Corporate Finance and the Monetary Transmission Mechanism*

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Revised June 2003

Abstract

This paper analyzes the transmission mechanisms of monetary policy in a general equilibrium model of securities markets and banking, where banks funding have a specific role in restructuring defaulting firms. Banks' optimal asset/liability policy is such that in equilibrium capital adequacy constraints are always binding. Asymmetric information about banks' net worth adds a cost to outside equity capital, which limits the extent to which banks can relax their capital constraint. In this real economy context, shocks on real interest rates triggered by monetary policy do not affect bank lending through changes in bank liquidity. Rather, it has the effect of changing the spread of bank loans over corporate bonds, of modifying aggregate composition of financing by firms and of changing the incentives of banks to raise capital. The model also produces multiple equilibria, one of which displays all the features of a "credit crunch". Thus, monetary policy can also have large effects when it induces a shift from one equilibrium to the other.

J.E.L. No(s): G32, E50

*We thank Ben Bernanke, Tryphon Kollintzas, Marcus Miller and Xavier Vives and an anonymous referee for helpful comments. We have also received comments from seminar participants at the I.M.F., the Hebrew University of Jerusalem, Universitat Pompeu Fabra, H.E.C. Paris, the Stockholm School of Economics, the New York Fed and the CEPR workshop on Banking and Financial Markets. Support from DGICYT grant no. PB98-1057 is gratefully acknowledged.

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1 Introduction

This paper is concerned with the general question of the monetary transmission mechanism through the financial sector, in particular the banking sector and securities markets. Specifically, it analyzes the effects of changes in interest rates on bank lending and securities markets in a real economy. By building on recent advances in the microeconomics of banking it provides some underpinnings for the “credit view” of monetary policy, which, in its simplest form, relies on some exogenously given degree of substitution between bank lending and bond financing.

A key determinant of the effects of monetary policy on bank credit is the extent to which banks are capital constrained. In our model banks are capital constrained in equilibrium since equity capital is more costly than other sources of funding like deposits or bonds. Banks are economizing on their cost of funding by holding no more than the required amount of equity capital. In addition, banks limit the size of their equity issues in an effort to economize their cost of capital. The reason why equity capital has a higher cost than other sources of funding in our model is due to asymmetric information and information dilution costs as in Myers and Majluf (1984). That is, when a bank decides to raise additional equity through a seasoned offer, the market tends to undervalue the issue for the better banks. But since it is the better banks that drive the decision whether to raise equity, the overall effect on all banks’ equity issues (whether good or bad) is to reduce the amount of equity raised relative to the full information optimum. Thus, because of information asymmetries about the true value of bank assets, there is an endogenous cost of equity, and by extension an endogenous cost of bank lending. Hence, banks’ equity base (and internally generated funds) are a key variable in determining the total amount of bank credit.

An important consequence of this endogenous cost of equity is that multiple equilibria may exist. In one equilibrium the endogenous cost of capital (generated by self fulfilling market beliefs) is high while in the other it is low. The former has all the main features of a “credit crunch”, namely that: i) bank lending is limited by a lower endogenous stock of bank capital; ii) there is a correspondingly lower volume of bank credit, and; iii) equilibrium bank spreads are high[1]. In contrast, the other equilibrium has a high stock

[1] ‘Bank spreads’ here refer to the difference between the expected return on a bank loan and the yield on government bonds. These spreads are difficult to measure accurately, as banks do not systematically disclose the precise lending terms on the loans they extend.

of bank capital, a high volume of credit and lower equilibrium bank spreads.

Another way of thinking about this multiplicity of equilibria is in terms of hysteresis in market beliefs about underlying bank values. Starting from a low level of equilibrium bank capital, any equity issue is likely to be interpreted by the market as a bad signal about the issuing bank's value (resulting in a reduction in the market price of bank equity), thus inhibiting new equity issues. Vice-versa, in a situation where most banks are expanding their capital base, a failure to expand will be interpreted as a negative signal. This is the source of multiplicity of equilibria in our model.

This potential multiplicity raises the question for monetary policy transmission of a possible policy induced switch from one equilibrium to another. In our model there is a potential amplifying effect of monetary policy. For example, a tightening in monetary policy has the effect in our model of reducing equilibrium bank spreads and thus of reducing banks' incentives to raise capital. It is then possible that a tightening monetary policy may induce a switch to a "credit crunch" equilibrium, when the equilibrium bank spread hits a critical low level. Once the economy has settled in a credit crunch equilibrium, a major change in interest rates may be required to pull it out of this low lending equilibrium. The economy may be stuck in the inefficient equilibrium as long as market beliefs are unchanged.

An important effect of monetary policy that our analysis highlights is related to the financial composition of the corporate sector between securities issues and bank credit. Recent empirical work suggests that one effect of monetary policy is to change firms' financing decisions, corporations substituting bank lending for commercial paper issues. A common explanation for these changes is that when bank capital is tight, firms turn to the securities market to raise funds (see Kashyap and Stein (1994) and Gertler and Gilchrist (1994)).

We can analyze the effects of monetary policy on financial composition as our model allows for both a securities market and a banking sector. We also let firms determine endogenously their capital structure. The corporate financing side of the model here builds on the analysis in our related paper (Bolton and Freixas, 2000).

What distinguishes bank debt from corporate bond financing in our model is the flexibility of the two modes of financing: bank debt is easier to restructure but because bank capital and therefore bank loans are in short supply, there is an endogenous cost of flexibility. What makes bank loans expensive is the existence of a capital requirement regulation together with a dilution cost for outside equity. This is one important source of the positive equilibrium spread between bank loans and bonds.

Firms with higher variance in cash-flows are willing to pay this intermediation cost because they have a greater benefit of flexibility. This is where monetary policy affects the composition of financing: by affecting the equilibrium bank spread it induces the marginal firms to switch between intermediated and market financing. Bank debt is an imperfect substitute for bonds and therefore the effects of monetary policy on investment cannot be determined entirely by looking only at the effects on aggregate debt as the "money view" prescribes. One is, thus, inevitably led in the direction of a more complex view of the monetary transmission mechanism.Of course, the fact that our analysis is based on a real economy model, implies that we cannot simultaneously analyze the overall effect of monetary policy on prices. These effects are known (see, for instance, the surveys by Kashyap and Stein (1994) and Walsh(1998)). The contribution of our approach is to point out that in addition to the standard monetary policy channels, capital requirement regulation may have an effect on the credit risk spread that will change the equilibrium composition of funding between direct and intermediated finance as well as the incentives of banks to raise additional capital and increase their lending. These effects are essential for understanding the overall effects of monetary policy.

There are several recent papers dealing with the 'credit channel' of monetary policy that are related to ours. The four most closely related ones are Gorton and Winton (1999), Van den Heuvel (1999), Schneider (1998) and Estrella (2001). The first two papers focus on banks' capital adequacy constraints and the macroeconomic effects of changes in bank lending induced by changes in banks' equity base[2]. Bank capital is costly in Gorton and Winton because bank equity is risky and therefore requires both a risk and liquidity premium. Capital adequacy constraints impose a cost on banks whenever investors' optimal portfolio is less heavily weighted towards bank equity than is required by regulations. This is most likely to occur in recessions. Accordingly the amplification effects of monetary policy are greatest at the onset of a recession, when higher interest rates affect aggregate investment both directly and indirectly through a reduction in bank lending capacity.

[2] See also Thakor (1996), which assumes an exogenous cost of bank equity and explores the implications of raising banks' funding costs by requiring banks to hold more costly equity.

In Van den Heuvel the cost of bank equity is exogenous. Banks are not allowed to raise new equity, but they can increase their capital stock through retained earnings. The amplification effects of monetary policy then work through their effects on retained earnings. While Van den Heuvel's microeconomic model of banking is more rudimentary than that of Gorton and Winton his dynamic macroeconomic analysis goes considerably further, exploring lagged effects of changes in interest rates. In the same vein, Schneider provides an extensive dynamic macroeconomic analysis, which relies on a combination of liquidity and bank capital effects. Finally, Estrella provides a similar dynamic analysis focussing on the cyclical effect of Value at Risk regulation.

Neither of these models, however, allows for other sources of corporate financing besides bank lending and therefore cannot explore composition effects of monetary policy[3]. Nor do these models allow for multiple equilibria and the possibility of what we describe as a "credit crunch" equilibrium, where bank lending is constrained by investors' excessive pessimism about banks' underlying asset values.

Romer and Romer (1990) observe that if banks are able to obtain funds by tapping financial markets, then monetary policy would affect banks only through changes in interest rates. There would be no specific bank lending channel. In response to Romer and Romer (1990), Lucas and McDonald (1992) and Stein (1998) have argued that non-deposit liabilities are imperfect substitutes for deposit liabilities (which are subject to reserve requirements) when banks have private information about their net worth. They show that when certificates of deposit (CDs) are risky then banks are unable to perfectly substitute CDs for deposits, so that bank lending may be partially controlled by monetary authorities through changes in reserve requirements. Our model emphasizes instead the imperfect substitutability of equity capital with other sources of funds, and highlights that there is a bank lending channel operating through the bank equity-capital market even when banks have perfect access to the CD or bond market.

