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Monetary Shocks and the Cyclical Behavior of Loan Spreads

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Abstract

This paper examines the impact of monetary shocks on the loan spread in a DSGE model that combines the cost channel effect of monetary transmission with the role of collateral under asymmetric information. Its key feature is the endogenous derivation of the default probability that results in a lending rate being set as a countercyclical risk premium over the cost of borrowing from the central bank. The endogenous probability of default is shown to provide an accelerator effect through which monetary shocks can amplify the loan spread. The behavior of the spread appears to be consistent with existing empirical evidence.

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1 Introduction

Much recent research in dynamic stochastic general equilibrium (DSGE) modeling has focused on the role of banks and credit market imperfections. It is now well recognized that such imperfections may affect in a variety of ways the external cost of raising funds and thus price-setting behavior. Within this framework, endogenous developments in financial markets, which lead to variations in the cost of borrowing, work to amplify and propagate shocks to the economy.

A large strand in the literature assumes that monopolistic firms are usually credit constrained and need loans to finance their working capital needs. This introduces a cost channel effect that affects the marginal cost of firms and links the behavior of inflation to that of interest rates, as highlighted by Christiano, Eichenbaum, and Evans (2005), Ravenna and Walsh (2006), and Chowdhury, Hoffmann, and Schabert (2006).[1] This literature usually assumes a zero probability of default by the borrower; the cost of borrowing is thus directly related to changes in the risk free rate as determined by monetary policy. As a result, there is no role for a finance premium. Another strand in the literature, which focuses on financial accelerator effects, examines how under a positive probability of default the cost of borrowing is affected by variations in the borrowers' net worth and how this works to amplify and propagate shocks to the economy. This literature follows in the tradition of Bernanke and Gertler (1989), and Bernanke, Gertler and Gilchrist

[1] In another contribution, Hulsewig, Mayer, and Wollmershauser (2006) develop a New Keynesian model in which banks, which operate under monopolistic competition, set the loan rate in a similar fashion to a Calvo-type staggered price setting approach. Adjustments in the aggregate loan rate to a monetary policy shock are thus sticky. This is in contrast to Christiano, Eichenbaum, and Evans (2005) and Ravenna and Walsh (2006), who assume that banks operate costlessly under perfect competition, with the implication that the loan rate is always equal to the policy rate.

(2000) who emphasized the role of agency costs in assessing the impact of financial factors on the business cycle. Recent contributions that emphasize the role of agency costs and the financial accelerator within DSGE models include Carlstrom and Fuerst (1997), Faia and Monacelli (2007), Nolan and Thoenissen (2009), Dib (2010), and Cúrdia and Woodford (2009). Although this literature strand can explain the behavior of the finance premium, the assumptions made about the net worth of the borrower can result in opposing conclusions. In the Bernanke and Gertler (1989) and Bernanke, Gertler, and Gilchrist (2000) models, the finance premium is countercyclical, whereas in the Carlstrom and Fuerst (1997) model the finance premium is procyclical. The key reason between this difference is the behavior of borrowers' net worth. In general, if shocks that tend to increase output (for instance, a productivity shock or a drop in the policy rate) also increase the net worth of borrowers more than the cost of borrowing (resulting in a positive leverage effect), then the probability of default and thus the finance premium will tend to fall, leading to a countercyclical finance premium. In Carlstrom and Fuerst (1997), by contrast, the absence of entrepreneurial capital stock implies that shocks that increase the price of capital have no direct impact on borrowers' net worth and this leads to a procyclical finance premium.[2] Similar results are reached by other papers that build on the Carlstrom-Fuerst model, such as Gomes, Yaron, and Zhang (2003), Faia and Monacelli (2007), and De Fiore and Tristani (2009). Faia and Monacelli (2007), in particular, model credit market frictions along the lines proposed by Carlstrom and Fuerst (1997), but modify the behavior of the probability of default in order to obtain a countercyclical finance premium. As the production of goods is separated from the production of capital, with only the latter engaging

[2] For a detailed comparison of these two models, see Walentin (2005).

into borrowing, aggregate productivity shocks do not affect the probability of default by capital entrepreneurs. A critical assumption therefore in Faia and Monacelli (2007) is to assume that the mean distribution of investment outcomes across entrepreneurs depends also positively on the state of aggregate productivity. This implies that aggregate productivity shocks also raise the income of lenders (in relation to the cut-off point), thus reducing the probability of default and producing a countercyclical finance premium.

In this paper we combine these two literature strands in a simple model to show how a countercyclical risk premium can be derived endogenously within a DSGE model and from equilibrium conditions, without the need of either entrepreneurial capital stock (as in Bernanke and Gertler (1989), and Bernanke, Gertler, and Gilchrist (2000) or an assumption about the mean distribution of investment outcomes, as in Faia and Monacelli (2007). As with the first literature strand, we assume that monopolistic firms of intermediate goods require loans to cover their labor costs. This implies a cost channel effect that enters directly the marginal cost of price-setting firms and links the behavior of inflation to that of productivity shocks and interest rates (see also De Fiore and Tristani (2009)). However, in line with the second literature strand (which focuses on asymmetric information and agency costs), we assume that borrowers engage into risky production activities, and hence there is a positive probability of default by firms.[3] Firms do not rely on internal financing and so all labor costs must be financed by borrowing (as in Ravenna and Walsh (2006) and the first literature strand). Because firms have no net worth in our framework, they must pledge something else as "collateral." As in Agénor and Aizenman (1998), who themselves dwell

