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Abstract

This paper studies the limitations of the 'credit channel' in transmitting monetary policy into real economic outcomes. We focus on one particular failure of the credit channel in which although the central bank is infusing money into the banking system, liquidity remains stuck in banks and is not lent out. We use the term 'credit traps' to describe such situations and show how they can arise due to the interplay between financing frictions, liquidity, and collateral values. Our analysis offers a characterization of the problems created by credit traps as well as potential solutions and policy implications. Among these, the analysis shows how quantitative easing and fiscal policy acting in conjunction with monetary policy may be useful in increasing bank lending. Further, small shifts in monetary or fiscal policy can lead to collapses in lending, aggregate investment, and collateral prices.

Introduction

According to the 'credit channel' view of monetary policy transmission, shocks to monetary policy affect the economy through their impact on financial frictions and the availability of credit. This credit view is generally divided into two distinct channels. The first is the 'balance sheet channel' in which monetary shocks affect borrower balance sheets. An easing of monetary policy strengthens firms' balance sheets – e.g. by reducing interest rates and raising collateral values – which reduces the cost of external capital and promotes investment and spending. The second channel emphasizes the importance of bank loans to economic activity and is known as the 'bank lending channel'. According to this view, an expansion of monetary policy shifts the supply of banks loans outwards, and as a result leads to an increase in investment and aggregate demand. While both channels predict that expansionary monetary policy should lead to increased economic activity, there is little theoretical analysis of the limits to the transmission of monetary policy, and particularly one which takes a unified view of the two credit channels of the transmission of monetary policy.[1] In this paper we analyze the limitations of both the 'balance sheet channel' and the 'lending channel' in transmitting monetary policy into real economic outcomes.

Our paper focuses on one particular failure of monetary policy in which although the central bank is infusing money into the banking system, liquidity remains stuck in banks. Instead of using the increase in reserves stemming from expansionary monetary policy to provide credit to firms, banks choose to hold on to the additional funds. Our paper thus analyzes situations in which despite the best efforts of the central bank to provide liquidity to the corporate sector, banks will hoard the additional liquidity created. We use the term 'credit traps' to describe these scenarios, and show how they can arise even amongst banks with strong balance sheets. In doing so, our analysis points to the limits of monetary policy transmission when liquidity in the corporate sector is low.

The model relies on two building blocks. The first is the well known notion that collateral eases financial frictions and increases debt capacity. For ease of exposition, we follow Aghion and Bolton (1992) and Hart and Moore, (1994, 1998) and assume that firms cannot easily commit to repay their loans – say, due to agency problems or incomplete contracts. In such an environment, debt

[1]The exceptions are Diamond and Rajan (2006) who present a model unifying the traditional 'money channel' view with the 'balance sheet channel', and Holmström and Tirole (1997) who identify both 'balance sheet' and 'lending' channels.

capacity is determined solely by collateral values.

The second building block of the model is that the value of firms' collateral is determined, in part, by the liquidity constraints of industry peers. As in Shleifer and Vishny (1992) we assume that banks cannot operate assets on their own to generate cash flow and so must sell seized collateral to other industry participants. Liquidity constraints in these peer firms therefore plays a role in the value of collateral as it affects the amount which potential purchasers can pay for assets. In particular, when industry financial conditions are poor the liquidation value of collateral – which is the relevant value to the bank – can be lower than the intrinsic value of the assets.[2]

Based on these two building blocks, the mechanism of our model hinges on a feedback loop between collateral values, lending, and liquidity in the corporate sector. According to this, increases in collateral values allow greater lending due to the attendant reductions in financial frictions; Greater lending, in turn, increases liquidity in the corporate sector; Finally, increases in corporate liquidity serve to increase collateral values, as these are determined in part by the ability of industry peers to purchase firm assets (Shleifer and Vishny, 1992).

In our model, monetary policy affects real outcomes through its impact on the feedback loop between collateral values, lending, and corporate liquidity. By injecting liquidity into the banking sector the central bank shifts out loan supply. Banks then make their lending decision under rational expectations: anticipating the feedback loop, banks understand that using the funds supplied by the central bank to increase lending will increase corporate liquidity and hence collateral values. Still, actual lending will occur only when this increase in collateral values (and the concurrent increase in debt capacity) is sufficiently large to justify the additional lending.