Finally, since our model allows for the coexistence of bank lending and securities markets it is also related to a third set of papers by Holmstrom and Tirole (1997), Repullo and Suarez (1998) and Bolton and Freixas (2000),

[3] From a conceptual point of view, a common weakness of models which allow for only bank lending without any other direct source of funding for firms is that banks in these models look essentially like non-financial firms, the only difference being that they are subject to capital adequacy requirements.

which all characterize equilibria where bank lending and direct financing through securities issues are both present. The latter three papers take intermediation costs to be exogenous and do not analyse the effects of monetary policy on aggregate investment.

The paper is organized as follows: section 2 is devoted to the description of the model while section 3 deals with banks lending and their asset/liability structure. Section 4 characterizes the general equilibrium when banks' equity is fixed and Section 5 endogenizes the supply of bank equity and shows how a "credit crunch" equilibrium may obtain. Section 6 considers comparative statics and the effects of monetary policy. Finally, Section 7 offers some concluding comments. The proofs of most results are given in an appendix.

2 The model

2.1 Firms' investment projects and financial options

Each firm has one project requiring an investment outlay $I > 1$ at date $t = 0$. The project yields a return of $V > I$ when it succeeds. When it fails the project can generate a value v, as long as the firm is restructured. If the firm is unable to restructure its debts following failure then the value of the project is zero.

Firms' owner-managers invest $W < I$ in the firm and must raise $I - W = 1$ from outside. Firms differ in the probabilities p of success, where we assume that p is uniformly distributed on the interval $[0, 1]$

Firms can choose to finance their project by either issuing bonds or by means of a bank loan. To keep the corporate financing side of the model to its bare essentials, we do not allow firms to issue equity or to combine bonds and bank debt [4]. The main distinguishing features of these two instruments are the following:

1. **bond financing**: a bond issue specifies a time $t = 1$ repayment to bond holders of $R(p)$. If the firm is unable to meet this repayments the firm is declared bankrupt and is liquidated. Restructuring of debt is not possible because of the wide dispersion of ownership of corporate bonds (see e.g. Bolton and Scharfstein (1996)).

[4] However, these options are examined in Bolton and Freixas (2000).

2. **bank debt**: a bank loan specifies a repayment $\widehat{R}(p)$. If the firm defaults following failure of the project, the bank is able to restructure the firm's debts and obtain a restructuring value v[5].

As we will show, in equilibrium, firms will be segmented by risk classes in their choice of funding, with all firms with $p \in (p^*, 1]$ choosing bond financing and all firms with $p \in [0, p^*]$ preferring a bank loan[6]. Bond financing dominates for low risk firms (with a high p) because these firms are less likely to fail at date $t = 1$ and therefore have less of a need for the debt restructuring services provided by banks. These services are costly because banks themselves need to raise funds to be able to lend to firms[7].

Having described the demand side for capital by firms we now turn to a description of the supply side.

2.2 Households

There is a continuum of households in our economy represented by the unit interval $[0, 1]$, with utility function

$$U(c_1, c_2) = \log(1 + c_1) + \log(1 + c_2)$$

Each household is endowed with one unit of consumption good at time $t = 1$. We shall only be concerned with households' savings decisions that are derived from their optimal consumption choice. This is given by maximizing the utility under the bugdet constraint

$$c_1 + \frac{c_2}{R_G} = 1$$

Savings are equal to $1 - c_1$, and it is straightforward to check that households' optimal savings decision is given by

$$s^* = 1 - c_1 = 1 - \frac{1}{2R_G}.$$

[5]We assume for convenience that the bank appropriates the entire restructuring value. In other words, the bank is an informational monopoly as in Rajan (1992), which is able to extract the entire continuation value. Of, course, banks' ability to extract this value will be anticipated by borrowers and priced into the ex-ante loan terms.

[6]We avoid the complexities of the riskier firms issuing junk bonds, even if this may arise for some constellation of parameters

[7]In Bolton and Freixas (2000) these fund raising costs were specified exogenously. In contrast, here these costs are partially endogenized.

The supply of deposits is denoted by $D(R_D)$ (with $0 \leq D(R_D) \leq 1-\frac{1}{2R_G}$), where R_D is the remuneration of deposits. We allow for perfect substitutability between deposit accounts and financial assets. For positive amounts of both deposits and bonds, this will lead to the no arbitrage condition

$$R_G = R_D$$

Therefore, we will use the T-bills rate R_G to refer to both the interest rate on T-bills and on deposits.

Non deposited savings will be invested in T-Bills and corporate bonds.

In this later case the return obtained by household is a random repayment $R(p)$ yielding the same expected return, as T-Bills.

$$pR(p) = R_G \tag{1}$$

We will assume that bond returns are independently distributed and that customers hold diversified portfolios. This simplifies the analysis by allowing us to model investments in bonds as providing a safe return.

2.3 Banks

Banks, as firms, are run by self-interested managers, who have invested their personal wealth w in the bank. They can operate on a small scale by leveraging only their own capital w with (insured) deposits D, so as to fund a total amount of loans $w + D$. Their lending capacity will then be constrained by capital adequacy requirements[8]:

$$\frac{w}{w+D} \geq \kappa > 0.$$

Alternatively, banks can scale up their operations by raising outside equity-capital E to be added to their own investment w. In that case their lending capacity expands from $\frac{w}{\kappa}$ to $\frac{w+E}{\kappa}$. However, when they raise outside equity they may face informational dilution costs. Outside equity investors, having less information about the profitability of bank loans will tend to misprice banks' equity issues. In particular, they will underprice equity issues of the

[8] The BIS capital adequacy rules in our highly simplified model are that $\kappa = 0.08$ for standard unsecured loans.

most profitable banks. We assume that banks choose an amount of equity to issue within the interval $\left[0, \overline{E}\right]$, where $\overline{E} < \infty$[9].

Banks face unit operating costs $c > 0$. These costs are best interpreted as costs banks must incur to attract depositors and potential borrowers. As such, these costs are paid even if, in the end, the bank prefers not to lend.

To model banks' dilution costs of equity-capital we take as a basic premise that bank managers differ in their ability to profitably run their bank. Specifically, we assume that bank managers may be either 'good' or 'bad'. Good bank managers (or type H-banks in our notation) are able to squeeze out a return v from restructuring a defaulting firm, while bad bank managers (or L-banks) can only obtain a return βv, $(1 > \beta > 0)$. There are obviously other perhaps more plausible ways of modeling the difference between good and bad banks, but the appeal of our formulation is its simplicity.

Banks' outside investors do not know the bank's type; all they know is that there is a mass M of H-banks and m of L-banks. So, their prior belief about a bank's type is that they face an L-bank with probability $\mu = m/(M+m)$ and an H-bank with probability $1 - \mu = M/(M+m)$. We normalize the mass of respectively $H-$ and $L-$banks so that $M + m = 1$. This informational asymmetry about bank type gives rise to mispricing of each bank type's equity. It is the main source of costs of bank capital in our model.

A bank manager seeks to maximize its wealth. This implies that the bank managers care both about bank profits (i.e. wealth at date $t = 2$) and about the bank's share price. The reason why a bank manager cares about share price is that he may need to sell his stake in the bank before the returns of the bank's loans are fully realized and known.

We model these objectives by assuming that bank managers may need to liquidate their stake in the bank at date $t = 1$ with probability $\lambda \in (0, 1)$. Denoting by q the share price of the bank and by Π_2 the bank's accumulated wealth/profit up to period $t = 2$, the bank manager's objective is then to

[9] We justify the existence of an upper bound on E by the following potential incentive problem between bank mangers and bank shareholders: if the bank raises an amount superior to $\overline{E}$ then bank managers may have an incentive to abscond with the money or use it to increase their private benefits. Indeed, the larger is E the greater the private benefits relative to the cost in terms of loss of reputation.

maximize[10]

$$\max\left[q, \lambda q + (1-\lambda)\Pi_2\right].$$

If the manager is running an $L-$bank and he knows that $\Pi_2 < q$ (based on his private information) then he will always sell his stake at date $t = 1$ and he will only care about the bank's share price. If, on the other hand, he is running an $H-$bank such that $\Pi_2 > q$ then he will seek to maximize $\lambda q + (1-\lambda)\Pi_2$.

Having determined the banks' objectives, their investment opportunities and their sources of funds, we now can turn to an analysis of their optimal lending policy and asset/liability structure given fixed market terms.

Before doing so we briefly summarize the sequence of moves and events, and also recall the underlying information structure.

2.4 Timing

The following time line illustrates the order of decisions

1. At date $t = 0$

   - Banks quote their lending terms $\widehat{R}(p)$ to firms and choose the amount of new equity they want to issue, E.
   - The government sets the interest rate R_G and firms issuing bonds quote their terms $R(p)$.
   - Firms who prefer bank lending apply for a loan, those preferring bond financing tap financial markets.
   - Banks make their portfolio decision. In particular, they decide what proportion of their funds to invest in new loans and what proportion in government or corporate bonds. These decisions are unobservable to investors.
   - Households determine the fraction of their endowment they want to save, and the proportion of their savings they want to hold as deposits and in direct investments.

[10] Note that this objective function is similar to that considered by Myers and Majluf (1984). However, it is not vulnerable to the criticisms voiced against their specification (see e.g. Dybvig and Zender (1989)). Note also that bank managers' private benefits are not explicitly modeled. The reason is that banks never fail in our model so that the issue of bank managers' objectives regarding liquidation or continuation of the bank never arises explicitly.

