Monetary policy, leverage premium, and loan default probability

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PRELIMINARY AND INCOMPLETE

Abstract

This paper argues that monetary expansions increase the default probability of borrowers by encouraging them to take more leverage. In particular, it argues that the effect on defaults is asymmetric. Outstanding loans enjoy a decrease in defaults due to the unexpected increase in revenues generated by the expansion in aggregate demand, while new loans experience an increase in defaults because firms take more debt to benefit from the lower cost of borrowing. The model is consistent with the recent empirical evidence on the so called "risk taking channel of monetary policy". In the model, a 25 basis point decrease in the policy rate decreases on impact the annualized default rate from steady state 2.92 % to around 2.60 % and leads to a subsequent build up of leverage that pushes defaults up to around 3.30 % one year after the shock. It then takes several years for defaults to revert to steady state. The central bank can avoid the increase in defaults by either decreasing the persistence of the policy rate or by responding more aggressively to expectations of inflation and output in the feedback policy rule.

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1 Introduction

This paper studies the effect of monetary policy on the probability that firms default on loans.

It would be sensible to argue that monetary expansions reduce this default probability because they presumably shift down the yield curve, push up aggregate demand and boost firms' revenues, at least in normal times. Although intuitive, this conjecture is supported by empirical evidence only in part. Jimenez, Ongena, Peydro and Saurina (2007) use inferential techniques from the empirical literature on defaults to estimate the determinants of firms' default probabilities on loans with data from the Spanish credit registry between 1985 and 2006. They find that, other things equal, a reduction in the policy rate reduces the default probability of *outstanding* loans, i.e. loans originated before the monetary shock, but it increases the default probability of *new* loans, i.e. loans originated after the monetary shock. The same empirical result is found by Ioannidou, Ongena and Peydro (2007) for Bolivia and by Lopez, Tenjo and Zarate (2011) for Colombia.[1]

Jimenez and coauthors interpret their result in terms of an *indirect risk-shifting effect* across heterogeneous borrowers. Outstanding loans are argued to be positively affected by a monetary expansion through an increase in firms' revenues.[2] New loans, instead, are potentially subject to an additional effect because by definition they have not been issued yet and the lender has now the option of shifting towards borrowers with a different risk profile. The authors interpret their empirical finding as evidence that banks react to a monetary expansion by shifting towards more risky borrowers, a reaction that dominates on the expansionary effect on revenues and leads to loans with a higher default probability.[3]

This paper contributes to the literature by arguing that the same result on new loans could also be driven by an *indirect leverage effect* in a framework in which borrowers are homogeneous. The intuition is very simple. Outstanding loans benefit from a monetary expansion due to the unexpected increase in aggregate demand, as also argued by Jimenez *et al.* (2007). New loans, instead, are also subject to an additional leverage effect because the *size* of the loan (rather than the potential borrower) has not been chosen yet. By pushing down the cost of borrowing,

[1] Appendix A gives a brief introduction to the empirical strategy of duration models, synthesizes graphically the result by Jimenez *et al.* (2007) and comments the main advantages and limitations of this empirical approach to default estimation.

[2] An additional mechanism would eventually work through the decrease in the borrowing rate of loans with adjustable rates. Information on whether loans have fixed or flexible rates is not available from the Spanish credit registry, but most of the loans spanned by the dataset have a short maturity, making fixed interest rates more likely. Note 24 gives a full account of the differences between the median loan in the dataset by Jimenez *et al.* (2007) and the representative loan of the model economy.

[3] To argue that this shift in risk profiles is intentionally taken by banks, Jimenez *et al.* (2007) take the estimated probability density function of defaults as a good proxy of the expectation that loan officers attach to defaults of different loan applications. In this paper I do not go this far and interpret their result as suggestive evidence of an equilibrium phenomenon rather than as an effect intentionally driven by banks' behaviour.

monetary expansions give borrowers the incentive to increase debt and invest more than outstanding borrowers, but this increase in borrowers' leverage *increases* their default probability because net worth provides now a smaller buffer to the risky loan. If the hike in leverage is strong enough, the indirect leverage effect prevails and pushes up the equilibrium default probability, despite the ultimate decrease in the borrowing rate.

The approach followed in this paper features ex ante homogeneous borrowers who are hit by idiosyncratic productivity shocks drawn from a common distribution. Whether at the end of the period the shock forces the borrower to default on his debt depends on the borrowing conditions set at the beginning of the period, which depend in turn on the size of the loan (chosen by the agents) and on the opportunity cost of lending (chosen by the monetary authority). Such approach differs from the existing literature because it investigates an intensive margin along the quantity of investment rather than an extensive margin along the quality of different borrowers. In their celebrated work Stiglitz and Weiss (1981) consider the opposite case in which investment possibilities are fixed in size and differ along the probability distribution that generates returns. In their setting a lower interest rate *decreases* default probabilities by either bringing safe borrowers back into the credit market or by leading borrowers to finance safer projects. Other papers keep the margin of the size of the investment active, but shut down the borrower's incentives by assuming that the lender's investment possibilities are exogenous [Acharya and Naqvi (2009), Agur and Demertzis (2012), Dees and Eckwert (2012), Dubecq, Mojon and Ragot (2009), Cociuba, Shukayev and Ueberfeldt (2012)] or by assuming that the lender is a monopolist [Dell'Ariccia, Laeven and Marquez (2010), Valencia (2011)]. To the best of my knowledge, the only paper that explicitly allows monetary policy to affect firms' defaults by changing their leverage ratio is Riccetti, Russo and Gallegati (2011), who follow Delli Gatti, Gallegati, Greenwald, Russo and Stiglitz (2010) and study the interaction of reduced-form agents through stochastic, non-Walrasian prices. My contribution differs from theirs by taking a structural approach and deriving agents' behaviour from first principles.

The intuition that monetary expansions increase defaults by pushing borrowers to leverage up their net worth is formalized using the costly state verification model by Townsend (1979). This model has been extensively used in the macroeconomic literature to generate hump-shaped impulse response functions for output and to develop a financial accelerator [Carlstrom and Fuerst (1997), Bernanke, Gertler and Gilchrist (1999)]. The prediction of the model with regard to defaults has received less attention, except for commenting and fixing the procyclicality of default probabilities, which is predicted by the baseline model but rejected by the data [Gomes, Yaron and Zhang (2003), Dorofeenko, Lee and Salyer (2008), Medina (2004), Covas and Den Haan (2012)]. The paper argues that the empirical result by Jimenez and coauthors lends empirical plausibility to the costly state verification model in studying how monetary policy affects loan default probabilities.

The paper is divided in two parts. The first part (developed in section 2) uses the costly state verification model to develop the intuition behind the indirect leverage effect. This effect is driven by asymmetric information, because under symmetric information the Modigliani-Miller theorem would imply that the lender is indifferent to the leverage ratio of the borrower, canceling the leverage effect. To isolate the forces in play this first part of the paper proceeds in partial equilibrium and is static, so it can only capture the effect on new loans under the temporary assumption that net worth and other variables of the debt contract are constant. The second part of the paper (developed in section 3) enriches the environment of the model along a standard New Keynesian model to take one step forward in the analysis. In particular, it studies if the effect on defaults is still in place when net worth is accumulated through retained earnings and when other variables of the debt contract become endogenous. The exercise finds that, in the dynamic general equilibrium framework considered, a monetary expansion still increases the default probability on new loans and that the default probability of outstanding loans decreases due to an unexpected increase in the price of capital that pushes up revenues. A calibration of the model on empirical observations from Spain, the country spanned by the dataset by Jimenez *et al.* (2007), predicts that a 25 basis point decrease in the policy rate reduces on impact the annualized default rate from steady state 2.92 % to around 2.70 % and then increases defaults for several years after the shock up to around 3.30 % one year after the shock. The effect is found to be stronger the higher the persistence in the policy rate and the lower the weight that the central bank attaches to inflation and output expectations. This suggests that central banks can avoid the increase in defaults by avoiding long periods of low interest rates relative to steady state and by responding aggressively to output and inflation.

The paper has several limitations and should be thought of as a first step of a wider research agenda. The analysis is only positive, not normative, because it comments a mechanism behind the dynamics of default rates without addressing whether central banks should care about it from a welfare perspective. In addition, the effect on outstanding loans is probably underestimated in this paper because loans are assumed to have one period maturity and hence do not overlap with new loans. Maybe most importantly, the model does not include outside equity as a possible source of financing, leaving out an important determinant of firms' leverage. Addressing these and other non-trivial issues is beyond the scope of the paper and is left for future research. The scope here is to suggest that monetary expansions could push up default rates if the expansion in output is financed out of debt that is intermediated by credit markets under asymmetric information. Encouraged by the empirical result by Jimenez *et al.* (2007), I formalize this intuition with regard to firms, but nothing prevents from conjecturing a similar mechanism for banks and households. Much more research is certainly needed to understand if the intuition of the paper can contribute to the current debate on whether monetary policy should be re-thought with an explicit attention to financial stability.[4] The paper

[4]It is not straightforward to capture the concept of financial instability in a macroeconomic model, and this paper does not contribute in that direction. See Eichengreen *et al.* (2011) and Blanchard, Dell'Ariccia and Mauro (2010) for a general discussion of the future of monetary policy and Fahri and Tirole (2009), Brunnermeier and Sannicov (2011) and Stein (2012) for a theoretical analysis.

contributes to this challenging research agenda by arguing that the leverage effect commented in the analysis not only makes sense and is consistent with the emerging literature on the "risk taking channel of monetary policy" [Rajan (2006), Borio and Zhu (2008)], but that it is delivered by a microfounded model that had been well-received in the literature well before the debate on the risk taking channel started.[5]

2 The costly state verification model in partial equilibrium

This section uses the costly state verification model in partial equilibrium to formalize the key intuition of the paper. Parts 2.1 and 2.2 highlight the key features of the model, part 2.3 interprets the optimality condition graphically and part 2.4 simplifies the key result of the paper using a simple numerical example.

2.1 Environment

The partial equilibrium model is static and consists of one period. Agents are risk neutral, they receive a non-consumable endowment at the beginning of the period and consume at the end of the period. There are two technologies that transform the endowment into end-of-period consumption, a linear production function and a risk-free bond. Production is affected by an idiosyncratic shock and yields an expected return that exceeds the safe return on the risk-free bond. The combination of risk neutrality and higher expected return on production implies that it would be optimal for the economy to invest the entire endowment in the risky technology, although asymmetric information prevents credit markets from achieving this equilibrium (more on this later). No aggregate shock enters the partial equilibrium model.

Agents are heterogeneous with respect to initial endowment and investment possibilities. Assume that a continuum of agents called *entrepreneurs* receive limited net worth as initial endowment and have access to the risky production function, while a continuum of agents called *lenders* receive an abundant endowment and

[5] Empirical works in this field are, in addition to the ones already mentioned, Maddaloni and Peydro (2011), Altunbas, Gambacorta and Marquez-Ibanez (2010), Paligorova and Santos (2012) and De Nicolo', Dell'Ariccia, Laeven and Valencia (2010). Most of the theoretical contributions take a non-structural approach, as the ones commented in the text. A notable exception is Angeloni, Faia and Lo Duca (2011), who study the default probability of banks instead of firms, and Cociuba, Shukayev and Ueberfeldt (2012), who interact the risk taking incentives of the lender with the effect of monetary policy on collateral. The paper is related to the literature on monetary policy and asset prices, which argues that monetary expansions push banks and firms to take more leverage by increasing asset prices [Checchetti *et al* (2002)]. This view did not become part of the so-called "Jackson Hole consensus" due to the difficulty of determining ex ante the existence of a bubble and calibrating the policy rate to control it. This paper argues that monetary expansions do not lead to the build up in leverage due to the dynamics in asset prices but through the cost of borrowing. The paper also relates to the literature on the balance sheet channel of the credit view [Bernanke and Gertler (1995)] in arguing that monetary expansions improve the financial position of borrowers, but then argues that this could lead them to leverage up their net worth.

have only access to the risk-free bond. One can think of entrepreneurs as agents with limited funds but creative business ideas and lenders as savers with limited entrepreneurial skills but abundant funds.[6]

Entrepreneurs borrow from lenders on competitive markets in order to invest in the production technology more than their limited initial endowment. I follow Carlstrom and Fuerst (1997) and assume that competition takes the form of lenders competing among each other to provide loans to entrepreneurs.[7] Given perfect competition among lenders and risk neutrality of all agents, the contract maximizes the expected profits of the entrepreneur under the condition that the expected return on lending equals the opportunity cost of lending.[8] I follow the literature and assume that monetary policy affects this opportunity cost of lending by either controlling the real risk-free interest rate directly (in partial equilibrium, this section) or by affecting it indirectly through nominal price rigidities (in general equilibrium, section 3).