Formally, our model identifies three mutually exclusive types of potential equilibria describing the transmission of monetary policy into the real sector. In the first type of equilibrium, which we call the 'conventional equilibrium', shifts in monetary policy successfully influence aggregate lending activity. This rational expectations equilibrium can be described by the following series of interlocking forces. When the central bank eases monetary policy, the supply of loanable funds increases. Similar to a standard lending channel effect (see e.g. Stein (1998)), banks will tend to lend out more funds which will increase liquidity in the corporate sector. As liquidity in the corporate sector increases, liquidation value of assets will increase due to a Shleifer-Vishny 1992

[2]Following the intuition in Shleifer and Vishny (1992), we use the notions of collateral values and liquidation values interchangeably.

effect – firms become less liquidity constrained, and can hence bid more aggressively when acquiring assets of liquidated firms. As in a standard 'balance sheet channel' effect (e.g. Bernanke and Gertler (1989, 1990, 1995) Lamont (1995)), the endogenous increase in liquidation values improves firms' collateral positions, and thus enables them to borrow the additional liquidity which was injected to the commercial banks by the central bank. The lending and balance sheet channels of monetary policy are therefore linked in a rational expectations equilibrium through endogenous collateral values: increased bank lending leads to greater liquidity in the corporate sector and thus higher collateral prices, while higher collateral prices enable banks to utilize the central-bank injection of liquidity and actually engage in lending. In this conventional equilibrium, an easing of monetary policy thus translates into three effects: an increase in lending, an increase in collateral values, and a change in the interest rate associated with bank lending.

Since the transmission of monetary shocks does not occur through a neoclassical cost-of-capital effect, we show that in a conventional equilibrium, large changes in aggregate lending and investment can be associated with small changes in interest rates.[3] The intuition is that an expansion in monetary policy shifts out both loan supply and loan demand – the latter occuring due to the increase in debt capacity associated with the rise in collateral values. The outward shift in loan supply and demand have counteracting effects on the equilibrium interest rate, although both serve to increase lending and investment.

The second type of equilibrium in our model is the 'credit trap' equilibrium. In this equilibrium, any easing of monetary policy beyond a certain level is completely ineffective in increasing lending – banks simply hold on to the additional reserves created by the central bank. In the 'credit trap' equilibrium aggregate lending is constrained by low collateral values. To increase collateral values the central bank would need to induce banks to inject additional liquidity into the corporate sector so as to increase firms' ability to purchase the assets of other industry participants. However, the marginal increase in collateral values (and the associated increase in debt capacity) stemming from additional lending is not sufficiently large to actually induce banks to lend. Regardless of the amount of liquidity added by the central bank, credit remains stuck in banks and collateral values do not increase.

Figure 1a depicts a credit trap equilibrium. For any level of reserves R, Curve A depicts the

[3]This is consistent with empirical findings showing that monetary shocks have large real effects even though components of aggregate spending are not very sensitive to cost-of-capital variables (for a survey, see Bernanke and Gertler 1995).

value of collateral assuming that R is lent out by banks. (Curve A increases in R: As the amount of loans rises implied collateral values increase due to the increased liquidity in the corporate sector.) Curve B depicts the minimum level of collateral needed to *extract* R in loans from banks. (Curve B increases in R since collateral values need to be higher to extract a larger amount of loans.) The maximum loan amount that can then be extracted is R^*, where the two curves intersect: for any $R > R^*$, the implied collateral value assuming that R is lent out will be smaller than the minimum collateral value needed to extract R. Banks will therefore lend out R^* and hoard any additional reserves provided by the central bank beyond R^*.

While monetary policy on its own is ineffective in a credit trap equilibrium, our model shows how *fiscal* policy acting in conjunction with monetary policy can be useful in easing the credit trap and increasing bank lending. This occurs because expansionary fiscal policy can circumvent financial intermediaries and inject liquidity directly into the corporate sector. The increase in corporate liquidity increases collateral values which enables some of the liquidity trapped in banks to then be lent out. Further, the model shows how the impact of fiscal policy will be state-contingent and, in particular, depend on the level of liquidity in the corporate sector. Assessing the magnitude of the fiscal policy multiplier using an unconditional average of historic estimates, as conducted during the debate regarding the fiscal stimulus passed in the first quarter of 2009, may therefore provide a misleading result as to fiscal policy efficacy.