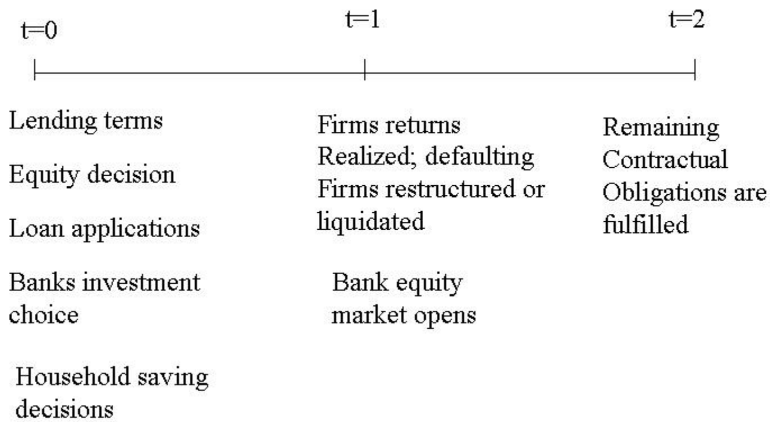

Figure 1:

2. At date $t = 1$ firms' returns are realized. Those firms whose project has failed may be restructured if they have been financed with a bank loan.

   Bank managers have the option to sell their equity stake in the secondary market.

3. At the end of date $t = 1$ all remaining debts as well as dividends are paid and households consume their net income.

3 Bank Lending and Optimal Asset-Liability Structure

We consider optimal lending and asset-liability management from the perspective of H-banks, who know that their observable actions are mimicked by L-banks (in a pooling equilibrium). The reason why L-banks always mimic H-banks is that in equilibrium L-banks are negative NPV institutions, which would not get any outside equity funding once they are identified. Below, we give sufficient conditions guaranteeing that L-banks are not profitable.

The reason why we restrict attention to pooling equilibria where L-banks always mimick H-banks is to keep the analysis as tractable as possible. Also, dilution costs incurred by H-banks in a pooling equilibrium are easier to relate to the empirical evidence that bank equity prices fall on average following the announcement of a new equity issue[11]. An H-bank contemplating an equity issue faces the following trade-off. If it issues equity it can increase lending and thus raise profits, but since its equity is undervalued in the financial market the bank's manager does not appropriate the entire increase in profits. Depending on the profitability of loans and the extent of the undervaluation of equity the H-bank may or may not decide to relax it's lending constraint by issuing more equity. Thus, to determine an H-bank's choice we need to specify the profitability of loans and the extent of dilution.

3.1 Optimal Lending Policy

In a pooling equilibrium H-banks quote lending terms $\widehat{R}(p)$ to equalize the expected profit on every loan they make. We denote by ρ_H the expected net excess return per loan for H-banks over government bonds. The reason why the spread on each loan for an H-bank must be the same at an optimum is that otherwise an H-bank could increase its profit by lending only to the firms with the highest spread. The spread ρ_H corresponds to the rents banks earn because of the specific role their funding plays in restructuring and because of the limited amount of capital they may have:

$$\rho_H = p\widehat{R}(p) + (1-p)v - R_G \qquad (2)$$

[11] The reader may wonder whether our analysis depends in a fundamental way on our restriction to pooling equilibria. We believe this is not the case. The monetary transmission mechanism in separating equilibria of our model would operate in the same way. But separating equilibria would be more involved. To see this, observe that in a separating equilibrium H-banks would limit the size of their equity issues to separate themselves from L-banks, who would be willing to issue any amount of outside equity and would generate a net equilibrium expected return of zero. The firms with the highest probability of success would still get funds through bond issues to avoid paying an intermediation cost. As the discussion in section 6 indicates, the basic comparative statics obtained in a pooling equilibrium would carry through to separating equilibria, but would be slightly more involved to characterize.

We will make the following assumption on the expected spread banks obtain in equilibrium

$$\text{A1: } \rho_H + R_G \geq v \geq \rho_H$$

The first part of A1 is required since otherwise bank loans would be riskless. The second part always holds in equilibrium since otherwise bonds would always be preferred to bank loans. This would lead to a contradiction, since then the equilibrium spread would be $\rho_H = 0$, as the demand for bank loans is equal to zero.

Note that given these lending terms, H-banks get a higher return per loan than L-banks. Indeed, the expected return on a loan with success probablility p for an L-bank is only

$$p\widehat{R}(p) + (1-p)\beta v - R_G. \tag{3}$$

Given the expected net excess return per loan over government bonds ρ_H and given rates on government bonds of R_G, an H-bank chooses its optimal mix of loans L, government bond holdings G_b, and deposits rates R_D, to maximize expected profits subject to capital adequacy constraints:

$$\begin{cases} \max\limits_{(L,G_b,B_b,R_D)} \{L(R_G + \rho_H - c) + (G_b - D(R_G))R_G\} \\ \\ \text{subject to:} \\ \\ L + G_b = D(R_G) + w + E \qquad (AL) \\ \\ L \leq \frac{1}{\kappa}(w + E) \qquad\qquad\quad (\kappa) \end{cases}$$

where $D(R_G)$ satisfies $0 \leq D(R_G) \leq 1 - \frac{1}{2R_G}$.

Note first that since by assumption the expected rates on deposits and government bond holdings are the same, we are only able to determine the net amount of bonds minus deposits (positive or negative) the bank holds, $G_b - D(R_G)$.

Second, it is easy to see from this program that the capital adequacy constraint is always binding if $\rho_H > c$. Indeed, if the excess return on bank lending is strictly positive, an H-bank can always make a profit by raising an extra dollar by selling bonds and investing it in a bank loan. If, on the other hand, $\rho_H < 0$, then it is best for the bank not to lend at all to firms and to invest only in the market.

We summarize these observations in the lemma below.

Lemma 1: The optimal amount of lending *for an H-bank* is $L = \frac{(w+E)}{\kappa}$ if $\rho_H > c$ and $L = 0$ if $\rho_H < c$.

This lemma highlights that banks' optimal lending policy and asset/liability structure is such that their equity capital base is always a binding constraint on their lending capacity. In other words, when bank spreads are positive banks can only increase lending by increasing their capital base. Thus, it becomes essential to consider how banks' capital base is determined.

An important implication of this lemma is that monetary policy cannot affect bank lending by changing bank reserves (while keeping interest rates fixed). In other words, the classical bank lending channel of monetary policy is absent. As has already been noted by Romer and Romer (1990), when banks can perfectly substitute non reservable liabilities for reservable ones, as in our model, monetary authorities can no longer control bank lending by controlling bank reserves. Bond issues may, of course, be imperfect substitutes for insured deposits if there was a risk of default as Stein (1998) has noted. However, this imperfect substitutability of risky bonds for safe deposits is only a necessary condition for bank liquidity to affect bank lending. It is not sufficient if capital adequacy constraints remain binding. Indeed, in our model, reserve requirements combined with an imperfect substitutability between bonds and insured deposits might simply raise the bank's overall cost of funds. But as long as spreads remain sufficiently high, banks would continue to raise funds up to the point where the capital constraint binds. Thus, when the central bank changes reserve requirements on deposits, the only imediate effect on banks is on profitability. It cannot affect bank lending if the capital constraint remains binding. Of course, profitability eventually or indirectly affects the availability of capital, so that there may be an indirect or lagged effect as in Van den Heuvel (1999). These points are made more formally in section 6 dealing with comparative statics.

Our result that bank equity capital is always a binding constraint on bank lending appears to be counterfactual as banks generally have a higher capital base than is required by BIS regulations. However, we show in the appendix that the fact equity capital is higher than is strictly required at any point in time does not necessary mean that banks' capital constraint is not binding.

The point is that if banks anticipate that their role of providers of flexible financing involves extending future lending to firms (as part of their loan commitments) then they will hold capital reserves in anticipation of those future loan increases. This is why they may appear to be unconstrained while in fact their equity base may actually constrain current lending. Introducing this idea formally into our model would have significantly increased the complexity of the model. This is why we have chosen not to introduce it. Instead, we briefly describe the main changes to be made to the model to obtain a time 0 non-binding capital constraint in the appendix.

4 General Equilibrium in the credit market

In this section we take banks' equity-capital as given and provide sufficient conditions for the existence of equilibrium rates R_G and $\widehat{R}(p)$ (or equivalently $R(p) = \frac{R_G}{p}$ and ρ_H) such that:

1. the aggregate demand for bank credit is equal to aggregate supply,
2. the aggregate demand for bank equity, corporate and government bonds is equal to the supply of funds to the securities markets,
3. bank demand for deposits equals deposit supply.

For a given level of equity issues E, the equilibrium analysis boils down to solving a system of four equations. We begin with the characterization of this solution and then proceed with the analysis of bank equilibrium equity issues E.

We do not consider the case where $\rho_H < 0$, since banks have always the option to invest in T-Bills which provide a zero spread.

4.1 Equilibrium in the bank credit market

Since firms do not appropriate any returns from restructuring, their demand for funds will be simply driven by the cost of borrowing. A firm of risk characteristics p will demand a bank loan if and only if

$$\widehat{R}(p) - R(p) \leq 0$$

Using equations (1) and (2), this is equivalent to:

$$\frac{\rho_H - (1-p)v}{p} \leq 0$$

Therefore, any firm with a probability of success lower than the threshold

$$p^* = \frac{v - \rho_H}{v}$$

prefers a bank loan to a bond issue, and any firm with a probability of success larger than p^* prefers to issue bonds.

