left(\frac{1}{\gamma + \varsigma} \right) \left[\frac{\kappa R^L}{(1 + \kappa(R^L - 1))} \right] \hat{R}_t^{L,n}$, where \hat{Y}_t^n and $\hat{R}_t^{L,n}$ denote the natural level of output and loan rate prevailing under flexible prices. However, unlike their model which assumes $\hat{R}_t^{L,n} = 0$, in our model the presence of the various financial frictions also lead to deviations in $\hat{R}_t^{L,n}$ and hence generate the wedge between \hat{Y}_t^n and \hat{Y}_t^e .

Given the demand function for each intermediate good, $Y_{j,t} = Y_t \left(\frac{P_{j,t}}{P_t} \right)^{-\lambda}$, we have,

$$\log Y_{j,t} = \log Y_t - \lambda (\log P_{j,t} - \log P_t),$$

⁴⁰Note that like Ravenna and Walsh (2006), the value of Ξ is increasing with the price markup and the loan rate, which in our model is larger due to the presence of the various financial frictions.

so,

$$\text{var}_j \log Y_{j,t} = \lambda^2 \text{var}_j \log P_{j,t}.$$

Note the price adjustment mechanism involves a randomly chosen fraction $1 - \omega$ of all firms acting optimally by adjusting prices in each period. Defining $\Delta_t \equiv \text{var}_j \log P_{j,t}$ then Woodford (2003, pp. 694-696) shows that,

$$\Delta_t \approx \omega \Delta_{t-1} + \left(\frac{\omega}{1 - \omega} \right) \hat{\pi}_t^2.$$

Assuming Δ_{t-1} is the initial degree of price dispersion, then

$$\sum_{t=0}^{\infty} \beta^t \Delta_t = \left[\frac{\omega}{(1 - \omega)(1 - \omega\beta)} \right] \sum_{t=0}^{\infty} \beta^t \hat{\pi}_t^2 + \text{tip}. \quad (33)$$

Combining (33) with (32), the present discounted value of the representative household welfare is,

$$\mathbb{W}_t \equiv \sum_{t=0}^{\infty} \beta^t U_t \approx U - \sum_{t=0}^{\infty} \beta^t \mathcal{L}_t,$$

where the associated losses from welfare are given by,

$$\sum_{t=0}^{\infty} \beta^t \mathcal{L}_t = \frac{1}{2} U_C C \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{\lambda}{\kappa_p} \right) \hat{\pi}_t^2 + (\varsigma + \gamma) \left(\hat{Y}_t^g - d^* \right)^2 \right],$$

with,

$$\hat{Y}_t^g = \hat{Y}_t - \hat{Y}_t^e = \hat{Y}_t^n + \left(\frac{1}{\gamma + \varsigma} \right) \left[\frac{\kappa R^L}{(1 + \kappa(R^L - 1))} \right] \hat{R}_t^{L,n},$$

$$d^* = \frac{\Xi}{\varsigma + \gamma} \text{ and } \kappa_p = \frac{(1 - \omega)(1 - \omega\beta)}{\omega}.$$

Assuming that $\frac{\Xi}{\varsigma + \gamma}$ is a small constant, we can write the welfare loss function in ‘gap’ form as follows,

$$\mathcal{L}_t = \frac{1}{2} U_C C \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{\lambda}{\kappa_p} \right) \text{var}(\hat{\pi}_t) + (\varsigma + \gamma) \text{var}(\hat{Y}_t^g) \right].$$

Welfare Measure

In considering Policies II, III, IV and V, we measure the welfare cost of a particular policy j as a fraction of the consumption path under the benchmark case (Policy I) that must be given up in order to obtain the benefits of welfare associated with the various optimal policy rules; $\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U_t (C_t^j, H_t^j) = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U_t ((1 - \Lambda) C_t^I, H_t^I)$, where superscript j refers to Policies II, III, IV or V and superscript I refers to Policy I. Given the utility function adopted and with $\varsigma = 1$, the expression for Λ in percentage terms is,

$$\Lambda = \left\{ 1 - \exp \left[(1 - \beta) \left(\mathbb{W}_t^j - \mathbb{W}_t^I \right) \right] \right\} \times 100,$$

where $\mathbb{W}_t^j = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U_t (C_t^j, H_t^j)$ represents the unconditional expectation of lifetime utility under policy $j = II, III, IV, V$, and $\mathbb{W}_t^I = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U_t (C_t^I, H_t^I)$ is the welfare associated with the benchmark Policy I. Converting the loss function to the welfare measure gives,

$$\mathbb{W}_t \equiv U - \frac{1}{2} \frac{U_{CC}}{(1-\beta)} \left[\left(\frac{\lambda}{\kappa_p} \right) \text{var}(\hat{\pi}_t) + (\varsigma + \gamma) \text{var}(\hat{Y}_t^g) \right].$$