Information is symmetric ex ante but asymmetric ex post. At the beginning of the period the contract is signed before entrepreneurs draw the realization of the idiosyncratic shock on revenues. If at the end of the period the idiosyncratic shock was costlessly observed by both parties, state-contingent contracts would allow the borrowing rate to be some optimal function of *ex post* entrepreneur's revenues. The costly state verification model assumes, instead, that at the end of the period the entrepreneur observes the shock costlessly, while the lender observes it only if he pays an auditing dead-weight cost. This assumption captures the richer set of information that borrowers typically have relative to lenders. Under this assumption the debt repayment can be, at best, a function of the *expected* entrepreneur's revenues because a contingency of the borrowing rate on ex post revenues would lead entrepreneurs to opportunistically under-report the realization of ω in order to pay a lower interest rate.

[6]Excluding entrepreneurs from the risk-free bond market does not impose a loss of generality to the model, since production dominates the risk-free bond in equilibrium. On the contrary, excluding lenders from accessing the production technology is necessary to generate borrowing and lending in equilibrium without modeling explicitly how agents end up on one side or the other of the credit market. I assume for convenience that each entrepreneur borrows from only one lender. Whether lenders provide loans to only one entrepreneur or are allowed to diversify the idiosyncratic shock is irrelevant with regard to the positive result of this paper, but it would matter for a normative analysis by affecting whether lenders cover the opportunity cost of lending in expected value or in every state of the world. In the general equilibrium extension of the model it is assumed that lenders perfectly diversify the idiosyncratic shock.

[7]Carlstrom and Fuerst (1997) consider this setting plausible by thinking of entry into lending as easier that entry into entrepreneurial activity. COMMENT IF COMPETITION IS ASSUMED THE OTHER WAY AROUND. NOT OPTIMAL ANYMORE? SEE WHAT TOWNSEND SAYS Note that here competition does not imply price-taking behavior because the borrowing rate is optimally solved for in the debt contract depending on the amount borrowed.

[8]The result of the paper does not rely on the assumption of perfect competition. In Dell'Ariccia, Laeven and Marquez (2010) a similar conclusion is reached because monetary expansions reduce the net return on lending by reducing the borrowing rate and increasing the monopolist bank's leverage ratio, which reduces the incentive to monitor and increases the default probability of the firm. In Valencia (2011) the result is driven by the fact that a lower opportunity cost of lending leads the monopolistic bank to extract more rent from firms by increasing lending, and this increases firms' leverage ratio and defaults.

2.2 Maximization problem

Define R the opportunity cost of lending and assume the following linear production function of the entrepreneurs:

$$y = \omega R^K K$$

ω stands for the idiosyncratic shock with $\omega \in [0, \infty)$, $E(\omega) = 1$ and known cumulative distribution function $\Phi(\omega)$, $R^K > R$ stands for the deterministic aggregate return on the risky technology known at the beginning of the period and K is the amount invested in production. The realization of ω is costlessly observed by the entrepreneur, but is not observed by the lender unless he pays a constant fraction $\mu < 1$ of ex post revenues. Production is subject to full depreciation.[9]

Townsend (1979) shows that in this setting the optimal contract takes the form of a risky debt contract.[10] The entrepreneur borrows $QK - N$ at the non-contingent gross interest rate R^B, where Q represents the price of one unit of capital and N the entrepreneurial net worth, which is exogenous in this section.[11] Given $\omega \in [0, \infty)$, there exists an endogenous threshold value $\bar{\omega}$ of ω pinned down by $\bar{\omega} R^K K = R^B(K - N)$ below which revenues are not high enough to cover the debt repayment obligation. At the end of the period ω is realized. If $\omega > \bar{\omega}$ the entrepreneur pays back $R^B(K - N)$ and keeps profits $\omega R^K K - R^B(K - N)$. If instead $\omega < \bar{\omega}$, the entrepreneur defaults and the lender recovers $(1 - \mu)\omega R^K K$.

The contract maximizes the expected profit of the entrepreneur under the condition that the lender is indifferent between issuing the loan and investing in the risk-free bond. The maximization problem is solved in $\bar{\omega}, R^B, K$ and can be written as

$$\max_{\{\bar{\omega}, R^B, K\}} \int_{\bar{\omega}}^{\infty} \omega R^K K - R^B(QK - N) d\Phi(\omega)$$

[9] The result does not depend on the linearity assumption in the production function nor on the assumption of full depreciation, which only make the intuition more legible. Covas and Den Haan (2012) study extensively the role of non-linearities and non-full depreciation in costly state verification models. Depreciation will be added in the general equilibrium version of the model, although for convenience it will not enter the production function but the aggregate return on capital R^K, as in Bernanke, Gertler and Gilchrist (1999).

[10] The key intuition behind the optimality of the debt contract relies on the fact that it is optimal to leave no revenue to the entrepreneur in case of default in order to reduce the probability that the dead-weight observation cost will be incurred by reducing the borrowing rate in the non-defaulting states. While optimal ex ante, it is suboptimal ex post, since agents would benefit from renegotiating the contract in order save on the observation cost. The contracts does not model credit rationing nor strategic defaults. COMMENT WILLIAMSON, AND OTHER KEY EXTENSIONS

[11] In the general equilibrium version of the model N evolves through retained earnings. For simplicity the model does not allow for outside equity, as for instance in Gertler and Kyiotaki (2010). I comment this point further in the conclusions.

subject to

$$\bar{\omega} R^K K = R^B (QK - N) \tag{1}$$

$$[1 - \Phi(\bar{\omega})] R^B + \Phi(\bar{\omega})(1-\mu) \frac{E(\omega \mid \omega < \bar{\omega}) R^K K}{QK - N} \geq R \tag{2}$$

Equation (1) defines the threshold value $\bar{\omega}$ as a function of R^B and K. Equation (2) guarantees the indifference condition of the lender by ensuring that the expected return on lending (left-hand side) is at least as high as the opportunity cost of lending (right-hand side). Note that the expected return on lending equals the weighted average of what the lender obtains ex post depending on whether the entrepreneur defaults or not.

To help develop the intuition and solve the maximization problem, define $F(\bar{\omega})$ and $G(\bar{\omega})$ the shares of expected revenues $R^K K$ to respectively the entrepreneur and the lender. These shares are easily computed by substituting equation (1) into (2) and into the objective function.[12] $F(\bar{\omega})$ and $G(\bar{\omega})$ determine the allocation of expected output net of expected monitoring costs between the borrower and the lender, as shown in equation (4). The key result of the paper is driven by the positive first derivative of $G(\bar{\omega})$ with respect to the default threshold $\bar{\omega}$: an increase in the share of expected revenues promised to the lender ($G(\bar{\omega})$) requires a decrease in the share that goes to the entrepreneur ($F(\bar{\omega})$) and is associated with an increase in the default threshold $\bar{\omega}$ because it is harder for the entrepreneur to meet the higher repayment obligation.

$$\underbrace{\left[1 - \mu \int_0^{\bar{\omega}} \omega d\Phi(\omega)\right] R^K K}_{\text{net expected output}} = R^K K \Big[\underbrace{F(\bar{\omega})}_{\substack{\text{share to the} \\ \text{entrepreneur}}} + \underbrace{G(\bar{\omega})}_{\substack{\text{share to the} \\ \text{lender}}} \Big] \tag{4}$$

$$\text{with} \quad F'(\bar{\omega}) < 0 \quad \text{and} \quad G'(\bar{\omega}) > 0$$

The convenience of equations $F(\bar{\omega})$ and $G(\bar{\omega})$ lays in the fact that they allow to

[12]Simple algebra gives

$$F(\bar{\omega}) = \int_{\bar{\omega}}^{\infty} \omega d\Phi(\omega) - [1 - \Phi(\bar{\omega})]\bar{\omega} \quad ; \quad G(\bar{\omega}) = 1 - F(\bar{\omega}) - \mu \int_0^{\bar{\omega}} \omega d\Phi(\omega) \tag{3}$$

with $F'(\bar{\omega}) < 0$, $F''(\bar{\omega}) > 0$ and $G'(\bar{\omega}) > 0$, $G''(\bar{\omega}) < 0$. More precisely, $G(\bar{\omega})$ is increasing in $\bar{\omega}$ only in the lower support of $\bar{\omega}$, where the higher promised repayment share more than offsets the higher probability that the repayment will not be met. Since it would be suboptimal to agree on a $\bar{\omega}^*$ where $G(\bar{\omega})$ decreases (both parties would strictly benefit from a reduction in $\bar{\omega}$) we can disregard the decreasing part of $G(\bar{\omega})$ from the analysis. As shown in Bernanke, Gertler and Gilchrist (1999), condition $G'(\bar{\omega}^*) > 0$ is guaranteed by assuming that

$$\frac{d}{d\omega} \omega \frac{d\Phi(\omega)}{1 - \Phi(\omega)} > 0 \tag{Assumption 1}$$

which is satisfied for standard distributions, including the log normal distribution used later.

simplify the maximization problem as

$$\max_{\bar{\omega},K} \quad F(\bar{\omega})R^K K$$
$$\text{subject to} \quad \frac{G(\bar{\omega})R^K K}{QK - N} \geq R \tag{5}$$

Constraint (5) ensures that the expected return on lending (left-hand side) is at least as high as the opportunity cost of lending (right-hand side). To understand the intuition of the model it is important to note that the expected return on lending $\frac{G(\bar{\omega})R^K K}{QK-N}$ increases in the share $G(\bar{\omega})$ to the lender because, given K, he receives a higher share of expected revenues, and it decreases in K because, given $G(\bar{\omega})$, an increase in investment pushes up the entrepreneur's leverage, implying a smaller buffer offered by the exogenous net worth to the risky loan. To solve the maximization problem, substitute the constraint in the objective function and derive the optimality condition for $\bar{\omega}^*$: [13]

$$-F'(\bar{\omega}^*) = F(\bar{\omega}^*)\frac{G'(\bar{\omega}^*)}{Q \cdot \left(\frac{R^K}{R}\right)^{-1} - G(\bar{\omega}^*)} \tag{6}$$

Equation (6) pins down the default threshold $\bar{\omega}^*$ and hence the default probability $\Phi(\bar{\omega}^*)$. To close the model, substitute $\bar{\omega}^*$ in constraint (5) and compute the equilibrium level of investment K^*. Last, use $\bar{\omega}^*$ and K^* to compute the equilibrium borrowing rate R^B from equation (1).

2.3 Interpreting the optimality condition

The threshold value $\bar{\omega}^*$ pinned down by equation (6) is a decreasing function of R independently on the parametrization of the model (see Covas and Den Haan (2012) appendix C for a proof). This means that a decrease in the opportunity cost of lending *increases* the equilibrium default probability of entrepreneurs, which is consistent with the empirical evidence by Jimenez *et al.* (2007) on new loans.

To develop the economic intuition behind this result it is worth to decompose in two opposite effects the equilibrium effect on defaults that is generated by a reduction in R:

1. the default probability decreases because the lower opportunity cost of lending mitigates the entrepreneur's debt burden by allowing the entrepreneurs to pay a lower borrowing rate to the lender (*direct effect on the borrowing cost*);

[13] Assume that the maximization has an interior solution for K, which requires that, in the optimum, $\bar{\omega}$ satisfies $R^K < Q\frac{R}{G(\bar{\omega})}$. If this was not the case, the aggregate return R^K would be high enough to make the asymmetric information irrelevant because the lender would be willing to supply an infinite amount of credit for any level of $\bar{\omega}$ This condition ensures that the leverage premium derived in note 15 is positive.

2. the default probability increases because the reduction in the opportunity cost of lending increases the discounted return to capital and pushes up the optimal level of investment and the optimal leverage ratio (*indirect leverage effect*).

The negative equilibrium relationship between R and $\bar{\omega}$ reflects the fact that in the costly state verification model the indirect leverage effect always dominates on the direct effect on the cost of borrowing. The intuition behind this result is developed graphically. Figure 1, panel a, shows the initial equilibrium as the point on constraint (5) (the upward-sloping line) that corresponds to the optimal level of $\bar{\omega}$ pinned down by equation (6). All combinations of $(K, G(\bar{\omega}))$ below the constraint meet the indifference condition of the lender, while combinations above the constraint violate the indifference condition of the lender. A decrease in R rotates the constraint upwards and expands the set of combinations compatible with the lender's indifference condition because the lender requires now a lower expected return on lending.[14]

Isolating the direct effect on the borrowing cost

To isolate the direct effect on the borrowing cost start from the initial equilibrium, decrease R and shut down the indirect leverage effect by assuming that the level of investment K remains fixed at the initial equilibrium level (figure 1, panel b). If K is arbitrarily constant to the initial value, the upward shift in the constraint moves the equilibrium to point B. In B, $G(\bar{\omega})$ and the corresponding default probability have decreased because the entrepreneur borrows the same amount at a lower borrowing rate. If this was the only effect in place, the reduction in R would decrease the default probability.