The third equilibrium type in our model is the 'jump start' equilibrium. In this equilibrium monetary policy can be effective, but only when the central bank acts sufficiently forcefully in injecting reserves to the banking sector. When increasing reserves by only a moderate amount, credit remains trapped in the banking sector as in a credit trap equilibrium. Banks rationally understand that when they can employ only a moderate amount of reserves to lend to firms, the implied collateral values are too small to justify any actual lending. However, when the central bank eases monetary policy sufficiently, a high lending - high collateral value rational expectations equilibrium arises: banks lend, corporate liquidity increases, and hence collateral values are sufficiently high to justify the large amount of lending. Figure 1b depicts a jump start equilibrium – no amount of reserves R strictly between R_1^* and R_2^* can be lent out by banks, as the value of collateral implied by R being lent out is smaller than the minimum value of collateral needed in order to extract R in loans from banks. In contrast, if the central bank acts sufficiently forcefully and injects R_2^* in reserves into the banking system, banks will be able to lend out R_2^*.

The 'jump start' equilibrium in our model provides theoretical support for a policy of quantitative easing, showing how such easing, under certain circumstances, can be effective in increasing lending.[4] Such quantitative easing was used by the Bank of Japan from March 2001 to March 2006 as part of its attempt to stimulate the nation's stagnant economy. However, while the Bank of Japan injected large amounts of reserves into the banking system, reducing the overnight call rate effectively to zero, quantitative easing had limited success in spurring bank lending. Consistent with a 'jump start' equilibrium, the limited success of quantitative easing is, in part, attributed to the Bank of Japan's failure to act decisively in injecting liquidity and its decision to withdraw the added liquidity too early.

We argue that the level of liquidity in the corporate sector and its distribution are two important factors in determining the nature of the equilibrium that arises – a 'credit trap' in which quantitative easing is ineffective, or a 'jump start' equilibrium, in which quantitative easing can result in renewed lending. Still, since the model predicts that interest rates and lending in the two equilibria will behave similarly so long as the central bank does not actually undertake a sufficiently forceful policy of quantitative easing, differentiating between the two equilibria will be difficult.

Finally, the model shows how small shifts in fiscal or monetary policy can lead to collapses in lending, aggregate investment, and collateral prices. Again, the intuition is based on the reinforcing feedback loop between lending, liquidity, and collateral values. For example, a small contraction in monetary policy decreases lending thereby reducing expected liquidity in the corporate sector. The reduction in corporate liquidity reduces expected collateral values which, in turn, reduces lending still further. Under certain conditions, this process reinforces itself until it reaches a low collateral value and low lending equilibrium. This result is very much consistent with Bernanke and Blinder (1995) who argue that the "crash of Japanese land and equity values in the latter 1980s was the result (at least in part) of monetary tightening; and that this collapse in asset values reduced the creditworthiness of many Japanese corporations and banks, contributing to the ensuing recession."

The rest of the paper is organized in the following manner. Section 1 provides a brief review of related literature. Section 2 explains the setup of the model. Section 3 analyzes the benchmark case in which liquidation values are determined exogenously. In Section 4 we endogenize liquidation

[4] Quantitative easing is a monetary policy tool in which a central bank focuses on increasing the money supply when standard interest rate targeting is of little use, such as when the funds rate is close to zero. By conducting open-market operations, lending money directly to banks, or purchasing assets from financial institutions, banks are encouraged to lend.

values and study their effect on the credit channel of monetary policy. Section 7 summarizes the results of the theoretical model and discusses policy implications. Section 8 concludes.

1. Related Literature

Our work is related to a number of areas of research. These include the literature on the credit channel of monetary policy; the literature on credit cyclicality and the financial accelerator; work studying the ongoing financial crisis of 2008 - 2009, and studies on the interplay between liquidity, asset prices, and fire sales.