[3]Our premise is that the same agency cost problems that financial intermediaries face when lending to finance investment with an uncertain future return, occur also when they lend (short term) for working capital needs, if output is subject to random shocks.

on Townsend (1979), we assume that actual repayment following default is a proportion of the firm's actual output. The role of net worth in mitigating agency costs is now replaced by the fraction of realized output that lenders can seize in case of default. Default occurs when the cost of borrowing (that is, the contractual repayment) is greater than the actual repayment in case of default. As with Faia and Monacelli (2007), we show that there is a probability of default that can be endogenously determined by the cut-off value of an idiosyncratic productivity shock. However, in our model the *countercyclicality* of the finance premium, is not the result of an assumption made about the mean distribution of investment outcomes. With all intermediate-producing firms engaging in borrowing, and with borrowing decisions made before shocks are realized, any innovation that reduces output also reduces the real value of collateral that the lender receives in case of default. This endogenously increases the probability of default and amplifies the spread between the loan and risk free rates—thereby generating an accelerator effect.[4]

In particular, we show that in general equilibrium the probability of default is a function of the expected volume of loans, the economy-wide productivity, the idiosyncratic productivity shocks and the proportion of firms' output that can be seized by banks in case of default, which here acts as collateral. Following a monetary shock, the finance premium, and thus the spread between the loan rate and the risk-free policy rate, is shown to be driven endogenously by the probability of default. An increase in the policy rate reduces deposits, aggregate demand and consumption and this increases

[4] Note that in this paper we focus on monetary shocks, but supply shocks also produce a countercyclical finance premium and loan spread through the same mechanism. This is in contrast to the results in Gelain (2010), who found that whether the calibrated finance premium, in a model where financial market frictions are modeled as in Bernanke, Gertler, and Gilchrist (2000), is countercyclical or not depends on the nature of the shock.

(through intertemporal substitution) the level of working hours, thus reducing real wages and hence real marginal cost on impact; but the rise in the policy rate also increases the loan rate. An increase in the loan rate has a twofold effect: it raises directly the cost of borrowing, through the standard cost channel effect, and also the probability of default. Moreover, as the loan rate is itself a function of the probability of default there is a further endogenous rise in the loan rate, which further increases the finance premium and the loan spread. The fall in consumption will reduce the level of credit demanded by firms, but in our model it also reduces the collateral; this latter effect raises further the probability of default and hence the loan spread. This amplified increase in the loan spread, coupled with the fall in aggregate demand and consumption, generate a countercyclical risk premium. Eventually, the higher loan rate which also raises the real marginal cost (through the cost channel effect), forces sticky prices and expected future inflation to start slowly adjusting upwards, thus causing output and real wages to start adjusting upwards again towards equilibrium. We show that impulse responses to a monetary shock cause this spread in our model to behave very similarly to that suggested by some recent empirical evidence including Aliaga-Díaz and Olivero (2010), using US data, and Gerali et al (2009), using Bayesian techniques with euro-area data.[5]

The remainder of the paper is organized as follows. Section 2 presents the model, whereas section 3 discusses its equilibrium properties. Section 4 presents its log-linearized version and its calibration. Section 5 studies the dynamic effects of a monetary shock and performs some sensitivity analysis, aimed at gauging the amplification effect of credit market imperfections on the behavior of the risk premium. The last section offers some concluding

[5] See aslo Gilchrist and Leahy (2002) for a survey.

remarks.

2 The Model

We consider a closed economy producing a continuum of differentiated goods, which are used for consumption only. There are four categories of agents: households, firms, commercial banks, and a central bank. For simplicity we assume that there is a continuum of identical firms indexed respectively by $j \in (0, 1)$. Households supply labor to firms, consume goods from all firms and at the end of each period receive profits from firms and commercial banks. Households are homogenous and work at the market wage. Firms operate under imperfect competition and their production is subject to uncertainty, due to an idiosyncratic productivity shock. Each firm j sets its price by choosing the level of labor demand which, at the going wage, maximizes the expected value of its profits. We assume that each firm covers labor costs entirely by borrowing. Hence labor payments determine the amount of loans that each firm requires from the credit market. Commercial banks are also homogeneous; they receive deposits from households, borrow from the central bank, and extend loans only to firms. Deposit and loan rates are based on arbitrage conditions.

The timeline of events is as follows. Time is discrete and within each period (say, period t) there are two subperiods: one before shocks are realized (or beginning of the period), which we denote by t^-, and one after shocks are realized (or end of the period), which we denote by t^+.[6] In the first subperiod, (at t^-), banks receive deposits from households and liqudity borrowed from the central bank and make decisions on their lending rate, based on the

[6] We assume that times t^+ and $(t + 1)^-$ are arbitrarily close.

expected state of the economy and the announced cost of borrowing from the central bank. Also, firms decide on their required level of borrowing and hence employment and pricing decisions, but only *after* banks have set and posted the lending rate; thus, they take the lending rate as given when optimizing. At the end of every period, (at t^+), the differentiated goods produced by firms at t^- become available, a fraction of firms can adjust their prices while the rest must keep them fixed, in a Calvo staggered price setting fashion. Households receive all income, at which point the goods market opens and transactions take place.