This is quite intuitive. Banks obtain a rent from restructuring firms. Their comparative advantage is therefore higher when they face a riskier firm, which is more likely to go through a restructuring[12].

While all firms with $p < p^*$ apply for a bank loan not all of these will be granted one. Indeed, some of these firms may be too risky and have too low a rating p to be worth investing in. The threshold p^B below which firms do not obtain credit is given by

$$p^B V + (1-p^B)v = R_G + \rho_H. \tag{4}$$

Under our assumption that p is uniformly distributed on the unit interval the mass of firms (with $p \leq p^B$) which cannot get any funding at the cost of funds $(R_G + \rho_H)$ is also given by [13]:

$$p^B(R_G + \rho_H) = \frac{R_G + \rho_H - v}{V - v} \tag{5}$$

Thus, firms with $p \in [p^B, p^*]$ compose the total demand for bank loans.

Note that there is also a minimum p for which bond financing is available, that is given by $\frac{R_G}{V}$. In what follows we will restrict attention to parameter values such that $\frac{R_G}{V} < p^*$. This inequality holds if we slightly strengthen assumption A1 to:

$$\text{A3: } \rho_H + R_G > v > v\left(\frac{V - R_G}{V}\right) > \rho_H$$

[12] This does not mean, however, that riskier firms pay a lower interest rate $\widehat{R}(p)$. In fact, it is easy to show that assumption A1 implies that firms with higher risks will pay higher interest rates. The reason is simply that firms with higher risks also generate lower expected returns.

[13] Note that assumption A1 implies that $p_1^B > 0$ for $\rho_H > 0$.

It is easy to see that in equilibrium we must have $p^*(R_{G,}\rho_H) > p^B$. Indeed, the opposite inequality, $p^*(R_{G,}\rho_H) \leq p^B$, implies that $\rho_H = 0$ since there is no demand for bank loans. This, in turn, implies that $p^* = 1 > p^B = \frac{R_G - v}{V - v}$, a contradiction (whenever $R_G < V$).

Given that risk-types p are uniformly distributed between 0 and 1, the aggregate effective demand for bank loans is given by:

$$p^*(R_{G,}\rho_H) - p^B(R_{G,}\rho_H) = \frac{v - \rho_H}{v} - \frac{R_G + \rho_H - v}{V - v}$$

Equilibrium in the bank credit market requires that the aggregate supply of bank credit $L(R_G, \rho_H)$ equals aggregate effective demand.

When $\rho_H > 0$ all H-banks supply as much credit as they can given their equity-capital stock. The same is true for L-banks as long as they earn a positive spread on their loans. That is, as long as

$$p\widehat{R}(p) + (1 - p)\beta v \geq R_G,$$

or

$$\rho_H - (1 - p)(1 - \beta)v \geq 0$$

over the loans they make. Notice that, in contrast to H-banks, the expected net excess return per loan over government bonds for L-banks is higher the lower the risk of the loan. Therefore L-banks will concentrate in the safer segment of the bank-loan market and will cover a risk-segment $[p^L, p^*]$, where $p^L > p^B$.

We shall characterize an equilibrium (and identify conditions under which it obtains) such that

$$\rho_H - (1 - p^L)(1 - \beta)v \geq 0, \tag{6}$$

in which case L-banks along with H-banks lend all the funds they can subject to meeting capital adequacy requirements. When L-banks lend all they can the cut-off p^L is given by the following equation

$$p^* - p^L = \mu\frac{w + E}{\kappa} \tag{7}$$

Therefore, replacing p^* by its value in (7)and replacing the necessary condition for an equilibrium with maximum bank-lending in (6) we obtain the necessary condition

$$\rho_H \geq \frac{v(1 - \beta)}{\beta}\mu\frac{w + E}{\kappa}. \tag{8}$$

When condition (8) holds the aggregate supply of bank-credit is given by $L = \frac{w+E}{\kappa}$ and the bank credit equilibrium equation becomes:

$$\frac{w+E}{\kappa} = \frac{v-\rho_H}{v} - \frac{R_G+\rho_H-v}{V-v} \tag{9}$$

Put more conveniently equation (10) below defines for each level of equity E a linear bank credit equilibrium schedule relating ρ_H to R_G, which we can rewrite as:

$$\rho_H \frac{V}{v} = \left(1 - \frac{w+E}{\kappa}\right)(V-v) + v - R_G \tag{10}$$

This equation allows us to write ρ_H as a linear decreasing function $\rho_H^C(R_G)$ of R_G.

When condition (8) does not hold (for example when R_G is large) then L-banks will not lend up to capacity and will invest part of their funds in government bonds. Interestingly, L-banks are likely to invest a larger fraction in government bonds the lower is the equilibrium spread ρ_H.

4.2 Securities market equilibrium

The demand for funds on this market is the sum of the demand by the highest rated risk-types $(1-p(R_G,\rho_H))$ who issue corporate bonds, the demand by the Treasury G, and the demand by banks that issue equity E. The supply of funds is given by household savings $1-\frac{1}{2R_G}-D(R_G)$ on the one hand, and investments by the banking sector in Government bonds G_b on the other.

The securities market equilibrium condition therefore is:

$$1-\frac{1}{2R_G}-D(R_G) = 1-p^*(R_G,\rho_H)+E+G-G_b \tag{11}$$

Replacing $p^*(R_G,\rho_H)$ by its value, using (AL) to replace $D-G_b=(w+E)(\frac{1}{\kappa}-1)$, and rearranging we obtain:

$$\frac{v-\rho_H}{v} = \frac{1}{2R_G}+\frac{E}{\kappa}+w(\frac{1}{\kappa}-1)+G \tag{12}$$

This equation allows us to write ρ_H as an increasing concave function of R_G, which we denote by $\rho_H^S(R_G)$.

Notice that the equation (11) may not hold for the relevant values of the parameters if G is too large. It is to be expected that, if the treasury absorbes all the resources in the economy the standard equilibrium conditions no longer hold. We therefore need to set some restriction on the size of G. This we do by replacing $D(R_G)$ in (11) to obtain the condition

$$1-(\frac{E}{\kappa}+w(\frac{1}{\kappa}-1)+G)>0 \tag{13}$$

4.3 Existence and Uniqueness

We now establish the existence of a unique full bank-lending equilibrium in the capital market for any sufficiently low fixed level of bank equity-capital $(w+E)$.

Proposition 1: A unique full bank-lending equilibrium exists for $(w+E)$ is sufficiently low that condition (8) holds.

Proof. One can immediately see why a unique equilibrium must exist by looking at Figure 2. This figure highlights that the credit market equilibrium schedule $\rho_H = \rho_H^C(R_G)$ is linearly downward sloping in R_G and the securities market equilibrium schedule $\rho_H = \rho_H^S(R_G)$ is an increasing function of R_G.

Defining $\Upsilon(R_G) = \rho_H^S(R_G) - \rho_H^C(R_G)$, it is clear that Υ is continous, takes negative values for R_G close to zero and positive values for R_G large enough, as long as condition (13) holds.

This ensures the existence of a solution to $\Upsilon(R_G) = 0$. Since, in addition, Υ is strictly increasing, this establishes the uniqueness of the solution.

5 Endogenous bank equity

Having established the existence of equilibrium rates, R_G and $\widehat{R}(p)$ that clear all financial markets under full bank-lending for a given stock of bank equity-capital we now turn to the endogenous determination of banks' equity-capital.

It has often been suggested informally (by Bernanke and Gertler (1990) among others) that banks may face higher costs of equity capital due to equity market concerns about information dilution. A number of empirical studies of bank equity offerings have also pointed to such costs. Surprisingly, however, there are no models of bank lending that explicitly consider bank equity issues under asymmetric information, whether for single banks or in a bank market equilibrium. Stein (1998) comes the closest to such a model when

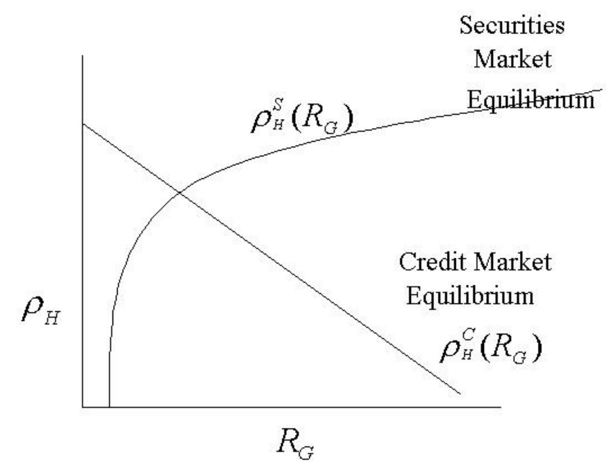

Figure 2:

he considers a single bank's decision to issue risky bonds under asymmetric information.

Stein (1998) focuses on separating equilibria, while our focus here is on pooling equilibria. In addition, we considerably extend Stein's analysis by considering banks' decisions to issue equity in a full competitive financial market equilibrium setting. If banks must pay a premium for equity capital, they will expand their equity base only if the rate of return on bank-loans exceeds the cost of equity-capital. This is why equilibrium bank-spreads $[p\widehat{R}(p)+(1-p)v-R_G]$ will be strictly greater than banks' average operating costs, c. Also, given that bank-spreads are strictly positive in equilibrium, banks have an incentive to lend up to the point where the capital constraint binds[14]. As is well known, signalling games generally have multiple equilibria. We argue in this section that this observation may have important implications for equilibrium bank lending. Indeed, we show that for some parameter constellations, a high-lending equilibrium, with low rationally ex-

[14] As we explain in appendix B, dynamic consideration may induce banks to keep a small equity-capital 'cushion', for inventory-management reasons. This is why they will generally hold equity-capital slightly in excess of 8 percent.

pected dilution costs and low equilibrium bank-spreads, may exist along with a low-lending "credit-crunch equilibrium", with high spreads and high rationally expected dilution costs.