The literature on the credit channel of monetary policy analyzes how changes in the money supply affect real economic activity through their impact on financial frictions and the availability of credit. Studies in this field include Bernanke and Blinder (1988), Kashyap and Stein (1994), (1995), (2000), Lamont et al. (1994), Gertler and Gilchrist (1994), Bernanke and Gertler (1995), and Stein (1998). Gale and Allen (2000) show how lax monetary policy can lead to credit expansion, asset bubbles, and eventually financial crisis. In contrast to these studies, our paper focuses on the limitations of the transmission mechanism of monetary policy within a credit channel framework, showing how the interplay between liquidity, collateral values and lending can give rise to credit traps.

A second strand of literature related to our work is that studying the ongoing financial crisis of 2008 - 2009. This includes Diamond and Rajan (2009), Kashyap, Rajan and Stein (2008), and Shleifer and Vishny (2009) which provide a theoretical framework for the crisis based on the role that securitization played in recent years. In a setting of asymmetric information, Bolton and Freixas (2006) analyzes the role that depleted bank equity capital plays in the transmission of monetary policy. While our model is not meant to capture the full detail of the current crisis, and importantly, does not rely on the depletion of bank equity capital, the model shows how credit traps and bank cash hoarding can arise even amongst banks with strong balance sheets. Our model can, therefore, be thought of as a baseline case to which capital depletion, uncertainty regarding the strength of bank balance sheets, and debt-overhang or asymmetric information frictions in bank financing can be added. Unsurprisingly, adding these effects only serves to further hinder the transmission of monetary policy.

Our paper is also related to numerous previous studies on credit cyclicality and the financial accelerator. In this literature, pioneered in Bernanke and Gertler (1989), countercyclical frictions in the cost of external finance driven by procyclical variation in the strength of firms' balance sheets serve to amplify the business cycle. Important studies in this field include Shleifer and Vishny (1992), Kiyotaki and Moore (1997), Holmström and Tirole (1997), and Fostel and Geanakopols (2008).

Finally, as explained above, our work is closely related to Shleifer and Vishny (1992) which first introduces the positive feedback loop between liquidity and collateral values, debt capacity, and the provision of credit. Other recent papers which study the interplay between liquidity, fire sales, and asset pries are Acharya and Viswanathan (2009), Acharya, Shin and Yorulmazer (2009), and Rampini and Viswanathan (2009). Our analysis is also related to Holmström and Tirole (1997) which analyzes how the distribution of wealth across firms and suppliers of capital affects lending and investment. Holmström and Tirole, however, consider exogenous asset values while we endogenize these values and analyze their interplay with liquidity and lending.[5]

2. Model Setup

Consider an economy comprised of a continuous set of firms with measure normalized to unity, a set of commercial banks which can supply capital to firms, and a central bank. The firms in our model are each endowed with an identical opportunity to invest in a project which requires an initial outlay of I at date 0, and returns a cash flow of X_1 in date 1 and X_2 in date 2. As in Hart and Moore (1998) cash flows are assumed to be unverifiable. For simplicity we assume that $I < X_1 < X_2$. While by no means necessary, this assumption eases exposition and is consistent with our main interest of tight liquidity in date 1. If undertaken, a project can be liquidated at date 1 for a value denoted by L. The liquidation value of assets will play a key role in the analysis and will be described further below.

Firms differ in their level of internal wealth, A, with A distributed over the support $[0, I]$. For convenience, firms are parameterized by the level of borrowing that they require in order to invest in the project $B = I - A$. We assume that B, the initial amount of funding needed by firms to invest in their project, is distributed according to the cumulative distribution function $G()$.

To invest in their project, firms can borrow capital from banks. We assume that firms cannot

[5] Indeed, according to Holmström and Tirole (1997): 'A proper investigation of the transmission mechanism of real and monetary shocks must take into account the feedback from interest rates to capital values.'

issue bonds in the capital markets. While this is a strong assumption, adding a bond market does not change our results qualitatively, as long as banks are assumed to have some informational or monitoring advantage in providing capital.[6]

As is common in the literature on the lending channel of monetary policy (see, e.g. Kashyap and Stein (1994)) we assume, for simplicity, that the supply of loanable funds, R, is directly determined by the central bank through its choice of open market operations.[7] Implicitly, therefore, we are assuming that, as in Myers and Majluf (1984) or Stein (1997), there are frictions in banks' ability to raise external non-insured finance such as equity. The interest rate on loans, r, is determined in equilibrium so as to equate demand and supply of loanable funds.