2.1 Households

The objective of a representative household at time t^+ is to maximize

$$E_{t^+} \sum_{s=0}^{\infty} \beta^s u \left[C_{t+s}, (M_{t+s}/P_{t+s}), N_{t+s} \right]$$

$$= E_{t^+} \sum_{s=0}^{\infty} \beta^s \left\{ \frac{(C_{t+s})^{1-1/\sigma}}{1-1/\sigma} + \eta_M \ln(\frac{M_{t+s}}{P_{t+s}}) - \eta_N \frac{(N_{t+s})^{1+\gamma}}{1+\gamma} \right\}, \tag{1}$$

where E_{t^+} is the expectations operator conditional on information available at t^+ (which includes, therefore, the realized value of the shocks). C_t is aggregate consumption; N_t is working time; $\beta \in (0,1)$ a subjective discount factor, σ the intertemporal elasticity of substitution in consumption, $\eta_M, \eta_N > 0$, $\gamma > 0$. At subperiod t^+ households receive interest income on deposits, denoted D_t. They pay lump-sum taxes, T_t, and decide on how to allocate their financial wealth between alternative assets. At the end of each period, households also receive actual profits made by all firm $V_t^F = \int_0^1 V_{j,t}^F dj$, and the representative commercial bank, V_t^B. The representative household's budget constraint is thus given by,

$$M_t + D_t = M_{t-1} + (1 + i_t^D)D_{t-1} + W_t N_t \tag{2}$$
$$+V_t^F + V_t^B - T_t - P_t C_t,$$

where W_t denotes the nominal wage rate, so that $W_t N_t$ represents wage payments, and i_t^D is the nominal interest rate on bank deposits.

The consumption index is

$$C_t = \left[\int_0^1 (C_{j,t})^{(\theta-1)/\theta} \, dj \right]^{\theta/(\theta-1)}, \tag{3}$$

where $C_{j,t}$ is the consumption of product j and θ is the elasticity of substitution between goods in the consumption basket. The demand for each differentiated good $C_{j,t}$ is

$$C_{j,t} = \left(\frac{P_{j,t}}{P_t} \right)^{-\theta} C_t, \tag{4}$$

where the average price index, P_t, is given by

$$P_t = \left[\int_0^1 P_{j,t}{}^{1-\theta} dj \right]^{1/(1-\theta)}. \tag{5}$$

Maximizing (1) with respect to C_t subject to (2) to (5), and together with the transversality condition, $\lim_{s\to\infty} E_{t+s}\lambda_{t+s}\beta^{t+s}(M_{t+s} + D_{t+s})/P_{t+s} = 0$, yields the following first-order conditions,

$$C_t = E_{t+} \left\{ \beta C_{t+1}^{-1/\sigma} \left(\frac{1 + i_t^D}{1 + \pi_{t+1}} \right) \right\}^{-\sigma}, \tag{6}$$

$$W_t^R = \eta_N N_t^\gamma C_t^{1/\sigma}, \tag{7}$$

$$\frac{M_t}{P_t} = \eta_M C_t^{1/\sigma} \left(\frac{i_t^D}{1 + i_t^D} \right), \tag{8}$$

where $\pi_{t+1} = (P_{t+1} - P_t)/P_t$, is the inflation rate and $W_t^R = W_t/P_t$ is the real wage, which is common to all sectors.

2.2 Firms

There is a continuum of monopolistically competitive firms, $j \in (0,1)$, producing differentiated final goods. At the beginning of each period, at time t^-, firms borrow in advance to cover their borrowing needs given the loan rate that has already been set, and thus before the state of the economy has been revealed. Once the state of the economy is revealed at time t^+ (a fraction of) firms can adjust their prices.

Specifically, we assume that firm j produces good $Y_{j,t}$ by employing a linear production technology,

$$Y_{j,t} = N_{j,t} Z_{j,t}, \qquad Z_{j,t} = A + \varepsilon_{j,t}, \tag{9}$$

where $Z_{j,t}$ is the total level of productivity of firm j; A is the economy-wide average level of productivity and $\varepsilon_{j,t}$ is an idiosyncratic productivity shock with constant variance distributed over the interval $(0, \bar{\varepsilon})$. To ensure that output remains positive even in the worst state of nature ($\varepsilon_{j,t} = 0$ here), we impose $A > 0$.

In each period firms demand credit from banks, before production and sales have taken place, to finance their working capital needs.[7] In particular, firms borrow from banks at the beginning of the period to cover their wage costs, $W_t N_t$, at the gross nominal interest rate $1 + i_t^L$, and repay their loans at the end of the period (i.e. after the realization of the productivity shock). Let $L_{j,t}$ denote the nominal amount of borrowing by firm j at t^-; the financing constraint in real terms is thus

$$L_{j,t}^R \geq E_{t^-}(W_t^R N_{j,t}), \tag{10}$$

[7] Here firms must rely solely on bank credit to finance the cost of variable inputs, because for simplicity we assume no equity market, where firms could issue claims on their capital stock.

where $L^R_{j,t} \equiv L_{j,t}/P_t$. As in Agénor and Aizenman (1998), the representative bank's revenue in case of default consists of a fraction $\chi \in (0,1)$ of the firm's output that the lender can seize, net of state verification and contract enforcement costs. Consequently, a borrower will choose to default if

$$\chi Y_{j,t} < (1+i^L_t)L^R_{j,t}, \tag{11}$$

where the left-hand side is firm j's actual repayment following a default, whereas the right-hand side is the contractual repayment, both expressed in real terms.