Ultimately the relevant equilibrium is tied down by market beliefs and, as Spence (1974) has compellingly argued, a complete theory of how market beliefs are formed involves historical, psychological and cultural considerations, which go beyond the scope of our analysis. We can, however, narrow down somewhat the equilibrium set by appealing to intuitive refinement ideas along the lines of Cho and Kreps (1987). Nevertheless, as we show in this section a fundamental multiplicity will remain. We believe that this is a strength and not a weakness of the theory, as it provides the underpinnings for the notion of a "credit crunch" equilibrium.

We begin the section by considering a single banks' incentive to issue new equity, given equilibrium rates of return on lending. We then derive the aggregate supply of bank credit with endogenous bank equity capital. We show that there is a high critical cut-off point ρ_H^1 at which a representative bank decides to switch from an equity base w with no outside equity to one with outside equity $\overline{E}$. In other words, if the bank spread is high enough and bank loans are sufficiently lucrative then H-banks are prepared to pay a dilution cost in issuing equity in order to expand a profitable bank lending business. Similarly, we show that there is a low critical cut-off point $\rho_H^2 < \rho_H^1$ at which a representative bank with equity base $w + \overline{E}$ decides to repurchase its outside equity $\overline{E}$ in order to reduce dilution.

Because of the difference in the two cut-offs it is possible to obtain multiple pooling equilibria. One with a high spread, low bank equity capital and low aggregate bank lending and the other with a low spread, high bank equity capital and high aggregate bank lending. We refer to the former equilibrium as a credit-crunch or "equity-capital crunch" equilibrium.

5.1 Optimal equity issues

Recall that optimal lending and equity issues are viewed from the perspective of H-banks, who know that their observable actions are mimicked by L-banks. As we have explained, the reason why L-banks always mimic H-banks is that in equilibrium L-banks are loss-making institutions that would not be able to attract any investors once they are identified.

To simplify our notation, we shall denote by Γ_J the return on equity-capital of a type J bank (where $J = H, L$). Both types of bank must incur a cost per asset unit of $c > 0$. And, H-banks earn a unit spread of ρ_H over R_G on each loan they make, while L-banks earn only $p\widehat{R}(p) + (1-p)\beta v - R_G$. Thus, H-banks have a return on equity capital of

$$\Gamma_H = R_G + \frac{\rho_H - c}{\kappa}$$

and L-banks of

$$\Gamma_L(p) = R_G + \frac{\rho_H - (1-p)(1-\beta)v - c}{\kappa}.$$

so that

$$\Gamma_L = R_G + \frac{\rho_H - \frac{1}{p^* - p_L}\int_{p_L}^{p^*}(1-p)(1-\beta)v - c}{\kappa} = R_G + \frac{\rho_H - (1 - \frac{p^* + p_L}{2})(1-\beta)v - c}{\kappa}$$

In what follows we take c, a free parameter, to be such that $\Gamma_L \leq 0 < \Gamma_H$, or, equivalently $\rho_L < c < \rho_H$, This restriction allow us to focus on the pooling equilibria. If, instead we consider the case $\rho_L > c$, $L-$banks may have an incentive to issue equity even when H-banks are not issuing.

When a bank raises an amount of equity E in a perfect capital market, new shareholders end up owning a fraction of the bank's capital α equal to:

$$\alpha \Gamma_E (w + E) = E \cdot R_G \tag{14}$$

where Γ_E denotes the market's expected return on capital for a bank raising new equity E. If we denote by $\delta_H(\widehat{R}(p), E)$ and $\delta_L(\widehat{R}(p), E)$ the beliefs of new shareholders about the bank's type conditional on a new equity issue E and lending terms $\widehat{R}(p)$, then

$$\Gamma_E = \delta_H(\widehat{R}(p), E)\Gamma_H + \delta_L(\widehat{R}(p), E)\Gamma_L.$$

Therefore, substituting for Γ_H and Γ_L we obtain:

$$\Gamma_E = R_G + \frac{\delta_H \rho_H - c}{\kappa}$$

(where our notation ommits the dependence of δ_H and δ_L on $(\widehat{R}(p), E)$).

An H-bank manager's expected payoff from issuing E is therefore:

$$(1-\alpha)\left[\lambda \Gamma_E + (1-\lambda)\Gamma_H\right](w + E).$$

(recall that bank managers face liquidity shocks which force them to unwind their equity holdings with probability λ before loan returns are realized and the bank's type is revealed).

Substituting for the value of α in (14) and rearranging, the manager's payoff can be rewritten as:

$$V_H(E) = \frac{\Gamma_E(w+E) - ER_G}{\Gamma_E}\left[\lambda\Gamma_E + (1-\lambda)\Gamma_H\right] \tag{15}$$

Thus, given a market expected value Γ_E, an H-bank manager is better off issuing equity $E > 0$ than issuing no additional equity if and only if,

$$\frac{\Gamma_E(w+E) - ER_G}{\Gamma_E}\left[\lambda\Gamma_E + (1-\lambda)\Gamma_H\right] \geq \left[\lambda\Gamma_0 + (1-\lambda)\Gamma_H\right] w \tag{16}$$

where Γ_0 is the market value of the firm if it does not issue equity.

Under the same market expectations, an L-bank manager decides to issue equity $E > 0$ if and only if,

$$\Gamma_E(w+E) - ER_G \geq \Gamma_0 w \tag{17}$$

Conditions (16) and (17) differ because a manager of an L-bank is better off selling his equity stake at date $t = 1$ than holding on to it, irrespectively of whether he has a liquidity need, since the market always (weakly) overvalues the shares of an L-bank.

5.2 Aggregate credit supply

We are now in a position to derive the equilibrium supply of bank loans, by characterizing the Bayesian-Nash equilibrium of the equity-capital issue game banks play given lending terms $\widehat{R}(p)$ (or ρ_H).

Definition: A Bayesian-Nash Equilibrium in the banking sector is characterized by:

- Banks' best equity issue strategies, $\widehat{E}^i \in [0, \overline{E}]$, $i = H, L$ given equity-market beliefs, $\delta_H(R(p), E)$ and $\delta_L(R(p), E)$, and
- equity-market conditional beliefs about the bank's type that are consistent with the banks' best responses. That is, the equity-market's conditional beliefs must be consistent with Bayesian updating.

What are banks' equilibrium equity-capital choices given $\widehat{R}(p)$? Under our assumption that $\Gamma_L \leq 0$, an L-type bank would be a loss-making bank. Therefore, there cannot be any separating equilibria where equity investors are able to perfectly identify the bank's type from its equity-capital choices. Equilibria with these lending terms must be either pooling equilibria, with both types of banks making the same equity issue decisions, $E^H = E^L = \widehat{E}$, or semi-separating equilibria, where H-type banks partially separate by randomizing between two levels of equity issues.

Pooling equilibria can be supported by out-of-equilibrium beliefs such that $\delta_L(\widehat{R}(p), E) = 1$ for all $E \neq \widehat{E}$. As one might expect, since out-of-equilibrium beliefs are arbitrary, a continuum of pooling equilibria, characterized by the size of the equilibrium equity issue $\widehat{E} \leq \overline{E}$ may exist. We select the pooling equilibrium that is best from the point of view of an H-Bank, partly on the grounds that Cho and Kreps' intuitive criterion would select this equilibrium over all other pooling equilibria in our game (see Cho and Kreps, 1987)[15].

The optimal equity issue for a type H-bank in a pooling equilibrium with lending terms $\widehat{R}(p)$ is generically either 0 or $\overline{E}$, as is established in the following lemma.

Lemma 2: Given lending terms $\widehat{R}(p)$ such that $p\widehat{R}(p) + (1-p)v - R_G = \rho_H$ and $p\widehat{R}(p) + (1-p)\beta v - R_G < c$ for all p, the optimal equity issue for an H-bank under pooling is either $\overline{E}$, if $\delta_H \rho_H > c$ or, 0 if $\delta_H \rho_H < c$, or undetermined if $\delta_H \rho_H = c$.

Proof. The sign of the derivative with respect to E of (15) is equal to the sign of

$$\Gamma_E - R_G = \frac{\delta_H \rho_H - c}{\kappa}.$$

■

In light of lemma 2, we are able to derive a relatively simple aggregate bank credit supply schedule. We establish the existence of two tresholds for equilibrium bank spreads ρ_H that characterize a bank's equity-capital issue or buy-back strategy. One cut-off above which an H-bank always wants to issue more equity-capital. And, another strictly lower cut-off below which an H-bank always prefers not to issue any equity-capital. Since these two

[15] Note that our qualitative results and comparative statics analysis do not depend on this refinement in any way. What is important for our analysis is essentially that pooling equilibria do indeed exist and that bank lending may vary with equity-market beliefs.

cut-offs are distinct we may obtain multiple equilibria. That is, for the same underlying parameter values of the model we may have one equilibrium with high bank lending, high equity-capital issues and low spreads, supported by "optimistic" out-of-equilibrium beliefs, next to a low bank lending, low equity-capital, and high spreads equilibrium, supported by "pessimistic" out-of-equilibrium beliefs.