Finally, both banks as well as firms can invest in a security yielding a return normalized to zero rather than engaging in lending or borrowing related to a project. One can think of this security as investment in government debt.[8]

While most of our predictions stem from a general equilibrium analysis in which we endogenize the liquidation value L of the project, it is useful to begin the analysis with the benchmark case of exogenous liquidation values.

3. The Benchmark Case: Exogenous Liquidation Values

We begin by assuming that the liquidation value of the project L is exogenously determined. As we show in the next section, we can restrict our attention to cases in which L is smaller than X_1, since once L is endogenized this inequality holds in equilibrium. Further, we consider the more interesting case where $L < I$.[9]

Consider a firm which needs to borrow an amount B to invest in its project and is faced with an interest rate r. Since cash flow is unverifiable, there is no way to induce the firm to repay at date 2. As is common in the literature in incomplete financial contracts, the only method to induce the firm to repay at date 1 is through the threat of liquidation (e.g., Aghion and Bolton (1992), Hart and Moore (1994)). Assuming that at date 1 the firm has all the bargaining power in renegotiating

[6] That intermediated loans are somehow 'special' is a fundamental assumption in the lending channel literature (see Bernanke and Blinder, 1988).

[7] The central bank is exogenous to the model – its sole role is in influencing R – so that it is not assigned an objective function.

[8] The interest rate provided by government debt could be endogenized and depend on the level of demand for such debt by both the banking and corporate sector. Doing so would not change our main results.

[9] When $L > I$ the analysis continues to hold but the financial frictions are negligible since liquidation of the project at the end of the first period would yield enough to fully repay the bank.

its debt obligation with its bank, the firm will never be able to commit to repay more than L at date 1 as it can always bargain down its repayment to the bank's outside option. Thus, the firm will be able to borrow an amount B only when $B(1+r) \leq L$, or equivalently, when

$$B \leq L/(1+r). \tag{1}$$

Faced with an interest rate r, a firm will choose to borrow B and invest in its project rather than invest its internal funds A in the zero-interest security when

$$X_1 + X_2 - (1+r)B \geq A, \tag{2}$$

or equivalently, since $B = I - A$, when

$$B \leq (X_1 + X_2 - I)/r. \tag{3}$$

Inequality (3) represents the participation constraints of firms that is driven by the cash flows generated by the project and their initial financial constraints. Combining (1) and (3) yields that at an interest rate r, all firms with

$$B \leq min[L/(1+r), (X_1 + X_2 - I)/r] \tag{4}$$

are both able and willing to borrow funds to invest in their respective projects. Denoting by B^*(r) the marginal firm which borrows and invests in the project as a function of the interest rate r, we have that $B^*(r) = min[L/(1+r), (X_1 + X_2 - I)/r]$. At any interest rate r, the demand for capital generated by firms is therefore given by:

$$D(r) = \int_0^{B^*(r)} BdG(B). \tag{5}$$

Because of the financial frictions – as operationalized through the assumption that cash flow is nonverifiable – the demand for loanable funds is determined in part by the *ability* of firms to borrow and not just by their desire to do so. Figure 2 provides a graphic illustration of this situation. We plot the amount of funds that the firm needs, B, on the horizontal axis as a function of the prevailing interest rate r which is on the vertical axis. When $L \geq X_1 + X_2 - I$, for low enough r inequality (1) binds while inequality (3) does not, and demand for loanable funds is determined by firms' ability to borrow (as constrained by liquidation values) rather their desire to borrow (as determined by the participation constraint). In this case, the marginal firm that borrows is therefore given by $B = L/(1 + r)$.[10]

The liquidation value of assets, L, thus plays an important role in determining demand for loanable funds through its impact on financial constraints. To emphasize this, we refer to the demand function in (5) as 'effective demand', thereby differentiating it from the demand that would have been obtained under no financial frictions.[11]