Isolating the indirect leverage effect

To isolate the indirect leverage effect, start from the initial equilibrium and shut down the effect on the borrowing cost by keeping the opportunity cost of lending unchanged. Consider then what happens if the entrepreneur is unsatisfied with the level of K and decides to borrow more and increase leverage.

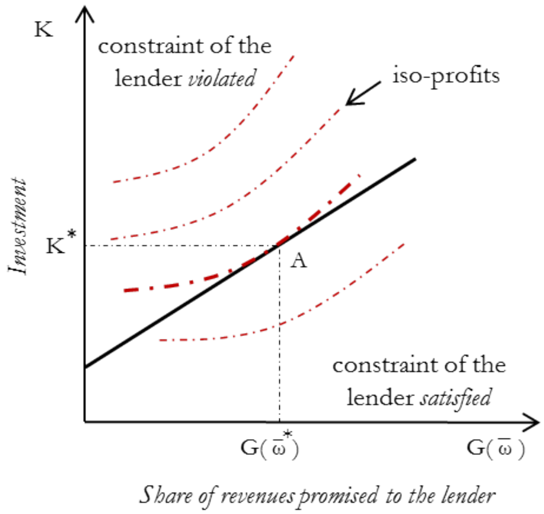
Constraint (5) implies that if the constraint is initially binding, an increase in K violates the indifference condition of the lender unless $G(\bar{\omega})$ increases. The intuition behind this effect is crucial and can be seen by rewriting constraint (5) in terms of an upward limit to the entrepreneur's leverage ratio:

$$\frac{K}{N} \leq \frac{1}{Q - \frac{R^K}{R} G(\bar{\omega})} \tag{7}$$

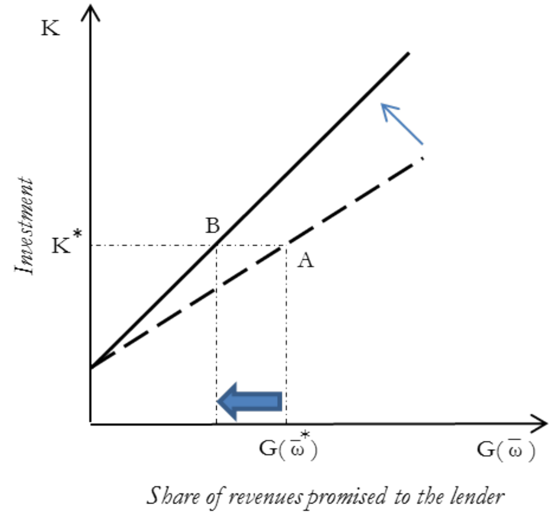
From equation (7) it is immediate to see that the maximum entrepreneurial leverage that the lender is willing to accept is an increasing function of $G(\bar{\omega})$. This positive relationship between $G(\bar{\omega})$ and K makes sense: given net worth N, and

[14] For convenience, figure 1 displays the relationship between K and $G(\bar{\omega})$ linearly, although constraint (5) implies a mildly convex relationship.

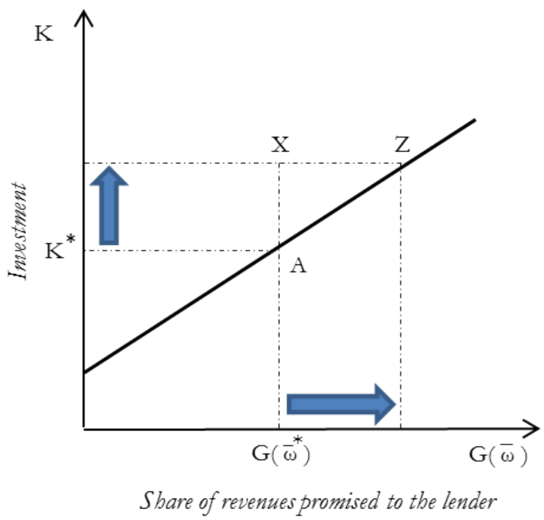
Figure 1: Isolating direct from indirect effect after $R \downarrow$



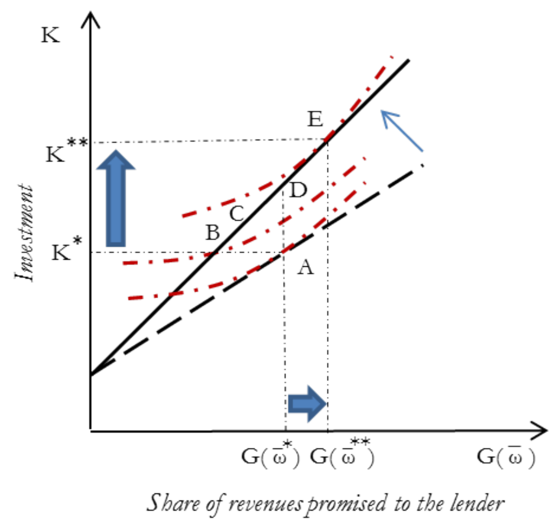
a: initial equilibrium



b: direct effect ($R \downarrow$, K constant)



c: indirect effect (R constant, $K \uparrow$)



d: direct and indirect effect

assuming that the constraint is initially binding, the entrepreneur can invest more only by borrowing more, but this increases his leverage which indirectly reduces the relative buffer that net worth provides to the risky loan. To compensate the lender for this leverage effect the borrower must pay a leverage premium that takes the form of a higher $G(\bar{\omega})$, i.e. a higher share of expected revenues promised to the lender. This increase in $G(\bar{\omega})$ pushes up the default rate because it is harder for the lender to meet the higher repayment obligation, but it is necessary in order to convince the lender to issue more credit and allow the entrepreneur to expand investments.[15]

[15] The leverage premium is defined here as the semi-elasticity of $G(\bar{\omega})$ with respect to the leverage ratio of the entrepreneur. The implicit function theorem gives

The leverage effect is shown in figure 1, panel c. Given an unchanged level of R, if $G(\bar{\omega})$ remains constant an increase in K moves the equilibrium above the constraint to point X where the indifference condition of the lender is violated. To convince the lender to issue more credit to fund the higher level of investment the entrepreneur must promise a higher $G(\bar{\omega})$, as shown in point Z. A higher value of $G(\bar{\omega})$ implies a higher default probability because it is harder to meet the higher repayment share.

Combining direct and indirect effect

Consider now the equilibrium effect on defaults of a decrease in R. A decrease in R reduces the cost of borrowing for each level of borrowing, but it also increases the optimal leverage because it increases the discounted return to capital R^K/R, making each unit of investment more productive in discounted terms. The ultimate effect on defaults depends on the outcome of these two opposite forces, which reflects the relative weight attached by the entrepreneur to running a bigger investment relative to accepting a higher default probability. This is exactly the trade-off captured by the optimality condition (6).[16] As clearly shown in figure 1, panel *d*, when R decreases the entrepreneur is willing to substitute out from small investment into higher default probability in order to take advantage of the higher discounted return to capital. In fact, the optimality condition (6) prescribes a new equilibrium in which $\bar{\omega}$ is higher because a higher value of $G(\bar{\omega})$ is needed to reach the new level of investment (point E).[17]

It is interesting to note that the increase in the default probability is entirely driven by asymmetric information. If information was symmetric the Modigliani-Miller theorem would hold, the lender would be indifferent to the level of en-

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$$\frac{dG(\bar{\omega})}{\frac{dK/N}{K/N}} = \underbrace{Q \cdot \left(\frac{R^K}{R}\right)^{-1} - G(\bar{\omega})}_{\text{Leverage Premium}} > 0$$

i.e., a 1 % increase in the leverage ratio of the entrepreneur requires an increase in the share of expected revenues to the lender of at least $\left(Q\left(\frac{R^K}{R}\right)^{-1} - G(\bar{\omega})\right) \cdot 100$ basis points.

[16] According to equation (6) the equilibrium is reached when the marginal cost of promising a higher share of expected revenues to the lender ($F'(\bar{\omega})$) equals the marginal benefit of investing more $\left(F(\bar{\omega})\frac{G'(\bar{\omega})}{Q\cdot\left(\frac{R^K}{R}\right)^{-1} - G(\bar{\omega})}\right)$.

[17] In this model the effect that increases defaults following a decrease in R is the same effect that increases defaults following a positive productivity shock, given an equivalent effect on the discounted return to capital in equation (6). While the result by Jimenez *et al.* (2007) suggests that this increase in defaults might be realistic for monetary shocks, there is evidence that defaults are countercyclical, not procyclical [Vassalou and Xing (2004)]. To fix the procyclicality of defaults in costly state verification models, Dorofeenko, Lee and Salyer (2006) assume that the business cycle is driven by shocks to the uncertainty on the idiosyncratic shock, Medina (2006) moves the expected idiosyncratic productivity procyclically while Covas and Den Haan (2012) add an equity contract in which the cost of issuing equity is countercyclical. CHECK IF EFFECT STILL IN PLACE FOR MONETARY SHOCK AND IF CAN RECONCILE BOTH. FOR ALL CASES COULD BE THAT THEY DON'T HAVE A INTEREST RATE

trepreneur's leverage and no leverage premium would be required. Appendix B gives a formal proof.

2.4 Numerical exercise

I now use a simple numerical exercise to strengthen the intuition developed graphically in the previous section. The calibration of this exercise is chosen to simplify the intuition as far as possible, leaving a full calibration of the model to section 3. Net worth is normalized to 1 as well as the price of capital. The initial net opportunity cost of lending is arbitrarily set at 2 % and the net return to capital at 4 %, implying a net discounted return to capital of 1.96 %. The variance of the idiosyncratic shock and the observation cost μ are calibrated to match an arbitrary but realistic equilibrium leverage ratio of 2 and a default probability of 3 %, obtaining $\sigma = 0.3434$ and $\mu = 0.1655$. Note that the normalization of net worth to 1 implies that investment and leverage ratio coincide.

Given these initial parameter values the entrepreneur and the lender sign an optimal contract in which the entrepreneur borrows 1 from the lender at 2.78 % interest rate and invests 2. Revenues from this investment equal 2.08 in expectation, but ex post they can range from 0 to ∞ depending on the realization of ω. At the end of the period, if the realization of the shock is such that ex post revenues are above the gross repayment obligation 1.0278 the entrepreneur pays back his debt and keeps what is left as profits. Instead, if revenues fall below 1.0278 the entrepreneur defaults and the lender obtains revenues, net of monitoring costs.

Table 1 compares optimal vs. suboptimal outcomes taken when the opportunity cost of lending is either equal to 2 % or 1 %, keeping all the other parameters fixed. As from figure 1, all combinations from B to E differ by how much investment increases in response to the lower value of R. Optimal combinations are marked by *. To simplify the comparison, basis point variations from the initial equilibrium are reported in parenthesis.[18]

Start from the equilibrium described above (point A). Following the decrease in R, if the entrepreneur invests the same amount perfect competition reduces the cost of the loan by 107 basis points, which pushes down defaults by 20 basis points (point B). A constant level of investment, though, is not optimal, because the reduction in the risk-free rate pushes up the discounted return to capital R^K/R from 1.96 % to 2.97 %, making each unit of investment more productive in discounted expected terms. The entrepreneur can take advantage of this higher return to capital by investing more, but given constant net worth, an increase in investment requires an increase in his leverage. This increase in leverage dampens the reduction in the cost of borrowing because the lender anticipates that net worth provides the same buffer to a bigger loan and prices the loan accordingly by demanding a leverage premium. The overall effect on defaults depends on whether the increase in leverage is strong enough to offset the direct effect of the initial decrease in the cost of borrowing.