Let ε^M_j denote the highest value of the realized productivity shock below which default always occurs; that is, the value of $\varepsilon_{j,t}$ for which (11) holds as an equality. Using (9) and the assumption that the amount of borrowing, hence employment, are decided in advance, yields in real terms[8]

$$\chi(A+\varepsilon^M_{j,t})E_{t^-}N_{j,t} = (1+i^L_t)L^R_{j,t}, \tag{12}$$

that is

$$\varepsilon^M_{j,t} = \frac{1}{\chi E_{t^-}N_{j,t}}(1+i^L_t)L^R_{j,t} - A.$$

Using (10), holding with equality, this expression can be rewritten as

$$\varepsilon^M_{j,t} = \chi^{-1}[(1+i^L_t)E_{t^-}W^R_t] - A. \tag{13}$$

2.3 Financial Intermediation

At the beginning of each period, banks receive deposits from households, following their portfolio allocation decisions taken at the end of the previous period; it also receives additional liquidity borrowed from the central bank,

[8] If default never occurs, as is the case if the left-hand side of (11) strictly exceeds the right-hand side, ε^M_j is set at the lower end of the support ($\varepsilon^M_j = 0$, $\forall j$).

L_t^B, at the going policy rate.[9] Commercial banks provide credit only to firms and pays interest on household deposits. Because banks provide loans to firms at the beginning of each period, that is, at t^-, and each firm's output is subject to random shocks, they face the risk of default on these loans at the end of each period, that is, at t^+. At the end of the period, deposits and liquidity borrowed from the central bank are repaid (together with interest), and profits are distributed to households. Assuming for simplicity no required reserves, the aggregate balance sheet of the banks is thus

$$L_t = D_t + L_t^B, \tag{14}$$

where $L_t = \int_0^1 L_{j,t} dj$ represents aggregate lending to firms.

Consider now the determination of interest rates. Regarding sources of funds, we assume that household deposits and loans from the central bank are perfect substitutes (at the margin) for funding lending operations. This assumption implies therefore that because there are no required reserve requirements or other costs, the interest rate on deposits must be equal to the cost of funds provided by the central bank:

$$i_t^D = i_t. \tag{15}$$

We next turn to the derivation of the lending rate, i_t^L. Because firm revenues are subject to random shocks, contractual repayments are uncertain. A loan contract specifies a premium-inclusive lending rate, which is set as a break-even condition. Specifically, this condition requires that in equilibrium the expected income from lending to firm j to be equal to what it would cost

[9] Instead of additional liquidity borrowed from the central bank, L_t^B, Ravenna and Walsh (2006) assume an exogenous cash injection of $M_t - M_{t-1}$; this, together, with the bank's balance sheet, where at equilibrium $L_t = W_t N_t$, determines the level of deposits, D_t.

the representative bank to borrow those funds from the central bank at the marginal cost i_t. Let, $E_{t^-}S_t$ be the expected income from lending $L_{j,t}$, based on information available up to t^-; then the break-even condition is

$$E_{t^-}S_t = (1 + i_t)E_{t^-}L_{j,t}, \tag{16}$$

which accounts for the fact that, when setting interest rates, banks do not know firm j's wage bill for subperiod t^+ and must therefore base their decisions on an expected demand for loans. As noted earlier, we also assume that commercial banks also observe the central bank's refinance rate prior to setting the lending rate.

To derive the risk premium, ρ_t^L that satisfies (16), we recall that in the event of default, after the shock is realized, the representative bank seizes a fraction, χ, of the realized value of the firm's output and receives a net repayment $\chi Y_{j,t}$ (see (11)).[10] Using the above results, we can write the expected income from loans in real terms as

$$E_{t^-}S_t^R = \int_{\varepsilon^M_{j,t/t^-}}^{\bar{\varepsilon}} [(1 + i_t^L)L^R_{j,t}]f(\varepsilon_{j,t})d\varepsilon_{j,t} + \int_0^{\varepsilon^M_{j,t/t^-}} [\chi Y_{j,t}]f(\varepsilon_{j,t})d\varepsilon_{j,t}, \tag{17}$$

where $f(\varepsilon_{j,t})$ is the density function of $\varepsilon_{j,t}$. Because the premium is set at the beginning of the period, prior to the firms' labor demand but also pricing decisions, as well as before the realization of the productivity shock, the break-even condition is based on the expected value, as of t^-, of the threshold level defined in (13), where we denote $\varepsilon^M_{j,t/t^-} = E_{t^-}\varepsilon^M_{j,t}$. Equation

[10] We keep monitoring costs implicit here. We could treat them as a nominal cost as in Fiore and Tristani (2009) but our equilibrium condition would remain unchanged, unlike other papers where monitorings costs are measured in real terms (see for instance Nolan and Thoenissen (2009)). Also, as with the rest of the literature, we assume that the credit market is dealing with a relatively large number of firms so that it diversifies away the idiosyncratic risk. This implies that the risk premium, ρ_t^L, charged by the bank is the same for all borrowers.