Equilibrium in the model is determined by equating effective demand for loanable funds to the supply of loanable funds:

$$\int_0^{B^*(r)} BdG(B) = R. \tag{6}$$

As the central bank increases the supply of funds, the interest rate decreases and the aggregate amount of loans increases. When the binding constraint on firm borrowing is determined by financial constraints (i.e. the marginal firm borrowing has a borrowing requirement of $B^* = L/(1 + r)$), the decrease in interest rates relaxes the borrowing constraint and enables effective demand to increase. However, as can be seen from (5), with exogenous L the maximal effective demand is obtained at $r = 0$ and equals $\int_0^L BdG(B)$; When the interest rate is at its lowest level, the maximal amount a firm can borrow is $B = L$ due to financial frictions. From (6), any increase by the central bank of loan supply beyond $\int_0^L BdG(B)$ will not increase actual loans made to the corporate sector, but will instead be invested by banks in the zero-interest security. Aggregate lending from banks to firms therefore increases one-to-one with the loan supply R, up to the point $R = \int_0^L BdG(B)$ where it flattens out, resulting in credit rationing of $1 - \int_0^L BdG(B)$ of firms.

In sum, with exogenous liquidation values the central bank can increase bank lending through its impact on the supply of loanable funds, but only up to a level determined by the liquidation value of assets. Beyond this level, monetary policy is ineffective in stimulating bank lending due to financial frictions in the loan market. To the extent that monetary policy does not increase collateral values, financial frictions will limit the ability of the central bank to promote lending by the banking sector. The balance sheet channel suggests, however, that monetary policy *can* influence collateral values. Endogenizing the value of collateral is therefore crucial to understanding the limits of monetary policy. We turn to this in the next section.

[10] When $L < X_1 + X_2 - I$, inequality 3 never binds, and demand for loanable funds is determined solely by inequality 1 – i.e. firms' ability to borrow as constrained by asset liquidation values. The marginal firm that borrows is therefore $B = L/(1 + r)$, for any r.

[11] The latter is determined solely by inequality (3).

4. The Credit Channel with Endogenous Liquidation Values

To endogenize liquidation values, we assume that when a bank repossess the assets of a firm which has defaulted it must sell these assets in a market instead of operating the asset itself. The value obtained in this sale is the liquidation value of assets. Following Shleifer and Vishny (1992), we assume that the best users of a defaulted firm's assets are other firms within the same industry.[12] Industry participants bid for the defaulted firm's assets, so that demand will be determined both by the potential value of the assets as well as, importantly, the liquidity constraints of the bidders. As in Shleifer and Vishny (1992), if the liquidity available to the bidders is sufficiently low, the value obtained for the asset will be lower than its first-best value.[13]

Before continuing, it is useful to provide a general description of the model's main effects. The model combines the 'balance-sheet channel' and the 'lending channel' in a general equilibrium rational expectation framework. This can be described with the following series of interlocking forces. When the central bank eases monetary policy, the supply of loanable funds increases. Similar to a standard lending channel effect (see e.g. Stein (1998)), banks will tend to lend out more funds, all else equal, which will increase liquidity in the corporate sector. As liquidity in the corporate sector increases, liquidation value of assets will increase due to a Shleifer-Vishny effect – firms become less liquidity constrained, and can hence bid more aggressively when acquiring assets of liquidated firms. As in a standard 'balance sheet channel' effect (e.g. Bernanke and Gertler (1989, 1990, 1995) Lamont (1995)), the endogenous increase in liquidation values improves firms' collateral positions, which enables them to borrow that additional liquidity which was injected to the commercial banks by the central bank. In equilibrium, the lending and balance sheet channels of monetary policy are therefore linked through endogenous liquidation values: increased bank lending leads to greater liquidity in the corporate sector and thus higher collateral prices, while higher collateral prices reduces financial frictions and enables banks to increase lending to firms.[14]

Rather than imposing a particular structure on the market for repossessed assets, we analyze the results using a general reduced-form specification. Specifically, the price of a firm's liquidated assets will depend in a general manner on the level of liquidity in the corporate sector and its

[12] Implicitly, this is equivalent to assuming that participants outside the industry value the assets at zero. This assumption can easily be generalized to a positive outside value.

[13] Empirical evidence for this industry equilibrium model and its implications for liquidation values, corporate liquidity and debt financing is provided in Benmelech (2009), Benmelech and Bergman (2009) and Pulvino (1998).