[18] Being static, this exercise can only compare levels of borrowing for new loans taken when R equals one value or the other, but it is not rich enough to study the effect of the variation in R on

Table 1: A decrease in the opportunity cost of lending from 2 % to 1 %

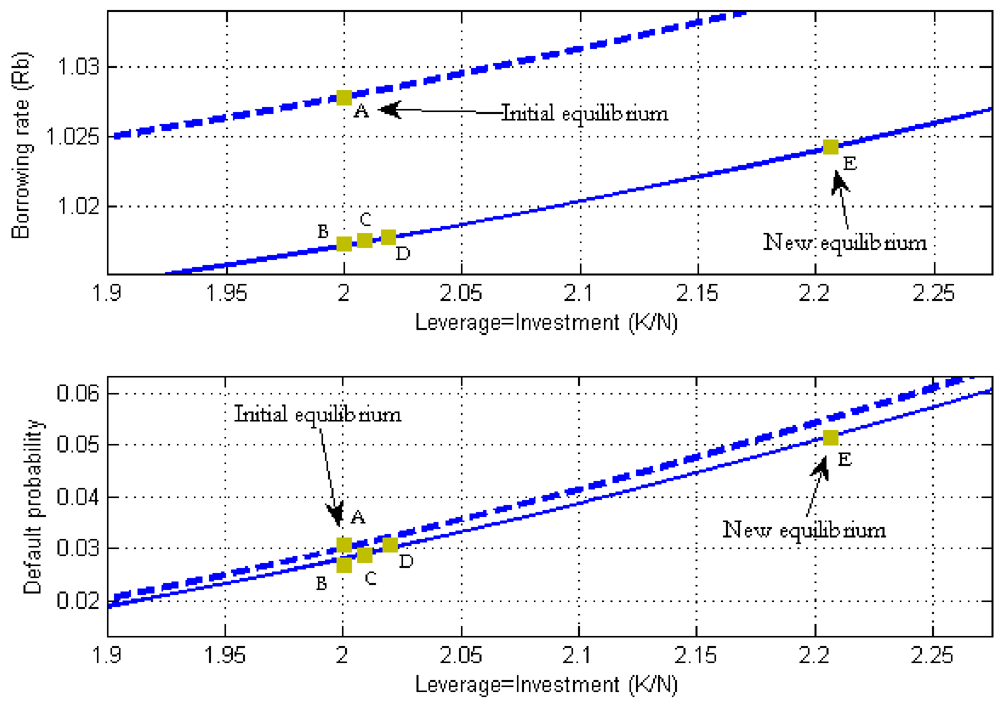
	Opport. cost of lending R	Borrower's leverage $K \equiv K/N$	Borrowing rate R^B	Share to the lender $G(\bar{\omega})$	Default probability $\Phi(\bar{\omega}) \cdot 100$	Borrower's expected revenues $F(\bar{\omega})R^K K$
A^*	1.02	2	1.0278	0.4901	3 %	1.0556
B	1.01	2	1.0172	0.4853	2.80 %	1.0659
		(**0**)	(**-107**)	(-48)	(**-20**)	
C	1.01	2.01	1.0175	0.4878	2.90 %	1.0660
		(**+50**)	(**-104**)	(-24)	(**-10**)	
D	1.01	2.02	1.0178	0.4901	3 %	1.0661
		(+100)	(-101)	(0)	(0)	
E^*	1.01	2.2057	1.0242	0.5309	5.14 %	1.0671
		(**+1034**)	(**-36**)	(+407)	(**+214**)	

The intuition becomes clear by comparing the different possible outcomes reported in table 1. If the entrepreneur increases investment by 0.01 (point C) the increase in leverage is not particularly strong (50 basis points above the initial equilibrium) and defaults still decrease, although by less than in the case in which leverage stays constant (10 basis points instead of 20). Of course the entrepreneur is not constrained to borrow only 0.01 more. If it is optimal to borrow 0.02 more (point D) his leverage ratio would increase by more (100 instead of 50 basis points above the initial equilibrium), leading to a reduction in the borrowing rate that is just enough to offset the increase in leverage and to keep defaults unchanged. The key intuition of the paper becomes then clear by comparing the bold numbers in table 1: if the increase in leverage is strong enough to offset the direct effect of a lower opportunity cost of lending, the equilibrium default probability *increases* despite the ultimate decrease in the borrowing rate. In the case considered in this numerical example, it is optimal for the entrepreneur and the lender to sign a contract in which investment and leverage increase by 10.34 % (point E) despite the fact that such increase in leverage ultimately increases the default probability by 214 basis points. Overall, the reduction in the opportunity cost of lending leads the entrepreneur to increase his leverage from 2 to approximately 2.20, which pushes his default probability from 3 % to 5.14 %. The lender is indifferent to the new default probability because he prices the loan accordingly. The entrepreneur, instead, is better off, as shown by the increase in his expected profits (last column of table 1).

The role of the leverage effect in driving the result becomes even clearer in figure 2. This figure shows the combinations of investment and borrowing rates that satisfy the indifference condition of the lender in the space (R^B, K) (top graph) and the corresponding entrepreneur's default probability (bottom graph). The indifference condition of the lender is increasing in the space (R^B, K) because of the leverage premium that the lender demands in exchange of a increase in credit supply. The

outstanding loans taken when R was equal to the initial value.

Figure 2: A decrease in the opportunity cost of lending from 2 % to 1 %



initial equilibrium is marked as point A and is equivalent to table 1 and figure 1. When R decreases from 2 % to 1 % the lender is willing to accept a lower borrowing rate for each level of investment and this shifts down the indifference condition and the default curve. The entrepreneur could potentially stick to the same level of investment and benefit from the lower default probability (point B). In the model, instead, it is optimal to move along the new indifference condition of the lender in order to benefit from the higher discounted return to capital. The new equilibrium is found at point E, where the default probability has ultimately increased due to the ultimate increase in leverage.

3 A general equilibrium extension of the model

While isolating the leverage effect as an important force in play, the analysis of the previous section falls victim of at least two important limitations: a) it is static, so it can only feature new loans, not outstanding loans, and b) it keeps some variables of the debt contract constant, potentially omitting important dynamic and general equilibrium effects. In this section I address such concerns. Part 3.1 explains why a general equilibrium extension of the model is needed, part 3.2 lays down the full model, section 3.3 describes the calibration in details, part 3.4 shows the results and part 3.5 discusses the robustness of the results.

3.1 Limitations of the partial equilibrium analysis

Section 2 showed that in the costly state verification model the default probability of the borrower can be implicitly rewritten as a function of the discounted return to capital and the entrepreneur's leverage, as synthesized in equation (8). A decrease in R increases the discounted return to capital and reduces the borrowing cost (direct effect), but since the entrepreneur reacts to this by increasing his leverage, the lender demands a leverage premium which ultimately pushes up defaults (indirect effect).

$$\text{Prob(default)} = f\Big(\frac{R^K}{R}, \frac{K}{N}\Big), \quad \text{with} \quad \underbrace{f_1' < 0}_{\text{Direct effect}} \;\; ; \;\; \underbrace{f_2' > 0}_{\text{Indirect effect}} \tag{8}$$

From equation (8) we see that whether the default probability still increases in a dynamic general equilibrium environment depends on the behaviour of N and R^K. There are several forces that potentially revert the result.

First, general equilibrium effects on R^K might be relevant. If a monetary expansion reduces R^K, say because capital is subject to decreasing marginal returns, the direct effect on the borrowing cost is weaker compared to the partial equilibrium case, strengthening the result of an increase in defaults. If instead R^K increases after a monetary expansion, say because investments are more productive or because more labour is used in production, the direct effect is reinforced and can potentially dominate and revert the result. While it is hard to find a direct empirical counterpart for R^K, the existing evidence of a negative relationship between policy rates and employment lends some plausibility to the latter scenario [Christiano, Eichenbaum and Evans (1999)]- (CHECK HOW THE TOBIN'S Q MOVES FOLLOWING A MONETARY SHOCK)

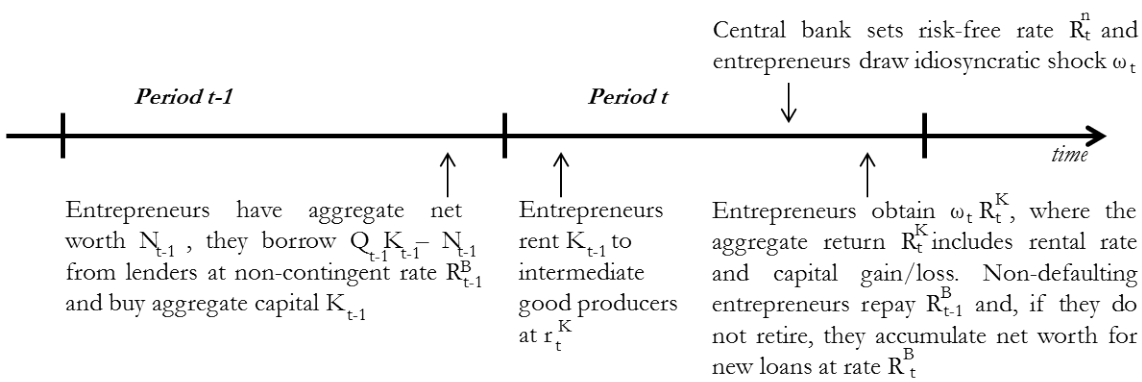
Second, the static environment of section 2 overestimates the increase in leverage because it rules out adjustment costs in capital and keeps net worth artificially constant. Capital adjustment costs are instead considered important determinants of firms investment decisions at least since the contribution by Eisner and Strotz (1963) [Chirinko (1993), Caballero (1999)], while firms' net worth realistically increases following a monetary expansion, either due to a conventional outward shift in aggregate demand or due to a lower cost of inventories and working capital [Barth and Ramey (2002)]. Both forces suggest that leverage might increase less rapidly than in the partial equilibrium case and that it could actually decrease, making the indirect leverage effect work in the opposite direction.

Addressing these concerns is far from trivial because dynamic general equilibrium effects on R^K and N can be modeled in many alternative and not mutually exclusive ways. In the rest of the paper I use one possible approach by borrowing a standard New Keynesian model from the literature which I use to study the effect of investment adjustment costs and retained earnings. It is shown that, within the framework considered, the first remark is consistent with the model and is at the origin of the decrease in the default probability of outstanding loans. The intuition is that, in the model, a monetary expansion unexpectedly increases asset prices and delivers an ex post aggregate return to capital that exceeds its expected value for the first period after the shock. The second remark, instead, is irrelevant for the result on new loans because the accumulation of net worth leads capital to increase even more, implying that leverage still increases despite the existence of costly capital adjustment. Needless to say, the quantitative predictions of the model should be taken with caution in view of the limitations of the general equilibrium model used.

3.2 The full model

The modeling framework used to nest the partial equilibrium contract of section 2 in a general equilibrium environment is a standard New Keynesian model and draws mainly from Bernanke, Gertler and Gilchrist (1999), Christiano, Eichenbaum and Evans (2005) and Christiano, Motto and Rostagno (2008, 2010). Since most of the features of the model are common in the literature I only discuss them briefly, unless they are key in driving the result.

Figure 3: Timing of the full model



The full model is populated by 6 representative agents: households, lenders, entrepreneurs, capital producers, intermediate good producers and retailers. The timing of this interaction, shown in figure 3, is crucial in generating the result and is taken from Bernanke, Gertler and Gilchrist (1999). The basic structure is as follows. At the end of period $t-1$ entrepreneurs use aggregate net worth to borrow from lenders at a non contingent interest rate in order to buy capital for the next period. At the beginning of period t entrepreneurs rent capital to intermediate good producers at a state contingent rental rate. Then each entrepreneur draws an idiosyncratic shock ω_t and the central bank sets the risk-free nominal interest rate. At the end of period t entrepreneurs receive $\omega_t R^K_t$ on each unit of capital, where R^K_t reflects both the rental rate and the capital gain or loss on non-depreciated capital. Depending on the realization of ω_t entrepreneurs either pay back their debt or default. The entrepreneurs that do not default nor retire accumulate aggregate revenues as end-of-period net worth, take new loans and proceed to period $t+1$.

This setting is now described more extensively. Households are risk averse and derive utility from a basket of imperfectly substitutable consumption goods and from leisure. The instantaneous utility function is $\log(C_t) - \chi \frac{H_t^{1+1/\eta}}{1+1/\eta}$. Households are infinitely lived and postpone consumption through the financial services of lenders, who act as intermediaries.[19] These services take the form of deposits, which pay the nominal risk-free rate R_t^n at period $t+1$.

Lenders are risk neutral, they raise deposits from households and provide loans at time $t-1$ to entrepreneurs at the borrowing rate R_{t-1}^B. Whether at time t the borrowing rate is actually paid by the entrepreneur depends on his revenues at time t. Lenders perfectly diversify idiosyncratic risk while aggregate risk is borne by entrepreneurs. Perfect diversification and competition implies that the relevant opportunity cost of lending is the real value of the nominal interest rate R_{t-1}^n. Lenders do not consume in equilibrium because they make zero profit.