(17) can be rewritten as

$$E_{t^-}S_t^R = (1+i_t^L)L_{j,t}^R - \int_0^{\varepsilon_{j,t/t^-}^M} [(1+i_t^L)L_{j,t}^R - \chi Y_{j,t}]f(\varepsilon_{j,t})d\varepsilon_{j,t}. \qquad (18)$$

Substituting (13) for $(1+i_t^L)L_{j,t}^R = \chi(A+\varepsilon_{j,t}^M)E_{t^-}N_{j,t}$, with $\varepsilon_{j,t}^M$ replaced by $\varepsilon_{j,t/t^-}^M$ (given the timing convention) in the second term on the right-hand side of the above equation, we obtain

$$E_{t^-}S_t^R = (1+i_t^L)E_{t^-}L_{j,t}^R - \int_0^{\varepsilon_{j,t/t^-}^M} [(\varepsilon_{j,t/t^-}^M - \varepsilon_{j,t})\chi E_{t^-}N_{j,t}]f(\varepsilon_{j,t})d\varepsilon_{j,t}. \quad (19)$$

Substituting the break-even condition (16) in real terms, $E_{t^-}S_t^R = (1+i_t)E_{t^-}L_{j,t}^R$, into (19), and dividing through by $E_{t^-}L_{j,t}^R$ we obtain the loan rate as

$$i_t^L = i_t + \rho_t^L, \qquad (20)$$

where i_t^L and i_t are the loan rates and risk-free refinance rate, respectively. Because from (7) and (13) the size of $\varepsilon_{j,t/t^-}^M$ depends on the state of the economy through χ, A, and W_t^R and thus it is the same for all firms, in what follows we drop the subscript j. The premium is given by

$$\rho_t^L = \frac{\chi E_{t^-}N_t \int_0^{\varepsilon_{t/t^-}^M} [(\varepsilon_{t/t^-}^M - \varepsilon_t)]f(\varepsilon_t)d\varepsilon_t}{E_{t^-}L_t^R},$$

or, using the definition of L_t^R,

$$\rho_t^L = \frac{\chi \int_0^{\varepsilon_{t/t^-}^M} [(\varepsilon_{t/t^-}^M - \varepsilon_t)]f(\varepsilon_t)d\varepsilon_t}{E_{t^-}W_t^R}.$$

Thus the risk premium is determined by the expected real revenue lost due to default in bad states of nature (that is, for realizations of ε_t less than ε_{t/t^-}^M), as a proportion of the real value of total loans made. The risk premium is also a function of the collateral realized in bad states of nature, through ε^M_{t/t^-}. As implied by (13), a higher real collateral (in terms of a fraction χ of seizable output), increases the cost of default, thereby reducing the frequency of defaults (that is, ε^M_{t/t^-} falls). Consequently, all else equal, a higher collateral, as we demonstrate below, reduces the lending rate.

To obtain further insight, we assume that the idiosyncratic productivity shock ε_t follows a uniform distribution over the interval $(0, \bar{\varepsilon})$. Its probability density is therefore $1/\bar{\varepsilon}$ and its mean $\mu_\varepsilon = \bar{\varepsilon}/2$.

Under these assumptions, (20) simplifies to

$$i^L_t = i_t + (\frac{\chi \mu_\varepsilon}{E_{t^-} W^R_t})\Phi^2_t, \tag{21}$$

where $\Phi_t \in (0, 1)$ is the probability of default, given by

$$\Phi_t = \int_0^{\varepsilon^M_{t/t^-}} f(\varepsilon_t) d\varepsilon_t = \frac{\varepsilon^M_{t/t^-}}{\bar{\varepsilon}}. \tag{22}$$

This result shows that the probability of default is positively related to the expected cut-off point ε^M_{t/t^-}, which from (13) depends on the expected real wage and the pre-announced loan rate. It also depends on credit market imperfections through χ. In general, equation (21) shows that the loan rate is a mark-up over the going policy rate; although the contractual loan rate upon which firms' borrowing costs at the beginning of each period are estimated depend on the policy rate announced at time t^-, it can change at t^+ as a result of a change in policy. The risk premium is a quadratic function of the probability of default, Φ_t. If there is no default risk ($\Phi_t = 0$), the premium is zero, and the equilibrium lending rate is equal to the refinance rate. From (22), the condition $\Phi_t = 0$ requires in turn that $\varepsilon^M_{t/t^-} = 0$.