[14] As far as we know, our paper is the first to explicitly link the 'balance sheet' and 'lending' channels.

distribution. Accordingly, we define a pricing function, P, for the liquidation value of assets which takes as inputs two variables which jointly span the level and distribution of liquidity at date 1 within the corporate sector. The first variable is the marginal firm that successfully obtained funding at date 0, B^*. The second variable in P is the equilibrium interest rate r^* paid by firms borrowing at date 0.[15] Thus, if a firm defaults and its assets are repossessed by its bank and sold on the market, the price of these assets will be $P = P(B^*, r^*)$. For simplicity, we assume that all assets of a firm are essential in generating cash flow, which implies that partial liquidation of assets is useless. This implies that if a firm defaults and its assets are repossessed by its bank and sold on the market, the maximal price of these assets will be X_1 – the maximal amount of cash holdings of any potential buying firm.

Since the price of liquidated assets will be nondecreasing in date 1 corporate liquidity, we make the following assumptions:

Assumption 1.
(i) $\partial P/\partial B^* \geq 0$
(ii) $\partial P/\partial r^* \leq 0$

These assumptions are straightforward. First, as the proportion of firms obtaining funding at date 0 increases, date 1 liquidity will increase so that the price of liquidated assets will be non increasing in B^*. Similarly, as the interest rate at which firms borrow increases, date 1 liquidity decreases, so that P will be non-increasing in r^*.

Given a pricing function P, an equilibrium in the lending market is characterized as follows:

Market Equilibrium. *An equilibrium in the lending market is a vector $\{R, r^*, L^*, B^*\}$, such that:*
(i) Firms optimize in their borrowing and investing choices given the interest rate r^* and the liquidation value of assets L^*.
(ii) Banks optimize in their lending choices, knowing that firms can commit to repay no more than L^*.
(iii) The market for loanable funds clears at date 0: Denoting by B^* the marginal firm which borrows to invest in a project (i.e. all firms with borrowing requirement $B \leq B^*$ borrow from banks),

[15] Other exogenous determinants of the date 1 distribution of liquidity is the date 0 distribution of internal funds, G, and the level of date 1 cash flows X_1. In this section, we suppress in our notation of the pricing function its dependency on G and X_1. In Sections 3.2 and 3.3, we consider how the pricing function varies with these exogenous variables. For simplicity, we assume that P is differentiable in B^*, r^*, and X_1, and is continuous in G under the uniform metric.

the market clearing condition is

$$\int_0^{B^*} BdG(B) \leq R, \tag{7}$$

with strict inequality only when $r = 0$.

(iv) L^* is an equilibrium liquidation value: $L^* = P(B^*, r^*)$.

The equilibrium requirements are quite intuitive. First, in equilibrium firms will optimize their borrowing choices. Since each individual firm takes the liquidation value L^* as exogenous, this requirement translates into the optimality conditions developed in the previous section in inequalities (1) and (3) – i.e. that a firm with borrowing requirement B borrows if and only if $B \leq min[L/(1+r), (X_1 + X_2 - I)/r]$

In optimizing lending decisions, banks will lend at the equilibrium interest rate r^* while understanding that firms cannot commit to repay more than L^*. In equilibrium for any rate $r^* > 0$ realized demand for loanable funds will equal supply, while, in contrast, when $r^* = 0$ the supply of loanable funds can be greater than the demand – any excess supply will simply be invested by the banks in the zero-interest security.[16]

Finally, equilibrium requirement (iv) is a rational expectations condition, stating that the liquidation value of assets taken as given by individual banks and firms when making their date 0 decisions is indeed the date 1 price of liquidated assets. As described above, this price is determined through a Shleifer-Vishny (1992) equilibrium by the liquidity in the corporate sector and is governed by the pricing function P. It should be noted that since there is no uncertainty about project outcomes there will be no liquidation on the equilibrium path.