Entrepreneurs are risk neutral. At time $t-1$ they own net worth accumulated out of retained earnings from previous periods and borrow from lenders to buy capital from capital producers. Capital is then rent at time t to intermediate good producers on competitive markets. The ex post return on capital R_t^K equals the rental rate r_t^K on capital plus the capital gain from non-depreciated capital:

$$R_t^K = \frac{r_t^k + (1-\delta)Q_t}{Q_{t-1}} \tag{9}$$

The ex post return R_t^K is affected by aggregate uncertainty because an unexpected variation in the nominal risk-free rate R_t^n affects the investment decisions at time t and unexpectedly moves price Q_t (more on this later). The ex post return to capital that the entrepreneur actually receives is $\omega_t R_t^K$, i.e. the aggregate return to capital R_t^K after it has been hit by the idiosyncratic shock ω_t.[20]

Non-defaulting entrepreneurs obtain aggregate revenues V_t given by

$$V_t = F(\bar{\omega}_t) R_t^K K_{t-1}$$

A fraction $1-\gamma$ of such entrepreneurs is assumed to retire and the same mass of entrepreneurs is born to keep the ratio of entrepreneurs to households constant.[21] Being risk-neutral, the entrepreneurs who remain in business allocate their revenues into net worth. They also provide labour services and invest their wage W_t in the purchase of capital. Entrepreneurial net worth at the end of period t is given by

$$N_t = \gamma V_t + W_t$$

[19] By separating households from lenders we can solve the costly state verification contract by assuming that both agents in the contract are risk neutral, as in section 2, while still deriving an Euler equation for the model. Since the return on lending ultimately goes to households, aggregate uncertainty is borne by the entrepreneurs despite the lender's risk neutrality.

[20] Contrary to the partial equilibrium model, ω_t is not a structural parameter from the production function but enters the model as a shock to the market return to capital R_t^K, as in Bernanke, Gertler and Gilchrist (1999). Christiano, Motto and Rostagno (2008) avoid this shortcoming by assuming that the idiosyncratic shock affects the share of the stock of capital that can be effectively used in production after it has been bought.

[21] The literature takes this assumption to avoid that the accumulation of net worth is strong enough to let the entrepreneur entirely self finances investment.

Entrepreneurs rent capital to intermediate good producers who use it together with labor input in a standard Cobb-Douglas production function. Intermediate goods are then sold to retailers on competitive markets.

Capital producers buy non-depreciated capital from the market, invest in new units of capital and sell the new stock to capital holders. Their investment technology is subject to adjustment costs, a feature that allows a time-varying price of capital and which the literature rationalizes in terms of disruptions costs, replacement of installed capital and costly learning. The adjustment cost function is borrowed from Christiano, Eichenbaum and Evans (2005), Christiano, Motto and Rostagno (2008) and Smets and Wouters (2003), who assume

$$K_t = (1-\delta)K_{t-1} + \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \tag{10}$$

Investment adjustment costs are assumed to be zero in steady state and with constant second derivative, implying $S(1) = S(1)' = 0,\ S(1)'' = \nu > 0$. Specifically, I assume $S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\nu}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$, where ν detects the inverse of the elasticity of investment to a one percent increase in the current price of installed capital.[22]

Retailers buy homogeneous intermediate goods, diversify them costlessly and sell them to consumers as final consumption goods. Since final goods are viewed as imperfect substitutes by households, retailers enjoy some price-making power. Under the assumption of Calvo price setting, prices are set as a mark up over the weighted average of marginal costs over time. This nominal rigidity gives monetary policy real effects in the short term.

The monetary shock enters at time t by changing the risk-free nominal interest rate R^n_t between t and $t+1$. In doing so it affects the opportunity cost of lending and the investment decisions starting from period t onwards. The policy rate is controlled through the following feedback rule:

$$\frac{R^n_t}{R^n_{ss}} = \left(\frac{R^n_{t-1}}{R^n_{ss}}\right)^{\rho} \left[\left(\frac{E(\Pi_{t+1})}{\Pi_{ss}}\right)^{\gamma_\pi} \left(\frac{E(Y_{t+1})}{Y_{ss}}\right)^{\gamma_y}\right]^{1-\rho} e^{\epsilon_t} \tag{11}$$

An important remark is due before continuing. Debt contracts are signed each period based on the mathematical expectation of the return to capital in the next period. Agents know that the ex post realization of the return to capital can potentially differ from its expected value because aggregate uncertainty enters the general equilibrium model due to the effect of the policy shock on the capital gain on non-depreciated capital. Entrepreneurs are willing to bear this uncertainty due to their risk neutrality, implying that the borrowing rate R^B_{t-1} is not a function of the realization of the aggregate shock. The borrowing rate is not even a function

[22] The assumption of convex adjustments costs is justified by convenience rather than realism. Existing empirical evidence documents that investment decisions at the micro data displays lumpiness, periods of inactions and spikes that are inconsistent with the smooth behaviour of investment implied by the convex adjustment costs, although the severity of these non-linearities is dampened by the aggregation [Caballero (1999), Cooper and Haltiwanger (2006)] and general equilibrium effects [Veracierto (2002)].

of the idiosyncratic shock because this is unobserved by the lender, as in section 2. The non-contingency of R^B implies that the default threshold $\bar{\omega}$ is necessarily a function of the aggregate shock. This link between $\bar{\omega}_t$ and the ex post realization of R^K is shared with Bernanke, Gertler and Gilchrist (1999) and plays a key role in generating the result on outstanding loans. When the contract is signed agents form an expectation of the default probability. Whether the actual rate of default is below or above the expected one depends on whether the ex post return to capital is respectively above or below its expected value. This effect is quite realistic and detects the fact that unexpected increases in firms revenues reduce their default probability because they increase the cash flow that can be used to meet the repayment obligation. An unexpected monetary expansion takes R^K above expectation and pushes up revenues, which on impact mitigates the default probability of outstanding loans. From the second period onwards this unexpected positive effect on revenues is lost, while the leverage ratio starts to increase, pushing up defaults of new loans.[23]

3.3 Calibration

I restrict the model economy using empirical observations on Spain, the same country for which Jimenez and coauthors carry their empirical analysis. The calibration is shown in table 2 and represents the midpoint of the range of parameter values considered in section 3.5 to assess the sensitivity of the results. The model is calibrated quarterly. For convenience, table 2 reports the equilibrium interest rate and default probability in annualized terms.

Calibrated parameters

The discount factor β is set to guarantee that the steady state risk-free rate R^n equals the quarterly sample average of the German and European interbank lending rate between 1985 and 2006, which are the policy rate and sample period used by Jimenez and coauthors. In the model, inflation is zero in steady state, implying that in steady state R^n and R coincide. To be consistent with this assumption I calibrate β to match the average real interbank rate which equals 0.8497 % annually (4.60 % nominal interest rate net of 3.75 % inflation), implying a quarterly discount rate of 0.9979.

The variance of the idiosyncratic shock ω and the observation cost μ are calibrated to match the Spanish firms' default probability and leverage ratio. Jimenez and coauthors estimate an average default probability of 0.6 % (2.4 % annually) for the median loan at one quarter after loan origination. As explained in appendix A, I adjust this measure to 0.7291 % (2.92 % annually) to control for the fact that the debt contract in the model economy differs from the median loan in Jimenez *et*

[23] In the model, the monetary expansion increases aggregate demand for consumption and investment, but only its investment component matters in unexpectedly increasing revenues and reducing defaults because only entrepreneurs borrow using a risky debt contract. The other agents of the model, in fact, either do not borrow or they use contracts that are not subject to defaults.

Table 2: Calibration of the full model

Description	Parameter	Value	Calibrated
Discount factor	β	0.9979	✓
Variance of idiosyncratic component e^{ω}	σ	0.1601	✓
Observation cost for the lender	μ	0.0925	✓
Probability that entrepreneur retires	$1-\gamma$	0.0139	✓
Weight on disutility of labour	χ	18.70	✓
Policy rate persistence	ρ	0.9846	✓
Weight on inflation in Taylor rule	γ_π	1	
Weight on output in Taylor rule	γ_y	0	
Investment adjustment cost	ν	3.60	
Marginal product of capital	α	0.35	
Depreciation rate	δ	0.025	
Elasticity of substitution across varieties	ϵ	10	
Frisch elasticity of labour	η	3	
Probability of Calvo price optimization	$1-\psi$	0.25	

Description	Moment	Model	Data	Source
Annualized default rate	$\Phi(\bar{\omega})$	0.0292	0.0291	Jimenez *et al.* (2007)
Leverage ratio	K/N	3.0786	3.0785	Kalemli-Ozcan *et al.* (2011)
Annualized risk free rate	R^n	0.0085	0.0085	Bundesbank
Discounted return to K	R_K/R	1.0049	1.0049	Bernanke *et al.* (1999)

al. (2007) for being non-collateralized with one quarter maturity.[24] A measure of leverage ratio, instead, is not available from their paper, which uses observations at the loan level instead of firm level. The average leverage for Spanish firms is taken from Kalemli-Ozcan, Sorensen and Yesiltas (2011), who construct a dataset that is rich enough to be comparable to the one used by Jimenez *et al.*.[25] The weighted average of the median leverage ratio of listed and non-listed non-financial Spanish firms equals 3.0785, which is the value used in the calibration.[26] [27]

The exogenous probability γ that entrepreneurs retire and the relative disutility of labour χ are set to guarantee that in steady state the discounted return to capital

[24] The model features non-collateralized, one-quarter-ahead financial loans issued by an intermediary with fixed interest rate. In the dataset used by Jimenez and coauthors, almost 85 % of the loans have no collateral, the average maturity is 5 quarters, 60 % are financial loans, around 90 % are issued by a commercial or saving bank and most have non adjustable rates [Jimenez and Saurina (2004)].

[25] The dataset covers the period between 2000 and 2009, which falls short of the period for which I calibrate the default probability of firms. Alternative empirical estimates were considered less suitable for the calibration because they range on an even shorter period of time and focus on only one type of firms: Reverte (2009) studies firms listed in the IBEX35 index in year 2005 and 2006, Inchausti (1997) concentrates on firms listed on the Valencia Stock Exchange, Garcia-Teruel and Martinez-Solano (2007) focus on small and medium enterprises in the manufacturing sector, Ferreira and Vilela (2004) study publicly traded firms between 1987 and 2000.

[26] 90 percent of the observations of the median leverage ratio of non-financial firms in the European Monetary Union range between 2.29 and 3.34, with the distribution skewed to the left (the skewness estimate equals 1.1535). I use the median instead of the mean value because the latter (9.0443) was found to be heavily biased upwards due to relatively few outliers. The dataset does not include Cyprus, Greece and Malta.

[27] I am grateful to the authors for having kindly shared with me these statistics.

that is consistent with the right moments on leverage and defaults implies a 200 basis point annual spread between the risk free rate and the aggregate return to capital. This measure is borrowed from Bernanke, Gertler and Gilchrist (1999). An alternative strategy would be to calibrate γ and χ to imply a discounted return to capital that matches the Spanish empirical borrowing rate R^B. This strategy was not viable because, to the best of my knowledge, information on the borrowing rate on loans is not publicly available for Spain.

The identification strategy of monetary policy by Jimenez *et al.* (2007) relies on the exogeneity of the policy interest rate, an assumption that the authors defend by arguing that this rate is set by the European Central Bank with limited concern to Spanish-specific considerations. It is not possible to fully account for this assumption in a New Keynesian model, because an exogenous risk-free rate would leave inflation expectations undetermined, giving room for sunspot equilibria. To reduce the divergence between the model and the empirical estimation by Jimenez and coauthors I calibrate the Taylor rule to ensure that the Taylor principle is just satisfied. Specifically, the coefficient γ_y in equation (11) is set equal to 0 and the coefficient γ_π marginally above 1. These values fall short of empirical estimates, which range around 0.5 for γ_y and between 1.3 and 2.3 for γ_π [Clarida, Galí and Gertler (1998, 2000), Rudebush (2001)], but they are in line with the calibration used by Bernanke, Gertler and Gilchrist (1999), who chose $\gamma_y = 0$ and $\gamma_\pi = 1.1$.[28] The persistence parameter ρ is calibrated to 0.9846, which is obtained by fitting a first order autoregressive process on the policy rate used by Jimenez and coauthors (the German interbank rate between 1986 and 1998 and the European Overnight Index Average between 1999 and 2006).