Substituting equations (13) into (22) for ε^M_{t/t^-}, and taking into account that the real price is unity in the steady state, we obtain the steady-state value of the probability of default (in reduced form) as[11]

$$\Phi = \frac{(\chi \vartheta_p)^{-1}(A + \mu_\varepsilon) - A}{\bar{\varepsilon}}. \tag{23}$$

Hence, at the steady state the probability of default is constant and depends endogenously on some key structural parameters on the production side: the average economy-wide and the idiosyncratic productivity levels of the firm, A and $\bar{\varepsilon}$, respectively; the size of the firm's price markup, ϑ_p; and the degree of credit market imperfections, as measured by the fraction of output that can be seized in times of default, χ. Note that the effect of average productivity, A, on the steady state probability of default is ambiguous. For high levels of χ, and hence for a larger fraction of seizable output in case of default, a higher average productivity implies a lower probability of default (given that with $\vartheta_p > 1$, $A/\chi\vartheta_p < A$). However, for lower values of χ and ϑ_p, average productivity may be positively related to Φ. The intuition here is that lower values of χ and ϑ_p reduce the firm's actual repayment in case of default in relation to the contractual repayment, thus increasing the probability of default.[12] We can show that for typical values of $A = 1$, $\vartheta_p = 1.2$, $\bar{\varepsilon} = 0.3$, $\chi = 0.95$ (also used for our baseline simulations below), the steady-state value of the probability of default is $\Phi = 0.029$, or around 3 percent.

2.4 The New Keynesian Phillips Curve

Firms are monopolistic competitors and set their prices given all information available up to period t. In particular, we assume Calvo-type price contracts

[11] Note that here we have used the assumption that at the symmetric price equilibrium real marginal costs (see (24) below) are equal to the inverse of the price markup.

[12] Also, note that unlike Faia and Monacelli (2007), the mean productivity of the idiosyncratic shock μ_ε here is independent of A, and it is determined by our uniform distribution as, $\mu_\varepsilon = \bar{\varepsilon}/2$.

according to which the price of each firm has a constant probability, ω, of remaining fixed at the previous period's price and a constant probability of $1-\omega$ of being adjusted to the new optimal real price based on the going real marginal cost. Firms' borrowing decisions are taken in the beginning of period t (that is, at t^-), and so based on expectations at that time and just after the loan rate has been set. Price decisions are formed at t^+, and so after the period t shock has been revealed and based, on the loan rate contract already set at time t^- (based on (21)). Given (9) and with (10) holding with equality, total real cost at time t^+ is $(1+i_t^L)W_t^R N_{j,t}$ and real marginal cost is

$$mc_t^R = \frac{(1+i_t^L)W_t^R}{Z_{j,t}}, \tag{24}$$

where i_t^L has already been determined by the the bank as shown in (21). Given this and constant returns to scale the firms' maximization problem can be expressed as

$$E_t \sum_{s=0}^{\infty} \omega^s \Delta_{s,t+s} \left(\frac{P_{j,t}}{P_{t+s}} Y_{j,t+s} - mc_{t+s}^R Y_{j,t+s}\right), \tag{25}$$

where $\Delta_{s,t+s} = E_{t^+}\beta(C_{t+s}^{-1/\sigma}/C_t^{-1/\sigma})$, is the stochastic discount factor that is based on the shadow value of the representative household's financial wealth between period s and $t+s$. From (25), and taking the loan rate as given, the NKPC is

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t^R, \tag{26}$$

where $\lambda = (1-\omega)(1-\omega\beta)/\omega$ and $\widehat{mc}_t^R$, is the log-linearized real marginal cost (see the log-linearized system below), that is derived based on (24) and (21).

As noted earlier, if the probability of default is zero, the loan rate becomes identical to the policy rate ($i_t^L = i_t$), In this case, an increase in the lending rate induced by an increase in the central bank refinance rate raises directly $\widehat{mc}_t$. This corresponds to the standard cost channel of monetary policy, discussed in a number of contributions (see, for instance, Ravenna and Walsh (2006), and Chowdhury, Hoffmann, and Schabert (2006)). However, with default risk the real marginal cost depends also on the state of nature. The probability of default, being a function of the threshold value of the productivity shock, depends on expected changes in the real wage, in addition to the loan rate itself, the expected value of total borrowing costs, the level of economy-wide and idiosyncratic productivity shocks, and the degree of credit market imperfections, as measured by the proportion of firms' revenue that can be seized by banks in case of default. In effect, monetary shocks here affects real marginal costs through two channels: *a*) the direct effect of i_t on i_t^L, that is, the standard cost channel of monetary policy; *b*) the endogenous effect that i_t has on i_t^L via the probability of default $\widehat{\Phi}_t$. The latter effect is generated because an increase in the lending rate, induced by a higher refinance rate, also raises the likelihood of default in this model, thereby making repayment of the firm's contractual obligation less likely. The effect of a change in the policy rate on the realized marginal cost $\widehat{mc}_t$ (and thus inflation) is consequently magnified by the endogeneity of the probability of default.[13] Note also that a lower χ raises the threshold level of the idiosyncratic shock below which default occurs and raises the default probability directly, thus raising marginal cost and inflation.

[13] Note that De Fiore and Tristani (2009) also show the spread to increase marginal costs, though their spread tends to be procyclical.

2.5 Central Bank

Assets of the central bank consist of loans to commercial banks, L_t^B, whereas its liabilities consists of the supply of cash to households and firms, M_t^s, which also makes up the monetary base. The central bank follows a standard Taylor-type policy rule, which relates the refinance rate to inflation and the output gap:

$$\widehat{i_t} = \chi_\pi \pi_t + \chi_y \widehat{y}_t + \epsilon_t, \tag{27}$$

where $\widehat{i_t}$ denotes deviations of the refinance rate from its steady-state value, $\widehat{y}_t$ the output gap, $\chi_\pi, \chi_y > 0$, and ϵ_t a random shock.