Denote by ρ_H^1 the cut-off at which an $H-$bank prefers choosing $E = \overline{E}$ to $E = 0$, even if by deviating it is perceived to be an $L-$bank. This ρ_H^1 solves the following equation

$$\frac{\Gamma_L(w + \overline{E}) - \overline{E} \cdot R_G}{\Gamma_L} \left[\lambda \Gamma_L + (1 - \lambda)\Gamma_H\right] = \left[\lambda \Gamma_0 + (1 - \lambda)\Gamma_H\right] w$$

where,

$$\Gamma_0 = R_G - \frac{c}{\kappa} + (1 - \mu) \frac{\rho_H^1}{\kappa}$$

- For ρ_H above the cut-off ρ_H^1 choosing $E = \overline{E}$ is the best response for an H-bank for any out-of-equilibrium beliefs.

- Conversely, for ρ_H below the cut-off ρ_H^2 choosing $E = 0$ is the best response for an H-bank for any out-of-equilibrium beliefs. The cut-off ρ_H^2 solves the equation

$$\frac{\Gamma_{\overline{E}}(w + E) - E \cdot R_G}{\Gamma_{\overline{E}}} \left[\lambda \Gamma_{\overline{E}} + (1 - \lambda)\Gamma_H\right] = \left[\lambda \Gamma_L + (1 - \lambda)\Gamma_H\right] w$$

  where,

$$\Gamma_{\overline{E}} = R_G - \frac{c}{\kappa} + (1 - \mu) \frac{\rho_H^2}{\kappa}$$

- The total supply of funds from the banking sector in a full bank-lending equilibrium for $\rho_H \geq \rho_H^1$ is then $\frac{w+\overline{E}}{\kappa}$. Similarly, below the cut-off ρ_H^2 an equity issue $E = 0$ is the best response for H-banks. Then the total supply of bank credit is $\frac{w}{\kappa}$.

The next proposition establishes that the cut-offs are such that $\rho_H^2 < \rho_H^1$, so that multiple equilibria may exist on the interval $[\rho_H^2, \rho_H^1]$. There may then be two pooling equilibria, one with $\widehat{E} = 0$ and the other with $\widehat{E} = \overline{E}$. A semi-separating equilibrium may also exist in which H-banks are indifferent between setting $E = \overline{E}$ or $E = 0$ and only a fraction chooses $E = \overline{E}$, while all L-banks choose $E = \overline{E}$. In this semi-separating equilibrium total bank-credit supply lies between $\frac{w}{\kappa}$ and $\frac{w+\overline{E}}{\kappa}$, with the fraction of H-banks choosing $E = \overline{E}$ being determined so that aggregate bank credit supply equals aggregate demand.

Proposition 3: Let $\rho_{\overline{E}} = \delta_H(\widehat{R}(p), \overline{E})\rho_H + \delta_L(\widehat{R}(p), \overline{E})\rho_L$ denote the equilibrium expected return per loan of a bank issuing new equity worth $\overline{E}$. And let out-of-equilibrium beliefs be such that $\delta_H(\widehat{R}(p), \widehat{E}) = 0$ for all $\widehat{E} \neq \overline{E}$. We can find c such that $\Gamma_L \leq 0 < \Gamma_H$ and the aggregate bank-credit supply function $L(\rho_H)$ in a pooling equilibrium is: $\begin{cases} L(\rho_H) = \frac{w}{\kappa} & \text{for } \rho_H \leq \rho_H^2 \\ L(\rho_H) = \frac{w+\overline{E}}{\kappa} & \text{for } \rho_H \geq \rho_H^1 \end{cases}$

with $\rho_H^2 < \rho_H^1$, and aggregate supply in a semi-separating equilibrium is given by:

$L(\rho_H) \in \left[\frac{w}{\kappa}, \frac{w+\overline{E}}{\kappa}\right]$.

Proof. See the appendix. ■

The source of multiplicity of equilibria in the interval $[\rho_H^1, \rho_H^2]$ is, as in all signalling games, due to the degree of freedom in specifying out-of-equilibrium beliefs. An equilibrium best-response of $\widehat{E} = \overline{E}$ is supported by out-of-equilibrium beliefs $\delta_H(R, E) = 0$ for all $E \neq \overline{E}$. On the other hand, an equilibrium best-response of $\widehat{E} = 0$ is supported by out-of-equilibrium beliefs $\delta_H(R, E) = 0$ for all $E \neq 0$. Given that we have different out-of-equilibrium beliefs supporting each equilibrium it is not entirely surprising that we should obtain two cut-offs $\rho_H^1 > \rho_H^2$.

Since in our model the level of bank equity depends on the equilibrium level of ρ_H a contractionary monetary policy leading to a reduction in ρ_H may in turn trigger a decrease in the level of bank equity-capital, and thus lead to a magnified contractionary effect. In particular it can provoke the onset of a bank capital crunch.

As Figure 3 highlights, if the equilibrium level of equity issued by banks is $\widehat{E} = \overline{E}$ the securities market and the credit market curves are shifted downwards.

We interpret the switch from the equilibrium with outside equity capital to the one without equity issues as a form of credit crunch induced by a bank equity crunch. The "bank equity crunch" equilibrium is characterized by a low level of lending, a low level of bank capital and high profitability on bank lending.

6 Comparative Statics and the Effects of Monetary Policy

Having characterized the general equilibrium and the optimal level of outside equity of banks) we are in a position to consider how monetary policy through open market operations and capital regulation may affect equilibrium investment. This analysis is again considerably simplified by referring to the above diagram. Below we illustrate the comparative statics effects in diagrams. We confine the formal analysis to the appendix.

We have in mind here a Central Bank holding a stock of T-bills and conducting monetary policy by buying and selling these bills against cash. An expansionary monetary policy is then implemented by buying T-bills (decreasing G) and a contractionary one by increasing G.

The effect of an increase in G is displayed in Figure 4 below.

The effect is to shift down the securities market equilibrium equation. The shift leads to a lower level of ρ_H and an increase in R_G. These effects on ρ_H and R_G in turn affect the equilibrium level of bank lending and bond issues by shifting overall financing to safer firms. That is, both $p(R_G + \rho_H)$ and $p_1^*(R_G + \rho_H)$ shift to the right by an amount proportional to the increase in G (see the appendix), so that total bank lending remains unchanged, but the increased supply of T-bills crowds out corporate bond issues. Finally, the increase in R_G induces banks to raise their remuneration on deposits and to rely more on deposits as a source of funds.

Thus, the effect of a monetary tightening on individual firms is to cut off the riskiest firms from bank lending and to induce substitution of bond financing for relatively cheaper bank lending at the firms with the lowest bond ratings. Overall, the total share of bank lending to corporate bond issues increases in response to a monetary tightening.

The effect of the monetary tightening on banks is only to induce substitution of bank bond financing for greater deposit financing. Total lending to the corporate sector remains unchanged.

We summarize these finding in the following proposition.

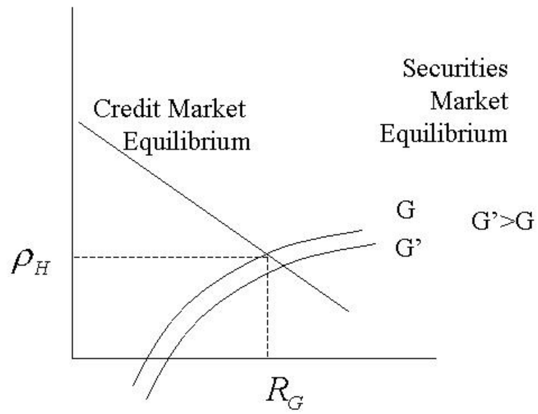

Figure 3:

Proposition 5: Effects of open market operations: A contractionary monetary policy (increase in G) has the effect of : i) increasing T-bill rates R_G, ii) decreasing bank spreads ρ_H, iii) increasing the overall cost of bank loans $R_G + \rho_H$, iv) decreasing corporate and bank bond issues by an amount superior to the additional amount of government borrowing, v) increasing bank deposits and, vi) leaving the aggregate amount of bank lending unchanged. However, bank lending is now directed to safer firms, so that on balance it is the marginal firms with the highest risks that are forced out of investment by the tightening in monetary policy.
Proof. See the appendix. ■

A key implication of our model is that the existence of multiple equilibria may lead monetary policy to a switch from one equilibrium to the other. This is in contrast to the effects expected in a standard interest rate channel for monetary policy transmission. Indeed, the standard mechanism is that monetary tightening reduces bank liquidity and results in an increase in both R_G and ρ_H. In our framework there is an additional effect through the change in bank equity-capital. The effect of a monetary tightening is to increase R_G

and $R_G + \rho_H$ as expected. But in contrast to the standard mechanism a monetary tightening also decreases bank spreads ρ_H. By diminishing ρ_H the monetary authorities reduce banks incentives to increase their equity-capital base. Capital-adequacy regulations thus may induce a decrease in the supply of loans through a contraction of the equity-capital base and thus magnify the contractionary effect of monetary policy.

A "bank capital channel" may be at play in our model when the following three conditions are satisfied: 1) banks spreads ρ_H, are endogenous; 2) the effect of a contractionary monetary policy is to decrease the profitability of bank lending; and 3) banks face capital constraints.