The calibration on Spain described above mainly differs from existing calibrations on the US economy in the value for the leverage ratio, which is higher in Spain by around 50 % or more. There is no significant difference, instead, on the default rate. Bernanke, Gertler and Gilchrist (1999) and Faia and Monacelli (2006) calibrate their model around an annualized default probability of 3 %, compared to 2.92 % here.

Non-calibrated parameters

The rest of the parameters are calibrated according to the literature. Robustness checks reduce legitimate concerns that the use of values considered realistic for the US drive a result that would be lost if one knew the true values for Spain.

The hardest parameter to calibrate is ν, which captures the second derivative of the adjustment cost function of investment. The difficulty in finding a precise estimate for this parameter partially reflects the disagreement in the literature concerning the correct specification of adjustment costs in investment decisions (see note 22). By construction, ν does not affect the steady state of the model, although it does play a role in the dynamics outside the steady state. The point calibration of ν is taken from Christiano, Eichenbaum and Evans (2005) and equals 3.60, implying

[28] See Kamber and Thoenissen (2012) for an assessment of the Bernanke, Gertler and Gilchrist model with alternative calibrations of the Taylor rule.

a 0.28 % increase in investment to a temporary 1 % increase in the price of installed capital. This value is taken as a lower bound, since it implies the very high 131 % elasticity to a permanent 1 % increase in the price of capital. Robustness checks consider ν up to the value required to generate the same elasticity as in Christiano, Eichenbaum and Evans (2005), which is 38 %.

The parameter α for the marginal productivity of capital is set equal to 0.35. There is very limited disagreement on the plausible set of values for this parameter, at least in models that feature both capital and labour in the production [Covas and Den Haan (2012), note 29].

As standard in the literature, the depreciation rate δ is set to 0.025, corresponding to a 10 % annual rate. For robustness checks I consider values of δ down to 0.005, equivalent to a 2 % annual depreciation.

The elasticity of substitution ϵ across varieties of consumption goods is set equal to 10. This value is based on Basu (1996) and Basu and Kimball (1997) and is also used by Chari, Kehoe and McGrattan (2000). The literature tends to use lower values, like 8, 5 and 3 (respectively Faia and Monacelli (2006), Schmitt-Grohé and Uribe (2007) and Christiano, Eichenbaum and Evans (2005)). I consider all these values for robustness.

The Frisch elasticity of labour supply η is set equal to 3 as in Bernanke, Gertler and Gilchrist (1999). This value is consistent with Cho and Cooley (1994) and King and Rebelo (1999), who choose Frisch elasticities that range from 2.6 to 4.0. This is the range of values that I also consider in the robustness checks.[29]

As in Bernanke, Gertler and Gilchrist (1999), the probability $1 - \psi$ that the retailer optimizes his price is set equal to 0.25, implying an average period of price adjustment of 4 quarters. I will also consider values down to 0.5, implying an average price duration of half a year.

3.4 Results

The general equilibrium model delivers three main results:

1. a 25 basis points decrease in the nominal interest rate leads to a reduction in defaults of outstanding loans from steady state 2.92 % to 2.67 % annually and a subsequent prolonged increase in defaults of new loans up to 3.39 % annually;

2. the stronger the monetary shock and the higher the build up in leverage and default;

3. the central bank can reduce the build up in defaults by avoiding a high level of persistence in the policy rate or by attaching high weights to inflation and output in the feedback policy rule.

The mechanism behind these results are explained below.

[29] Empirical estimates of the Frisch elasticity on macro data tent to exceed estimates based on micro data, which are usually below 1. See Reichling and Whalen (2012) for a survey.

Table 3: Effect of monetary shocks of different size on annualized defaults

			"Default gap"		"Lifetime" of the effect		
			defaults on impact	defaults at peak	quarters to peak	quarters before descending to 0.5*peak	to 0.25*peak
Panel A	monetary shock						
	-25 bps		2.67	3.39	4	11	24
	-50 bps		2.41	3.86	4	11	24
	-75 bps		2.16	4.33	4	11	24
Panel B	persistence						
	0.9846		2.67	3.39	4	11	24
	0.94		2.86	3.05	3	6	14
	0.80		2.90	2.96	2	3	5
Panel C	weights to						
	$E(\pi)$	$E(y)$					
	1.0001	0	2.67	3.39	4	11	24
	1.50	0.50	2.87	3.04	3	6	14
	2.13	0.93	2.88	3.01	3	4	11

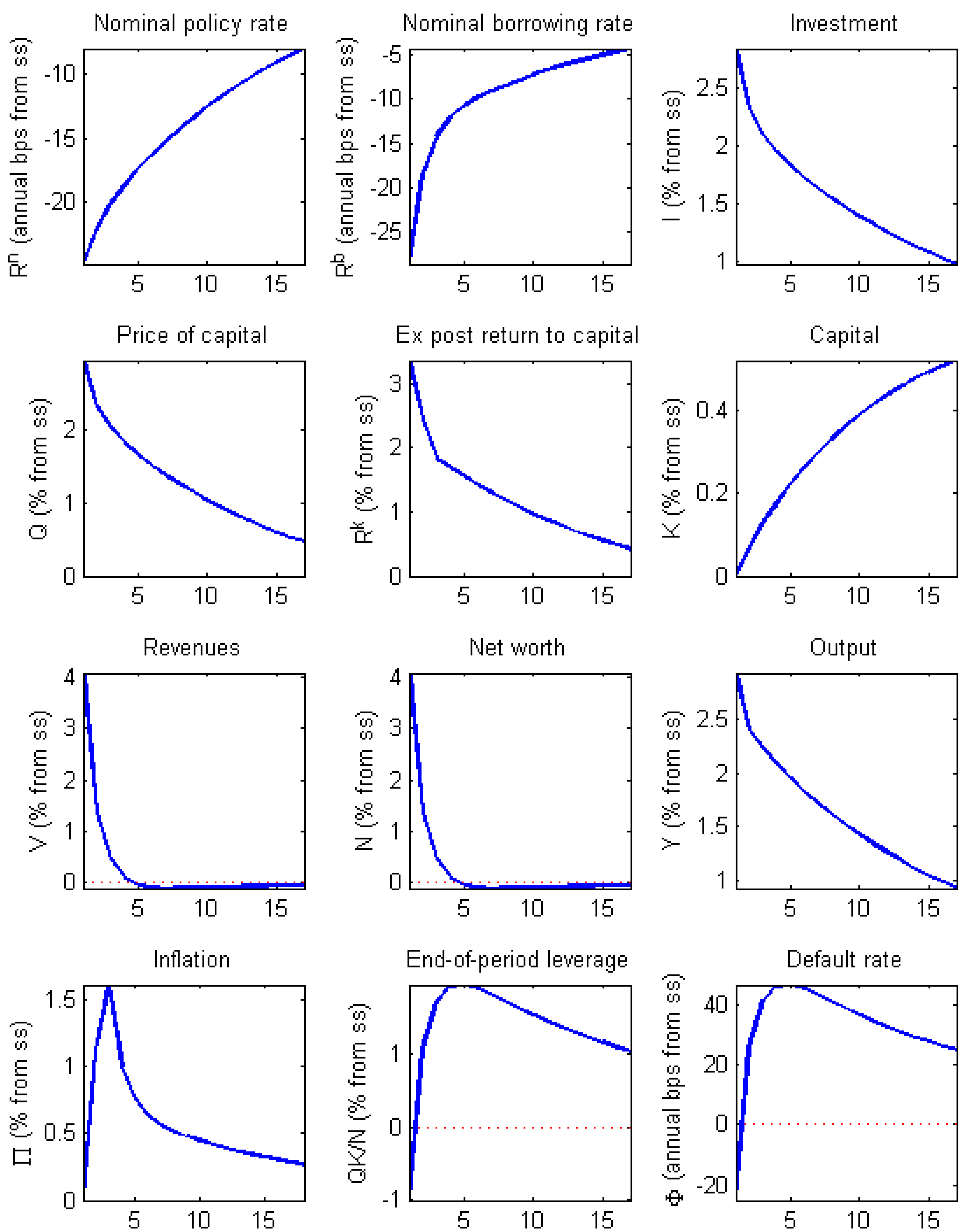
Result 1

Figure 4 shows the effects of a 25 annual basis point decrease in the nominal interest rate R_t^n. The horizontal axis represents quarters. All variables are displayed in basis point or percentage point deviations from the steady state, as specified for each variable. Interest rates, inflation and the default rate are reported in annualized terms.

When the nominal interest rate decreases, capital has already been chosen from the previous period. At time zero the net nominal borrowing rate decreases from 1.25 % to 0.97 % annually due to the lower nominal opportunity cost of lending. The decrease in the borrowing rate increases end-of-period investment by 2.85 % and pushes up the price of capital by 2.96 %. This unanticipated increase in the price of capital unexpectedly increases the return to capital above steady state from annualized 2.60 % to annualized 16.18 %. This increase is mainly driven by the capital gain on non-depreciated capital, but also reflects a 7.21 % increase in the rental rate of capital generated by a 4.1 % increase in labour (unreported in the figures). Capital starts accumulating from the second quarter onwards.

The unexpected increase in the return to capital pushes up entrepreneurs' revenues by 4.1 %. This decreases on impact the annualized default probability by around 25 basis points below steady state from 2.92 % to 2.67 % because the debt contracts of outstanding loans had been signed at the steady state non-contingent real borrowing rate of 1.25 %. On impact, the leverage ratio of entrepreneurs at the beginning of the period remains unchanged because capital was bought at the previous period. At the end of the first period, instead, the market value of leverage decreases because the unexpected increase in net worth dominates the increase in the price of capital and the slow increase in the purchase of new units of capital for the next period. On impact, output increases by 2.94 % and inflationary pressures arise from the second period onwards, going from 0 up to 1.61 % annually on the third period.

Figure 4: Expansionary monetary policy shock of 25 basis points annually



From the second period onwards no unexpected event occurs and the nominal interest rate and the price of capital slowly revert to the mean. The accumulation of capital pushes the leverage ratio up to 1.08 % above steady state on the first period after the shock, carrying with it the default rate. In fact, the behaviour of defaults mimics the one of leverage. Defaults display a hump-shaped response and peak to around 46 basis points on an annual basis above steady state after 4 quarters from the shock, i.e. from 2.92 % to 3.39 % annually. It is the increase in defaults that pushes revenues below steady state after the second period. As the leverage ratio reverts to the mean the default rate reverts to its steady state.

To measure how long it takes for defaults to revert to steady state I build on Chari, Kehoe and McGrattan (2000) and compute the number of quarters it takes for defaults to reach half and one quarter of the deviation from the peak after the peak. For instance, in this case the peak effect corresponds to around 46 annual basis points above steady state 4 quarters after the shock, so persistence is computed as the quarters required after the shock for defaults to decrease back to $46 \cdot 0.5 = 23$ and $46 \cdot 0.25 = 11.5$ basis points above steady state. I find that the effect on defaults is very persistent, because after a 25 basis point decrease in the policy rate it takes respectively 11 and 24 quarters after the shock for the effect on defaults to decline below half and one quarter of the peak effect.

It proves convenient for the rest of the paper to summarize result 1 with the "default gap" and "lifetime" of the effect as respectively the oscillation of defaults around steady state and the number of quarters to reach the peak, half of the peak and a quarter of the peak. As explained, a 25 basis point monetary shock implies a default gap of 2.67-3.39 and the lifetime of the effect 4, 11 and 24 quarters.

The rest of this section studies how the default gap and the lifetime of the effect on defaults change as the central bank gives monetary shocks of different size or follows a Taylor rule with different parameters.