3 Equilibrium

At equilibrium, markets for labour, goods, deposits, and credit must clear. Although the contractual lending rate cannot change between $t^-$and t^+, wages and prices can, subject to their flexibility.

We assume that at the steady-state flexible price equilibrium, inflation is zero, all firms produce the same output and all households supply the same hours of labour and prices are the same. Goods produced at t^- are sold at t^+ (after shocks are revealed) and transactions are completed. Thus at the macroeconomic equilibrium, aggregate output must be equal to aggregate consumption:

$$Y_t = C_t. \tag{28}$$

Because the supply of deposits by households and the supply of loans by banks are perfectly elastic at the prevailing interest rates, the markets for loans and deposits always clear. Finally, given the nature of our economy, at the steady-state equilibrium the probability of default is strictly positive and defined by equation (23).[14]

4 Log-Linearization and Calibration

Using standard log-linearization techniques, the model can be reduced to the following system of equations:

$$\widehat{y}_t = E_t\widehat{y}_{t+1} - \sigma(E_t\widehat{i}_t - E_t\widehat{\pi}_{t+1}),$$

$$\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} + \lambda\widehat{mc}_t^R,$$

$$\widehat{mc}_t^R = \frac{i^L}{1+i^L}\widehat{i}_t^L + \widehat{W}_t^R - \widehat{Z}_t,$$

$$\widehat{W}_t^R = (\gamma + 1/\sigma)\,\widehat{y}_t - \gamma\widehat{Z}_t,$$

$$\widehat{i}_t^L = \frac{1}{i + \frac{\chi\bar{\varepsilon}}{2W^R}\Phi^2}\left[i\widehat{i}_t + \frac{\chi\bar{\varepsilon}}{2W^R}\Phi^2(-E_t\widehat{W}_t^R + 2\widehat{\Phi}_t)\right],$$

$$\widehat{\Phi}_t = \frac{A\chi}{W^R(1+i^L) - A\chi} + \frac{[W^R i^L\widehat{i}_t^L + W^R\left(1+i^L\right)E_t\widehat{W}_t^R]}{W^R(1+i^L) - A\chi},$$

$$\widehat{Z}_t = -\frac{A}{A+\frac{\bar{\varepsilon}}{2}} + \frac{\frac{1}{2}\bar{\varepsilon}}{A+\frac{1}{2}\bar{\varepsilon}}\widehat{\varepsilon}_t.$$

Thus, together with (27), which determines the policy rate, the system consists of eight equations and eight endogenous variables.

To calibrate the model, we implement the parameterizations proposed by Woodford (1999) and therefore set $\sigma = 0.157$ and $\lambda = 0.0235$. Moreover, we assume that $\beta = 0.99$, $\gamma = 2$, $\bar{\varepsilon} = 0.3$, $A = 1$, $\theta = 5$, and $\chi = 0.95$ (see Table 1). As similar work and data on the parameters φ and χ, linked to the cost of bankruptcy, are previously limited we initially use relatively modest parameter values. In particular, we assume that the fraction of actual output

[14] As is usually the case in this type of models, even though the probability of default is not zero in equilibrium, there is no actual default.

seized by the bank in case of default $\chi = 95$ percent, (we also consider an alterantive value for χ below).

Table 1: Parameters of the Base Model

Parameters	Description	*Value*
β	Discount factor	0.99
γ	Inverse of the Frisch elasticity of labor supply	2.0
σ	Consumption elasticity in utility function	0.157
λ	Real marginal cost coefficient in NKPC	0.0235
θ	Elasticity of substitution in demand	5.0
A	Productivity Parameter	1.0
$\bar{\varepsilon}$	Idiosyncratic productivity shock's max. value	0.3
χ	Proportion of output seized in case of default	0.95

The cut-off point $\varepsilon_{j,t}^{M}$ and the probability of default, Φ_t, usually introduced exogenously in the literature, here are endogenously determined and can vary. The base model parameter values imply that the steady-state value of the probability of default is around $\Phi = 2.9$ percent (see equation (23)). This is very similar to the values assumed elsewhere in the literature. Faia and Monacelli (2007) calibrate their model to generate an average bankruptcy rate of three percent, whereas Nolan and Thoenissen (2009) also assume that the probability of survival in business is approximately 97 percent.