An increase in R_G and a reduction in ρ_H may trigger a decrease (or prevent an increase) in bank equity, and thus lead to a magnified contractionary effect, whenever ρ_H falls below ρ_H^2 or ρ_H^1. In particular it can provoke the onset of a credit crunch.

Perhaps the most interesting observation emerging from this analysis is that it is possible to observe a reduction in bank spreads at the same time as an increase in deposits and a reduction in total private investment. Here the only effect of the reduction in bank spreads is to change the composition of financing. There is a shift away from bond issues to borrowing through bank loans.

How do these results relate to empirical findings? The recent empirical literature on the monetary transmission mechanism has uncovered one broad finding on the composition effects of a contractionary policy. Kashyap, Stein and Wilcox (1993) have found that an important response to a monetary tightening is a surge in commercial paper issuance. They interpret this finding as a change in the composition of financing by firms in response to a monetary tightening: firms substituting bank debt for commercial paper. However, Gertler and Gilchrist (1994) and Oliner and Rudebusch (1995) find that the main factor behind this surge in commercial paper issuance is inventory build-up by large firms financed by commercial paper issuance. Small firms do not rely on commercial paper issues at all. Moreover, these firms bear the brunt of the monetary tightening. Thus, the story that seems to emerge from these studies is that:

> "..the main effect of a monetary contraction is to shift financing of all types from small firms to large firms. This shift produces a decline in the aggregate bank-loan share because large

firms rely less heavily on bank debt than do small firms." [Oliner and Rudebusch, pp 301]

Our results are consistent with these findings to the extent that they explain the shift in overall financing from small (or riskier) firms to large (or safer) firms that results from an increase in interest rates R_G. They seem, however, in contradiction with the empirical evidence to the extent that in our model the aggregate bank loan share increases as a result of the monetary tightening. But, note that our results concern the aggregate share of bank lending to long-term bond issues and not the share of bank lending to commercial paper or other short term debt, which is the focus of most of the empirical literature. The only study that investigates the ratio of bank loans to long term bonds is Gertler and Gilchrist(1983). They show that this ratio only declines slightly following a tightening in monetary policy.

Note also that our result that ρ_H decreases in response to a monetary tightening is consistent with the stylized fact that the yield on bank loans is sticky relative to the Treasury rate. Our model thus provides an alternative explanation for the observed stickiness of bank loan rates.

7 Conclusion

This paper proposes a model of the interface between corporate financing decisions and monetary policy in a general equilibrium model (of the capital market), which traces the effects of monetary policy on firms' investment decisions.

The model developed here, which abstracts from many other relevant considerations generates several qualitative predictions about the joint equilibrium in the credit and securities markets and the effects of open market operations on the real sector, which are broadly consistent with stylized facts on the effects of monetary policy on investment and firm financing uncovered by recent empirical studies.

The model considered in this paper is already somewhat complex and we have chosen to leave some interesting extensions for future research. An obvious immediate extension is to differentiate firms according to both the underlying risk of their cash flows and their size. If, in addition, one then introduces a fixed issuing cost for bonds (representing legal and administrative costs) we would expect to obtain an equilibrium segmentation where only the largest and safest firms issue bonds. Such a model could also be used to investigate how the size distribution of firms as well as the relative costs of securitization affect the aggregate composition of financing in the economy.

Another obvious but more ambitious extension is to introduce a final goods market and a household sector, which responds to changes in interest rates by altering its consumption/savings decisions. Extending the model to a multiperiod setting in order to explore the dynamics of the monetary transmission mechanism is perhaps the most interesting and difficult challenge.

8 Mathematical Appendix

Proof of Proposition 3: We begin by establishing existence of two pooling and a semi-separating equilibrium. We then proceed to show that the two pooling equilibria satisfy the inequality $\rho_H^2 < \rho_H^1$. Let ρ_E and ρ_0 be equity holders' equilibrium beliefs for a bank that issues an amount of equity respectively equal to $\overline{E}$ and 0. We define two functions ψ_H and ψ_L as follows:

$$\begin{aligned}\psi_H(\Gamma_E, \Gamma_0) &= \frac{\Gamma_E(w+E)-E}{\Gamma_E}\left[\lambda\Gamma_E + (1-\lambda)\Gamma_H\right] \\ &\quad - \left[\lambda\Gamma_0 + (1-\lambda)\Gamma_H\right] w\end{aligned}$$

or, equivalently,

$$\begin{aligned}\psi_H(\Gamma_E, \Gamma_0) &= (\Gamma_E - 1)\, E\left[\lambda + (1-\lambda)\frac{\Gamma_H}{\Gamma_E}\right] \\ &\quad -\lambda\,(\Gamma_0 - \Gamma_E)\, w\end{aligned} \tag{18}$$

and

$$\psi_L(\Gamma_E, \Gamma_0) = (\Gamma_E - 1)\, E - (\Gamma_0 - \Gamma_E)\, w \tag{19}$$

which represent the net payoff of issuing equity worth $E = \overline{E}$ instead of $E = 0$, for respectively an H and an L-bank.

Combining expressions (18) and (19) yields the following expression that will be useful

$$\psi_H(\Gamma_E, \Gamma_0) = \lambda\psi_L(\Gamma_E, \Gamma_0) + (\Gamma_E - 1)\, E(1-\lambda)\frac{\Gamma_H}{\Gamma_E} \tag{20}$$

Our different types of equilibria are then characterized by the values of the functions ψ_H and ψ_L, as follows:

1. The pooling equilibrium with $E = 0$ is characterized by $\psi_H(\Gamma_E, \Gamma_0) \leq 0$ and $\psi_L(\Gamma_E, \Gamma_0) \leq 0$.
2. The pooling equilibrium with $E = \overline{E}$ by
   $\psi_H(\Gamma_E, \Gamma_0) \geq 0$ and $\psi_L(\Gamma_E, \Gamma_0) \geq 0$
3. Separating equilibria by different signs for the functions ψ_H and ψ_L.
4. Semi-separating equilibria by a mixed strategy of one type of bank, which implies that either $\psi_L(\Gamma_E, \Gamma_0) = 0$ or $\psi_H(\Gamma_E, \Gamma_0) = 0$.

To prove Proposition 3, we first establish a preliminary lemma:

Lemma 3: *i)* If $\Gamma_E > 1$,then $\psi_L(\Gamma_E, \Gamma_0) \geq 0$ implies $\psi_H(\Gamma_E, \Gamma_0) > 0$
ii) If $\Gamma_E < 1$,then $\psi_L(\Gamma_E, \Gamma_0) \leq 0$ implies $\psi_H(\Gamma_E, \Gamma_0) < 0$
iii) $\psi_L(\Gamma_E, \Gamma_0) = 0$ implies $\psi_H(\Gamma_E, \Gamma_0) = (\Gamma_E - 1) E\left[(1-\lambda)\frac{\Gamma_H}{\Gamma_E}\right]$, so that if $\Gamma_E = 1$, $\psi_H(\Gamma_E, \Gamma_0) = 0$

Proof of lemma 3: is straightforward using (20)

We now proceed to prove proposition 3. Since there is a unique Γ_J associated with any δ_J we can take Γ_J to be the summary statistic for equity holders' beliefs.

We begin by showing that there are only three candidate equilibria:

- If $\psi_L(\Gamma_E, \Gamma_0) > 0$ only a pooling equilibrium with $E = \overline{E}$ can exist. Suppose not and assume that instead $\psi_H \leq 0$. The consistency of equilibrium beliefs imply then that only H Banks do not issue equity, so that $\Gamma_0 = \Gamma_H \geq 0$. Therefore $\Gamma_0 - \Gamma_E > 0$. Using (19) we obtain $\Gamma_E - 1 > 0$, so that from lemma 3, $\psi_H(\Gamma_E, \Gamma_0) > 0$, a contradiction.
- Symmetrically, if $\psi_L(\Gamma_E, \Gamma_0) < 0$ only a pooling equilibrium with $E = 0$ can exist. Assume again by way of contradiction that $\psi_H(\Gamma_E, \Gamma_0) \geq 0$. Equilibrium beliefs then imply that $\Gamma_0 = \Gamma_L$. But (19) then implies that $\Gamma_E < 1$. As before, lemma 3 then yields a contradiction.

- Finally, when we consider mixed strategies, notice first that $\psi_L(\Gamma_E, \Gamma_0) = 0$ can only lead to a mixed strategy if $\psi_H(\Gamma_E, \Gamma_0) = 0$ also holds. To see why assume $\psi_L(\Gamma_E, \Gamma_0) = 0$.Lemma 3 implies $\psi_H(\Gamma_E, \Gamma_0) = (\Gamma_E - 1)\, E(1-\lambda)\frac{\Gamma_H}{\Gamma_E}$. As a consequence, if $\psi_H > 0$, it implies $\Gamma_E - 1 > 0$, but then the equilibrium beliefs are such that $\Gamma_0 = \Gamma_L$, and expression (19) entails ψ_L is the sum of two positive terms, a contradiction. If instead, if $\psi_H < 0$, then, symmetrically, this implies $\Gamma_E - 1 < 0$, and equilibrium beliefs are such that $\Gamma_E = \Gamma_L$, so that expression (19) entails ψ_L is the sum of two negative terms.

As a consequence, the only possible semi-separating equilibrium, if any, would be obtained for $\psi_H(\Gamma_E, \Gamma_0) = \psi_L(\Gamma_E, \Gamma_0) = 0$.