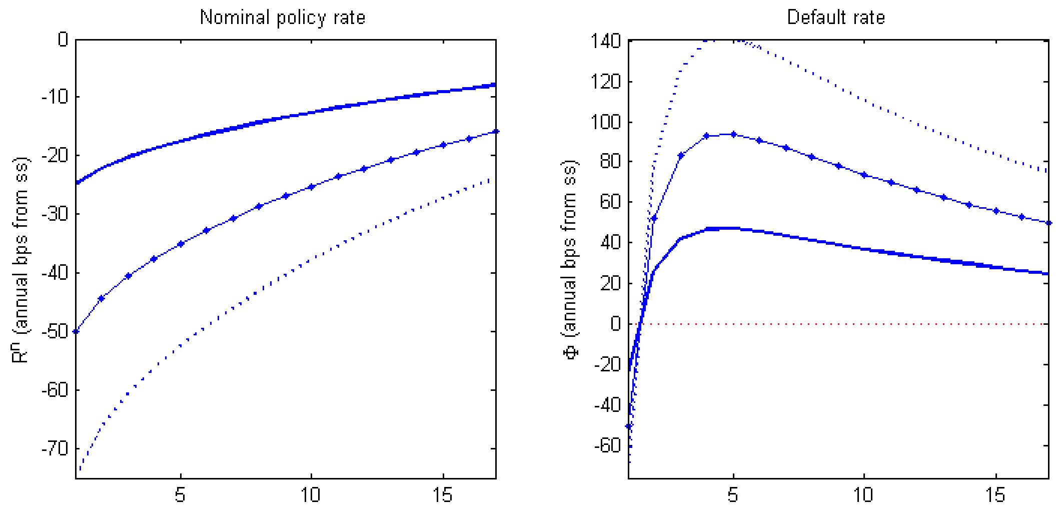
Result 2

Figure 4 studied the effects of a 25 basis point annual decrease in the nominal risk free rate. Figure 5 compares this scenario with the case in which the policy rate decreases by 50 or 75 basis points annually.[30] For simplicity, only the dynamics in the policy rate and defaults are reported, since the other variables behave in a qualitatively similar way to figure (**??**). As should be expected, the stronger the monetary expansion and the bigger the variation in defaults, because the economy experiences an initial stronger unexpected increase in revenues and a subsequent stronger build up of entrepreneurial leverage. For the case of a 75 annual basis point, the decrease in the policy rate reduces defaults on impact to 2.16 % and increases them up to 4.33 %, i.e. almost 1.5 percentage points above steady state.

Table 3, panel A, shows the effect of monetary shocks of 25, 50 and 75 basis points on the default gap and the lifetime of the effect on defaults. If no shock is imposed to the model defaults remain at steady state 2.92 %. As seen, a 25 basis point reduction in the policy rate generates an impact decrease of defaults to 2.67 % and a subsequent increase up to 3.39 % 4 quarters after the shock. The table shows that higher monetary shocks increase the default gap while leaving the lifetime of

[30]The case of a 100 basis points policy shock cannot be computed due to the very low steady state value of R^n.

Figure 5: Comparing monetary policy shocks



the effect unchanged. A 75 basis points expansion of monetary policy widens the default gap to 2.16-4.30.

Result 3

Let's now consider what happens when the central bank follows a Taylor rule with different parameter values from the baseline calibration. Figure 6 compares the effect on defaults of a 25 basis point decrease in the nominal interest rate when the persistence parameter in the Taylor rule (11) equals either 0.9846 (the baseline calibration), 0.94 or 0.8. We see immediately that the lower the persistence in R^n and the smaller the build up in defaults. More precisely, a persistence parameter down to 0.8 delivers a default gap of 2.90-2.96, making the effect on default effectively insignificant (table 3, panel B). The lifetime of this effect also shrinks, with a peak effect reached 2 quarters after the shock and three quarters of the peak effect disappearing after only one year and a half from the peak. I find this result interesting, since it suggests that, given an identical decrease in the nominal rate of 25 basis points, the longer it takes for the central bank to revert the policy rate to steady state and the stronger the accumulation of leverage and the corresponding increase in the default probability, a result reminiscent of the "too-low-for-too-long" criticism to monetary policy before the 2007 crisis [Taylor (2009)].

The other parameters in the Taylor rule have an equally important impact on the behaviour of the default rate. Figure 7 compares 25 basis point monetary shocks considering different values of the weights attached in the Taylor rule to expectations of inflation and output. Remember that the baseline calibration had $\gamma = 1$ and $\gamma = 0$. The upper bound considered in the exercise is given by the estimates by Clarida, Galí and Gertler (2000) for the US, which are 2.13 for γ_π and 0.93 for γ_y. Using these estimates the default gap shrinks to 2.88-3.01, with a lifetime of 3, 4 and 11 quarters (table 3, panel C). This result suggests that the build up effect on leverage and the following hike in defaults is less important in countries in which monetary policy is run aggressively relative to countries in which the policy rate is more exogenous to the current state of the business cycle. In particular, it suggests that the effect seems quantitatively important for Spain and potentially other peripheral countries, but maybe less important in the US, where monetary policy is run endogenously to the rest of the economy.

Figure 6: Comparing persistence of R^n in the Taylor rule

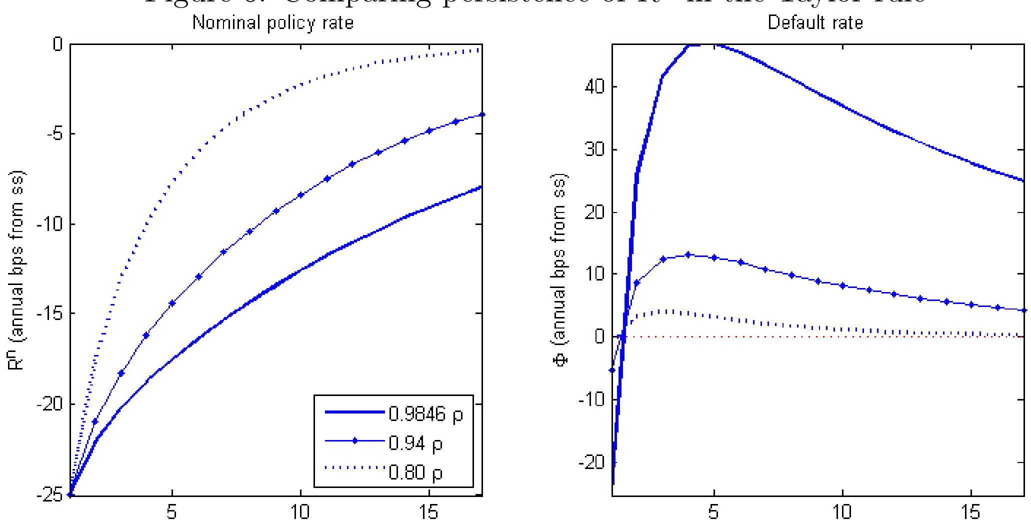
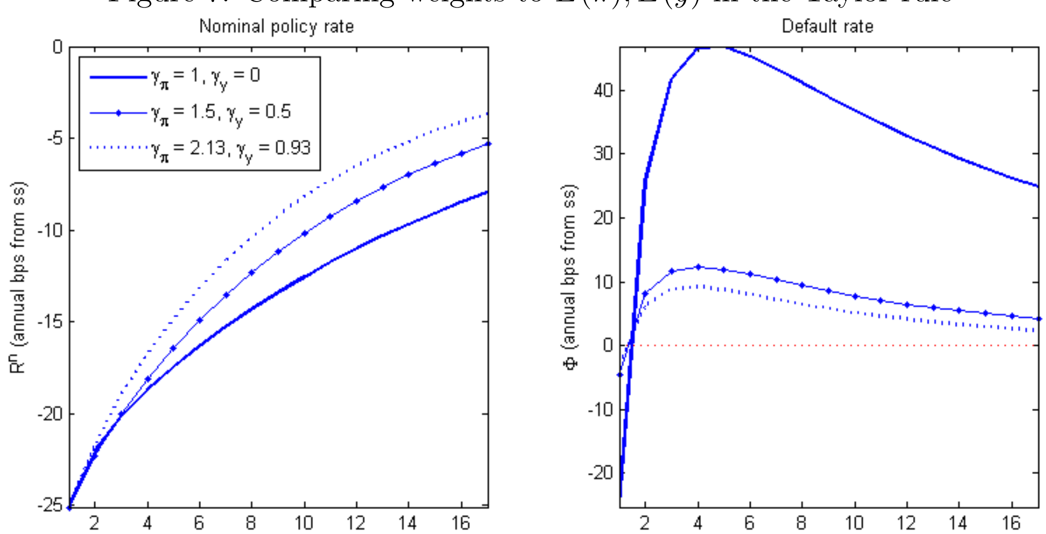


Figure 7: Comparing weights to $E(\pi), E(y)$ in the Taylor rule



3.5 Robustness checks

The robustness of result 1 has already been assessed with respect to the policy parameters $\rho, \gamma_\pi, \gamma_y$ in results 2 and 3, finding that the way the central bank runs monetary policy does affect the intensity of the build up in defaults in the years following the monetary shock. In this section I show that the result does not change much in the free structural parameters $\alpha, \delta, \epsilon, \eta, \psi, \nu$, nor in some key empirical moments matched in the calibration of the model. In all cases considered the monetary shock is adjusted to generate a 25 basis points annual decrease in R^n.

Alternative calibrations of $\alpha, \delta, \epsilon, \eta, \psi, \nu$ were considered for realistic alternative parameter values (see section 3.3). Overall, the default gap shrinks to a minimum of 2.80-3.13 for lower values of δ and expands to a maximum of 2.62-3.41 for lower values of the Frisch elasticity. Interestingly, the peak effect is reached always between 2 and 5 quarters after the shock. The persistence of the shock, instead, tends to decrease when using the alternative values of the non-calibrated parameters. The shortest lifetime of the effect was found with an elasticity of substitution across varieties of 3, which delivers a still significant lifetime of 4, 5, and 10 quarters. The only force that pushed up the persistence of the shock was the decrease in the elasticity of investment to the price of capital. Higher values of ν, in fact, push the lifetime of the effect to 5, 23 66 quarters and dampen the upper bound of the default gap to 3.09 %.

The model was also calibrated again around higher values of the steady state risk-free rate, which was remarkably low in the baseline calibration due to the high value of inflation in Spain (see section 3.3). No significant change was observed in neither the default gap not the lifetime of the effect. Recalibrating the model around lower annual default rates of 2 % and 1 % delivered no significant change as well. Considering default rates above 3 %, instead, expanded the default gap while leaving the lifetime of the effect almost unchanged.

4 Conclusions

This paper has argued that if monetary expansions boost output by leading firms to fund more investments using debt, defaults might increase. I used the "costly state verification" model by Townsend (1979) to formalize this intuition. Lower policy rates increase the incentive to invest because they make firms discount future returns by a lower rate. If the increase in investment is financed out of debt, the increase in leverage pushes up the equilibrium default ratio because net worth provides a relatively lower buffer to risky investments.

Following Jimenez *et al.* (2007), I calibrate the model to match empirical moments on Spain and find that a 25 basis point reduction in the policy rate reduces the default probability from steady state 2.92 % to around 2.70 % for outstanding loans and pushes the default of new loans up to around 3.30 %. The peak increase in default is reached around 4 quarters from the shock and fades away only after several years. Monetary policy can dampen the increase in default by taming the persistence of the policy rate and by following a Taylor rule that attaches relatively high weight to expectations of inflation and output.

The paper has several limitations which encourage further research. The model is less successful in matching empirical evidence on monetary shocks than existing contributions because the main effect on many variables is reached on impact, not with a lag. Extending the model along the nominal and real rigidities introduced by Christiano, Eichenbaum and Evans (2005) would most likely improve the performance of the model. An explicit welfare analysis is also needed before using the model to draw policy conclusions. In fact, the increase in investment might well outweigh the cost of a higher default probability, but to study this one should model explicitly how default probabilities impact on aggregate wealth. Maybe even more importantly, the model does not include outside equity as a source of firms' financing. The intuition of the paper draws, in fact, from an increase in leverage which might well disappear if firms were allowed to expand investment with equity rather than debt. The empirical literature on firms capital structure is silent about macroeconomic determinants of non financial firms' leverage [Rajan and Zingales (1995), Booth, Aivazin, Demirguc-Kunt and Maksimovic (2001), Lemmon, Roberts and Zender (2008)], but various arguments can be developed in favour of this concern. For instance, Covas and Den Haan (2010) find that equity issuance is largely pro-cyclical for most of firms, in particular for bottom 90 % firms according to their assets. If one accepts the view that monetary expansions push the economy upwards in the business cycle, a decrease in the policy rate would lead firms to issue more equity and dampen the effect on defaults. A similar conclusion is reached if one considers that lower returns on debt make equity less expensive by reducing the return on equity required by arbitrageurs. It becomes then important to study how monetary policy affects the cost of debt *relative* to equity [Miles (2010)]. All these and other research questions remain open for future research.

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Appendix A: Duration models and the empirical result by Jimenez *et al.* (2007)

This appendix gives a short introduction to duration models and synthesizes the estimation strategy used by Jimenez *et al.* (2007). The interested reader is referred to Kleinbaum and Klein (2005) and Keifer (1988) for a more comprehensive analysis.