5 Monetary Shock

The solid line in Figure 1 simulates the base model (see Table 1) and plots the impulse responses to a positive one standard deviation monetary policy shock. Monetary policy shocks are assumed to follow an AR(1) process with coefficient of 0.8. The immediate impact is a proportional increase in the policy rate, and thus in the deposit rate, which induces a shift away from currency toward bank deposits. Higher returns on financial assets lead to a drop in current consumption (through intertemporal substitution), which induces households to supply more labour. In turn, the increase in labor supply puts downward pressure on real wages and hence on the real marginal cost on impact. The increase in the refinance rate also raises the loan rate and the latter has multiple effects in this model. First, the increase in the cost of borrowing induced by the higher refinance rate leads to a drop in labor demand and output. Because real wages fall and the loan rate increases, the net effect on the *effective* cost of labor, $(1 + i_t^L)w_t$, is ambiguous in general. However, as shown in Figure 1, by assuming fully flexible wages in this model, the fall in the real wage dominates the increase in the lending rate and so the real marginal cost falls, thereby leading to lower inflation in the short run.[15] Moreover, the probability of default in this model is itself a function of the loan rate, thus the rise in the loan rate caused by the increase in the refinance rate causes a further endogenous rise in the cost of borrowing, which further increases the credit spread. The spread is further increased by the fact that the incipient fall in consumption reduces the level of labor demand and credit demanded by firms, but in our model this also reduces the value of collateral, thus raising further the probability of default and the spread. These effects, coupled with the fall in aggregate demand and consumption, generate a *countercyclical* risk premium. Eventually, the higher loan rate, which puts upward pressure on the real marginal cost (through the cost channel effect), forces sticky prices and expected future inflation to start slowly adjusting upwards, thus causing output and real wages to start adjusting upwards again towards equilibrium.

[15] In fact, given the parameter configuration chosen, the figure shows that the behavior of the effective cost of labor, through which we expect financial frictions to affect the supply side of the economy, does not differ very much from the behavior of the real wage.

[Figure 1. Impulse Responses to a Monetary Shock]

As can be inferred from Figure 1, there is also substantial inertia in the behavior of inflation and output.[16] More importantly for the purpose of this paper, our model has implications for the persistence of bank lending spreads. This is because interest rates have a twofold effect on the cost of borrowing: directly, via the standard cost channel effect, but also by endogenously raising the threshold value below which default occurs and thus the probability of default. This, in turn, raises the risk premium embedded in the loan rate and hence the spread between the loan rate and the risk free rate, thus causing the probability of default and the risk premium to display inertia.

The dotted line in Figure 1 considers a reduction in the value for χ, the fraction of seizable output, from 0.95 to 0.8.[17] As can be inferred from (23), a lower χ translates into a higher steady-state probability of default. The change in parameter values also implies that the impact of a monetary shock on that probability is also magnified; as a result, the increase in the loan rate and hence the spread are amplified. This leads to lower output but its effect on inflation is mitigated. This is because changes in real wages dominate movements in the effective cost of labour.[18] Given flexible wages, the drop in output is associated with lower real wages, thus mitigating the drop in marginal cost and hence inflation.

[16] Given that in the model there are no intrinsic sources of inertia, the persistence in inflation and output results essentially from the assumed autocorrelation structure of monetary shocks, as elsewhere in the literature.

[17] Values of χ that fall below 0.7 cause the steady-state probability of default to be higher than unity.

[18] A similar result is reported in Agénor and Alper (2009). Note, however, that from simulations we ran assuming partial nominal wage rigidity (not reported here), the net effect on the effective wage would lead to higher persistence in inflation.

Thus, a greater degree of credit market imperfections (as measured by a lower fraction of seizable output) hampers the effectiveness of monetary policy by increasing the probability of default and raising nominal interest rates. This has an amplified effect on the behavior of the loan spread and output.

6 Concluding Remarks

This paper examines the effects of monetary shocks on the loan spread in a DSGE model with banking. Its key feature is the endogenous derivation of the default probability, starting from a break-even equilibrium condition which leads to the loan rate being set as a premium over the cost of borrowing from the central bank. The risk premium, and thus the loan spread, are shown to be countercyclical and quite persistent following monetary shocks. This is because monetary shocks affect the loan rate through various channels, thus amplifying its spread from the policy rate. As we show, monetary shocks affect the loan rate directly, through the standard cost channel, but they also have a further effect on the loan rate via the probability of default, as the latter is itself a function of the loan rate. A higher loan rate, following a monetary shock, raises the probability of default and this amplifies the increase in the loan spread. At the same time, the rise in the policy rate causes the proportion of actual output seized in case of default to also fall and this causes a further endogenous increase in the probability of default, pushing the loan spread further up. The spread reaches its maximum in about three to four months following the shock, and remains positive for about two years.[19] The dynamic behavior of our spread tends to behave consistently

[19] Although simulation results show that the endogeneity of the default probability tends to magnify the effect of a monetary shock on inflation and persistence, the assumption of

with that identified in some recent studies, following a monetary shock, such as Aliaga-Díaz and Olivero (2010) for the United States and Gerali et al (2009) for the Euro area.

Our framework can also be extended to account for investment, along the lines of Bernanke, Gertler, and Gilchrist (2000), and subsequent studies along these lines, such as Meier and Muller (2006) and Faia and Monacelli (2007). As pointed out by Faia and Monacelli (2007), credit frictions may have a large impact on the behavior of investment (to the extent, for instance, that monitoring costs raise lending rates) and the price of capital. In our framework, adding fixed capital as collateral that can be seized in case of default would strengthen further the role of the default probability in transmitting monetary shocks and generating persistent loan spreads.

fully flexible equilibrium wages appears to result in real wages and marginal cost absorbing much of the impact of the monetary shock, thus dampening persistence.

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Figure 1. Impulse Responses to a Monetary Shock

(—— $\chi = 0.95$, - - - - $\chi = 0.8$)