Replacing in (20) implies $\Gamma_E = 1$, and (19), in turn, implies $\Gamma_0 = \Gamma_E$. Consequently the supporting beliefs are given by $\delta_L \Gamma_L + (1 - \delta_L)\Gamma_H = 1$ or

$$\delta_L(\rho_H) = \frac{\Gamma_H(\rho_H) - 1}{\Gamma_H(\rho_H) - \Gamma_L}$$

Which belongs to the interval $(0, 1)$ provided that $\Gamma_L = R_G - \frac{c}{\kappa} < 1$

We now show that any of the above candidate equilibria can exist. To do this we replace the equilibrium values for Γ_E and Γ_0 in the functions ψ_H and ψ_L. That is, for the pooling equilibrium with $E = 0$ we have $\Gamma_E = \Gamma_L$, and for the pooling equilibrium with $E = \overline{E}$ we have $\Gamma_0 = \Gamma_L$.

It is straightforward to show that equilibrium conditions for the pooling equilibrium with $E = 0$ and $\Gamma_E = \Gamma_L$ are satisfied when $\Gamma_L < 1$, since replacing in (19) we obtain $\psi_L < 0$ and Lemma 3,*ii* allow us to conclude. Both pooling equilibria $E = 0$ and $E = \overline{E}$ are met for a small enough $\Gamma_H \geq 1$, for which Γ_E will be close enough to 1. As a consequence, for the relevant range of parameters satisfying $\Gamma_H > 1 > \Gamma_L$, both equilibria exist. Since $\Gamma_H > \Gamma_L$ a necessary condition for existence of a semi-separating equilibrium is that $\Gamma_H > 1 > \Gamma_L$. This establishes the first part of proposition 3.

We now proceed to show that the cut-offs of the two pooling equilibria are ranked as follows: $\rho_H^2 < \rho_H^1$.

Consider first the pooling equilibrium with $E = 0$ and its cut-off ρ_H^1. We first observe that ρ_H^1 is the solution to the equation $\psi_H(\Gamma_E, \Gamma_0) = 0$ for $\Gamma_E = \Gamma_L$. We will write the function $\psi_H(\Gamma_L, \bar{\Gamma})$ as an explicit function of ρ_H,

$\psi_1(\rho_H) \equiv \psi_H(\Gamma_L, \bar{\Gamma})$. That is:

$$\psi_1(\rho_H) = (\Gamma_L - 1)\,\bar{E}\left[\lambda + (1-\lambda)\frac{\Gamma_H}{\Gamma_L}\right] - \lambda\left(\bar{\Gamma} - \Gamma_L\right) w \tag{21}$$

Where $\bar{\Gamma} = \Gamma_0$ is the pooling value, that is $\bar{\Gamma} = \mu\Gamma_L + \mu\Gamma_H(\rho_H)$

Consider now the pooling equilibrium with $E = \overline{E}$. By similar reasoning the cut-off ρ_H^2 is the solution to the equation $\psi_H(\Gamma_E, \Gamma_0) = 0$ for $\Gamma_0 = \Gamma_L$ and $\Gamma_E = \bar{\Gamma}$. As before, define $\psi_2(\rho_H) \equiv \psi_H(\Gamma_L, \bar{\Gamma})$. That is:

$$\psi_2(\rho_H) = \left(\bar{\Gamma} - 1\right)\overline{E}\left[\lambda + (1-\lambda)\frac{\Gamma_H}{\bar{\Gamma}}\right] - \lambda\left(\Gamma_L - \bar{\Gamma}\right) w \tag{22}$$

In order to prove that $\rho_H^2 < \rho_H^1$, (where ρ_H^k is the solution to $\psi_k(\rho_H) = 0$, $k = 1, 2$), remark first that, subtracting equation (21) from (22) and rearranging we obtain:

$$\psi_2(\rho_H) - \psi_1(\rho_H) = \lambda\left(\bar{\Gamma} - \Gamma_L\right)\overline{E} + (1-\lambda)\overline{E}\Gamma_H\left(\frac{1}{\Gamma_L} - \frac{1}{\bar{\Gamma}}\right) - 2\lambda\left(\Gamma_L - \bar{\Gamma}\right) w$$

so that $\psi_2(\rho_H) > \psi_1(\rho_H)$.

Next, notice that $\psi_1(\rho_H)$ is increasing. As a consequence, for any ρ_H satisfying $\rho_H \geq \rho_H^1$, we have $\psi_2(\rho_H) > 0$, establishing that ρ_H^2 if it exists satisfies .$\rho_H^2 < \rho_H^1$.

Finally, since $\rho_H = 0$ implies $\bar{\Gamma} = \Gamma_L < 1$, we have $\psi_2(0) < 0$. Therefore, by continuity ρ_H^2 satisfying exists.

■

Proof proposition 5: We use Cramer's rule to prove the different comparative statics results in the equilibrium where $R_D > 1$.

Define first the functions $\Phi(R_G, \rho_H)$ and $\Omega(R_G, \rho_H)$ from equations (10) and (12) so that both have zero on the RHS:

$$\Phi(R_G, \rho_H) \equiv R_G + \rho_H \frac{V}{v} - \left(1 - \frac{w+E}{\kappa}\right)(V - v) - v = 0$$

$$\Omega(R_G, \rho_H) \equiv \frac{1}{2R_G} + \rho_H \frac{1}{v} + \frac{E}{\kappa} + w\left(\frac{1}{\kappa} - 1\right) + G - 1 = 0$$

Then:

$$\begin{bmatrix} 1 & \frac{V}{v} \\ -\frac{1}{2R_G} & \frac{1}{v} \end{bmatrix} \begin{bmatrix} dR_G \\ d\rho_H \end{bmatrix} = \begin{bmatrix} -\frac{\partial \Phi}{\partial G} \\ -\frac{\partial \Omega}{\partial G} \end{bmatrix} dG$$

- for $\begin{bmatrix} -\frac{\partial \Phi}{\partial G} \\ -\frac{\partial \Omega}{\partial G} \end{bmatrix} = \begin{bmatrix} 0 \\ -1 \end{bmatrix}$

Straightforward computation leads to

$$\frac{dR_G}{dG} = \frac{2R_G^2 V}{2R_G^2 + V} > 0,$$

$$\frac{d\rho_H}{dG} = -v \frac{2R_G^2 G}{2R_G^2 + V} < 0$$

and

$$\frac{d(R_G + \rho_H)}{dG} = \frac{2R_G^2}{2R_G^2 + V} (V - v) > 0.$$

The effect on p^* and p^B of a change in G is thus:

$$\frac{dp^*}{dG} = \frac{2R_G^2}{2R_G^2 + V} > 0$$

and,

$$\frac{dp^B}{dG} = \frac{2R_G^2}{2R_G^2 + V} > 0$$

In words, there is a shift of bank lending towards safer firms with a constant aggregated amount of lending. The effect of the increase of G will be only on the corporate bond market.

9 APPENDIX: NON-BINDING CAPITAL ADEQUACY CONSTRAINTS

In practice, most banks have an equity capital base in excess of the BIS equity capital requirement. If equity capital involves a higher cost of capital than other sources of external funding, the obvious question arises, why banks hold equity capital in excess of regulatory requirements.

The answer seems to be that banks want to maintain a lending capacity to be able to meet unexpected new lending opportunities or to be able to carry out future loan commitments. We can model this idea by assuming that when a firm debt is to be renegotiatied, it involves a complete restructuring with an additional cash injection that we assume equal to l_1. Obviously, if the firm is succesfull at time 1, no additional external funds are required. Assumptions A_0 and A_1 have then to be adapted:

Assumption A0 stating that the average project has a positive net present value has to be modified as follows:

$$\text{A0: } \pi_H + \nu\pi_H - (1-p_1)l_1 > 1 + \omega$$

For simplicity we assume that banks can only issue equity at time 0, (In practice it is difficult to tap the equity market too often). Then, the bank is able to compute its time 1 capital constraint

$\frac{E_1}{L_1} \geq \kappa \geq 0$

where L_1 is the amount of outstanding loans at time 1, (which depends on the expected amount of additional loans, $\int_{p_1^B}^{p_1^*}(1-p_1)dp_1$, the nominal rate on these loans, the expected repayment, $\pi_H \int p_1 dp_1$ as well as the expected loan losses $(L_0 - A)(1-\nu)\int p_1 dp_1)$) and E_1 is the equity capital base at time $t = 1$, which includes time zero net profits if we assume a zero dividend at time $t = 0$.

Depending on the expected amount of profit, additional loans and loan losses, the binding capital constraint will be the one at time $t = 1$ while it will not be binding at time $t = 0$. Thus, we will observe equity capital slack because of the profitability of making additional loans to good firms in distress. Notice therefore that the slack will depend upon the business cycle since the proportion of good firms in distress, the proportion of repayments and the banks profits themselves depend upon the business cycle.

There is an additional condition that is required for banks to perform their rôle in the loan renegotiation process, that a loan to a firm in distress is more profitable than a new loan to the average firm.

$\frac{\pi_H}{l_1} \geq \rho_H$

This condition which is absolutely natural when we think in terms of the incentives and of the credibility of banks to renegotiate their loans is also interesting as it shows banks benefiting from their captive unlucky borrowers.

This condition will always hold for high cash flows π_H and low cost overruns l_1 and low future expected profitability on new loans ρ_H

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