The key intuition of duration analysis in studying default rates is the use of ex post information on the time to default to infer the stochastic process generating the observed switching from non-defaulting state to defaulting state.[31] Define $f(t)$ the probability density function determining the time to default, where t represents the time after loan origination. From $f(t)$ and from the corresponding cumulative distribution function $F(t)$ one can compute the surviving function $S(t) = 1 - F(t)$, which gives the probability that the loan survives until t. Having a dataset on loans until time T one can assume the functional form of $f(t)$ up to a parameter set, construct the log likelihood as a combination of densities and cumulative densities (respectively for observations of loans defaulted before T and for observations on loans still outstanding at time T) and solve for the parameters that maximize the likelihood that the default patter is the observed one.

In practice, it is convenient to synthesize the information content of $f(t)$ into the hazard function $h(t)$, which detects the instantaneous rate of defaulting at time t given that the loan has not defaulted yet (alternatively, the conditional rate of default per time unit in an infinitesimally small interval). Formally, $h(t)$ is defined as

$$h(t_0) = \lim_{\epsilon \to 0} \frac{P(t_0 < t < t_0 + \epsilon \mid t \geq t_0)}{\epsilon}$$

$h(t_0)$ detects approximately $P(t_0 < t < t_0 + \epsilon \mid t \geq t_0)$, i.e. the probability of default between time t_0 and $t_0 + \epsilon$ conditioning on the fact that the default has not occurred yet, with the approximating factor ϵ:[32]

$$P(t_0 < t < t_0 + \epsilon \mid t \geq t_0) \approx h(t_0)\epsilon$$

Duration analysis uses heuristic data inspection to infer a realistic hazard rate (usually the exponential or the Weibull distribution), computes the corresponding

[31] The switching from one state to another is studied extensively also in other branches of the social sciences, as for instance Medicine and Epidemiology.

[32] One can rewrite $h(t_0)$ as the ratio between the probability density function and the surviving function, or equivalently, as the rate of decrease of the surviving function:

$$h(t_0) = \lim_{\epsilon \to 0} \frac{F(t_0 + \epsilon) - F(t_0)}{\epsilon} \frac{1}{1 - F(t_0)} = \frac{f(t)}{S(t)} = -\frac{dlogS(t)}{dt}$$

From this it follows that $P(t_0 < t < t_0 + \epsilon \mid t \geq t_0)$ can be rewritten as

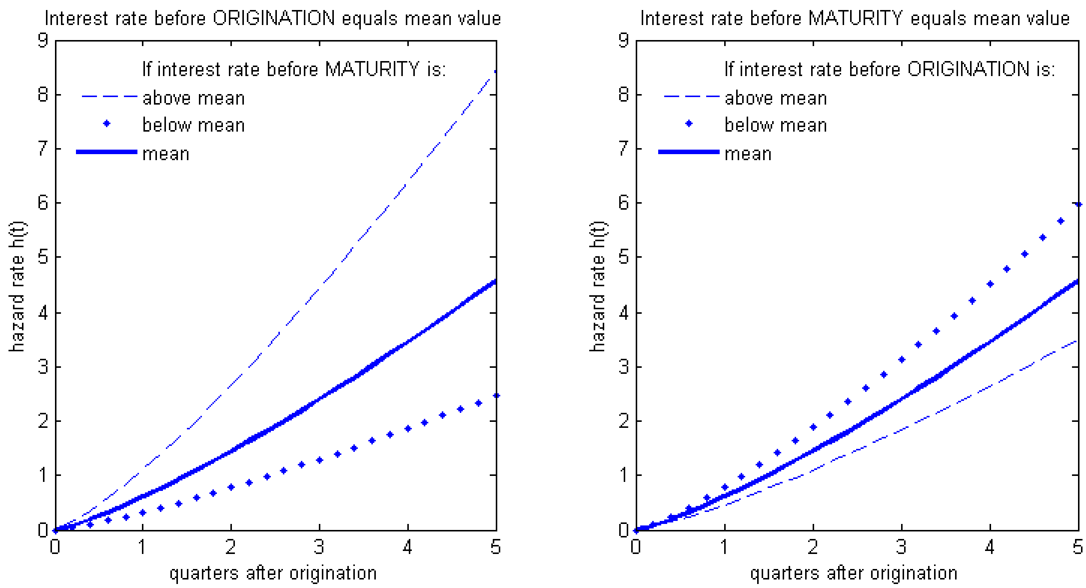
$$\int_{t_0}^{t_0+\epsilon} \frac{f(t)}{1 - F(t_0)} dt = \frac{F(t_0 + \epsilon) - F(t_0)}{1 - F(t_0)} \approx \frac{F(t_0) - F(t_0) + F'(t_0)\epsilon}{1 - F(t_0)} = \frac{t_0}{1 - F(t_0)}\epsilon = h(t_0)\epsilon$$

$f(t)$, constructs the likelihood function and solves the problem parametrically.[33] In particular, the baseline hazard function $h_0(t_0)$ can conveniently be assumed to be affected by covariates in the following convenient form:

$$h(t_0) = h_0(t_0) \cdot e^{X\beta}$$

A positive (negative) estimate of β_j implies that an increase in the covariate shifts the entire hazard function proportionally up (down).

Figure 8: Estimated hazards rate function in Spain, 1985 and 2006



Following the above-mentioned approach, Jimenez *et al* (2007) estimate the following hazard function for loans in Spain from 1985 to 2006: [34]

$$h(t) = 2.2614 \cdot t^{2.2614-1} e^{-0.127 \cdot i_{before} + 0.293 \cdot i_{after} - 2.0074} \quad (12)$$

i_{before} and i_{after} are the key variables of the regression and represent respectively the monetary policy interest rate on the quarter before the loan is originated and the monetary policy interest rate after origination and before the loan comes to maturity. The term -2.0074 includes the estimated effect of the covariates evaluated at the median value. The regression results suggest that, other things equal, a 1 percentage point increase in the interest rate before the loan was issued decreases the hazard rate by 0.127 percent along the entire life-time of the loan, while a 1

[33] Given $h(s)$, the corresponding cumulative distribution function is $F(s) = 1 - e^{-\int_0^t h(s)ds}$. Cox (1972) proposes a partial likelihood estimation approach that exploits the *ordering* in which the switch from a state to another, not the exact time. The result by Jimenez *et al.* (2007) is robust to this alternative estimation strategy.

[34] The computation of equation (12) from Jimenez *et al.* (2007) exploits the information that the hazard rate equals 0.6 for average interest rate before and after the origination, given that some estimates included in the regression are not reported in their paper.

percentage point increase in the interest rate after the loan was issued and before it comes to maturity increases the hazard rate by 0.293 percent along the entire life-time of the loan. The result is robust across alternative estimation strategies and is shown graphically in figure 8.[35] Both graphs represent the instantaneous rate of default for the median loan with 5 quarters maturity for each point in time between origination and maturity. The continuous lines show the case in which the interest rate before and after origination are equal to the mean value of 4.1 %. The left graphs shows the case of loans originated when the policy rate is at mean value and concluded when it is at its sample maximum (dashed line) or sample minimum (dotted line). Conversely, the right graph shows the case of loans for which the policy interest rate is equal to its mean value before maturity and that were originated when the policy rate was at its sample maximum (dashed line) or at its sample minimum (dotted line). We see from figure 8 that a decrease in the policy rate after the loan is originated decreases the probability of default, while a decrease in the policy rate before the loan is originated increases the probability of default.

Equation (12) includes the entire dataset and hence detects the hazard rate of the median loan. As emphasized in section 3.3, loans in the model differ from the median loan from the Spanish credit registry for being uncollateralized and for having one quarter maturity. To control for this difference, one needs to adjust the corresponding dummy variables, which delivers an average hazard rate at one quarter after origination of 0.7291 instead of 0.6, keeping everything else equal.

The main limitation of duration analysis to the study of defaults relates to how it treats non-defaulting loans that have come to maturity before the end of the sample period. Jimenez *et al.* (2007) treat them as right-censured data, which implies that they are dealt with as if they had not defaulted yet but could still default. One way to reconcile this is to consider that firms (although not loans) default with probability of one in the limit when time goes to infinity. Another way is to acknowledge that the cumulative density function in the likelihood function constructed at least captures the information that the loan has not default, which is in fact true. The counterpart of these limitations is that the duration approach to default avoid the use of imperfect market measures of default inferred from asset prices or on model-based measures from option prices. Which approach is preferable is subject to debate.

Appendix B: The benchmark case of symmetric information

In the model a default was defined as a state in which the lender incurs an observation cost to uncover the realization of the privately-observed idiosyncratic shock.

[35] All other estimations considered by the authors deliver a negative sign for the coefficient on i_{before} and a positive sign for the coefficient on i_{after}. The magnitude of the estimates for the first coefficient are between -0.0052 and 0.127 and for the second coefficient between 0.044 and 0.350, always remaining significantly different from zero at 1 % significance.

This appendix argues that, in accordance with the Modigliani-Miller theorem, the leverage effect discussed in the paper disappears if information is symmetric because under symmetric information between the borrower and the lender the borrower's leverage becomes irrelevant to the lender and agents sign contracts contingently on the realization of ω.

With symmetric information the contract solves

$$\max_{K,\{R^B(\omega)\}_{\omega=0}^{\infty}} \int_0^{\infty} \omega R^K K - R^B(\omega)(K-N)d\Phi(\omega)$$

$$\text{subject to} \int_0^{\infty} R^B(\omega)d\Phi(\omega) \geq R \tag{13}$$

$$\omega R^K K \geq R^B(\omega)(K-N),\ \forall\omega \tag{14}$$

where $\{R^B(\omega)\}_{\omega=0}^{\infty}$ is the state contingent repayment scheme and the other variables are the same as in section 3.2. Constraint (13) guarantees the indifference condition of the lender while constraint (14) ensures that the repayment scheme is feasible. Substitute constraint (13) in the objective function and rewrite the maximization problem as

$$\max_K\ (R^K - R)K + RN \tag{15}$$

$$\text{subject to } \omega R^K K \geq R^B(\omega)(K-N),\ \forall\omega$$

Being risk neutral, the entrepreneur is indifferent to the specific repayment scheme agreed in the contract as long as the borrowing rate does not exceed R in expectation. As for the optimal repayment scheme, there exist infinitely many sets of $\{R^B(\omega)\}_{\omega=0}^{\infty}$ that satisfy the feasibility constraint. Without loss of generality, one possible scheme is to repay the fixed proportion $\varphi < 1$ of ex post revenues, i.e. $R^B(\omega) = \varphi\omega R^K K$. This scheme is obviously feasible. Substituting it in the optimality condition and computing the optimal φ gives $R^B(\omega) = \omega R$.

We saw that under asymmetric information the lender requires a leverage premium as compensation for a higher entrepreneur's leverage ratio. Under symmetric information, instead, the optimal level of borrowing is infinite under the assumption of $R^K > R$ independently on the specific repayment scheme $\{R^B(\omega)\}_{\omega=0}^{\infty}$. This is because the borrower's leverage becomes irrelevant from the point of view of the lender as long as the repayment scheme gives R in expectation, in accordance with the Modigliani Miller theorem.[36] Under symmetric information the entire endowment of the economy (the entrepreneurs' net worth and the entire wealth of the lenders) is invested in the production function. This was not the case in the main model, where asymmetric information prevented the wealth of lenders from flowing to the entrepreneurs' production function above the optimal amount $K^* - N$.

[36] With decreasing returns to scale it is immediate to see that the repayment scheme remains independent on the entrepreneur's leverage and that the optimal level of borrowing is finite and increasing in the discounted return to capital.

Final notes

CHECK PAPER BY DE FIORE AND PEDRO TELES

CHECK ROLE OF PRICE STICKINESS IN INCREASE IN LABOUR

CHECK WHAT HAPPENS IF ABANDON RISK NEUTRALITY

CHECK WHY RK STILL ABOVE SS AFTER FIRST PERIOD DESPITE CAPITAL LOSS

COMPARE MOVEMENT IN SPREAD TO CURDIA WOODFORD

IF JUST DO PARTIAL EUQILIBRIUM PART DO CASE OF RISK AVERSION BUT CHECK WHY EXCLUDED BY TOWNSEND

EFFECT OF A HIGHER LEVEL COULD BE BECAUSE RN IS MOVING UP NOW. SHUT DOWN BY CONSIDERING PERMANENT SHOCK?

KOSTAS IDEAS, LINEARIZE OF SECOND ORDER 2 DIFFERENT EQUILIBRIAU THAT DIFFER FOR RK AND SEE THE EFFECT FRM VARIATION IN R

IN PARTIAL EQUILIBRIUM, UNIRE GRAFICO E TABELLA IN UNO

DISCUSS IF MU COST WAS FIXED, SE TOWNSEND