We solve for the equilibrium in the following manner. First, from our analysis in the case of exogenous liquidation values in Section 2, we know that for every potential liquidation value L and loan supply R, there exists an equilibrium interest rate r^* which clears the market for loanable funds, i.e. satisfies Inequality (7). We denote this market clearing equilibrium rate as $r^*(L; R)$. Furthermore, by condition (4) above, for any interest rate r, banks will agree to lend to any firm

[16] Note that the assumption that banks cannot raise external finance implies that no bank will be able to reduce the interest rate it offers to increase loan capacity and profits. Essentially, banks' marginal cost of raising funds beyond the reserves they have is assumed to be infinite. More generally, as in a standard lending channel, all that is required is non-zero marginal costs in raising non-reservable forms of liabilities.

with required borrowing B smaller than $L/(1+r)$. Finally, for any interest rate r, all firms with borrowing requirements $B \leq (X_1 + X_2 - I)/r$ will optimally choose to borrow and invest in their projects. Thus, for every potential liquidation value L and loan supply R, the marginal firm obtaining financing satisfies $B^*(L;R) = min[L/(1+r^*(L;R)), (X_1 + X_2 - I)/r^*(L;R)]$.

We can therefore define an *indirect* pricing function $p(L;R) \equiv P(B^*(L;R), r^*(L;R))$ as a function of the liquidation value L and the exogenously given loan supply R. For equilibrium condition (iv) to be satisfied, the equilibrium liquidation value L^* must then satisfy $p(L^*;R) = L^*$. That is, the price of liquidated assets should satisfy rational expectations in equilibrium: if banks at date 0 lend capital under the assumption that the date 1 liquidation value of assets will be L^*, then at date 1, the price of liquidated assets should indeed be L^*. Rational expectations are required since this date 1 price of liquidated assets is determined through a Shleifer Vishny (1992) equilibrium by the amount of liquidity in the corporate sector in date 1, which, in turn, is determined in part by the amount of loans provided by the banks in date 0. Formally, we thus have the following proposition:

Proposition 1. *Given an exogenous supply of loans R, all equilibrium liquidation values L^* satisfy*

$$p(L^*;R) = L^*. \tag{8}$$

The equilibrium interest rate is then given by $r^*(L^*;R)$, while the marginal firm that borrows in this equilibrium is given by $B^*(L^*;R)$.

Proof. See Appendix.

To characterize the pricing function $p(L;R)$, it is useful to define for every amount of loanable funds, R, the value $\bar{B}(R)$ which represents the marginal firm that obtains financing assuming that the *full* amount R is lent out by banks. It is easy to see that $\bar{B}(R)$ is given implicitly by the equation:

$$\int_0^{\bar{B}(R)} BdG(B) = R. \tag{9}$$

Having defined $\bar{B}(R)$, the indirect pricing function $p(L;R)$ is characterized in the following proposition.

Proposition 2. *Fix an exogenous loan supply* $R \leq \int_0^I BdG(B)$ *and liquidation value of assets* L.
(1) For any $L \leq \bar{B}(R)$*:*

(i) The equilibrium interest rate associated with L *will be* $r^* = 0$*, and the marginal firm able to borrow will have a borrowing requirement of* L.

(ii) The pricing function satisfies $p(L; R) = P(L, 0)$.

(iii) Demand for loanable funds, $\int_0^L BdG(B)$ *will be smaller than the supply* R*, implying that not all of the supply will be lent out.*

(2) For any $L > \bar{B}(R)$*:*

(i) The marginal firm able to borrow will have a borrowing requirement of $\bar{B}(R)$ *and the equilibrium interest rate associated with* L *will be that* r^* *solving* $\bar{B}(R) = B^*(r)$.

(ii) The pricing function satisfies $p(L; R) = P(\bar{B}(R), r^*)$.

(iii) The market for loanable funds clears: demand for loans, $\int_0^{\bar{B}(R)} BdG(B)$*, equals loan supply* R.

To understand Proposition 2 consider first a potential equilibrium liquidation value L satisfying $L \leq \bar{B}(R)$. To see why the equilibrium interest associated with L will be zero, note that the marginal firm successfully able to borrow will have a borrowing requirement of $B = L$, implying a realized demand of $\int_0^L BdG(B)$. Since, by assumption, L is smaller than $\bar{B}(R)$, realized demand at a zero interest rate will be smaller than $\int_0^{\bar{B}(R)} BdG(B) = R$, the supply of loanable funds. Since equilibrium interest rates cannot fall below zero, the equilibrium interest rate associated with any L smaller than $\bar{B}(R)$ will indeed be zero and the associated marginal borrowing firm will have $B = L$. Thus, the pricing function will satisfy $p(L; R) = P(L, 0)$ on the region $L \leq \bar{B}(R)$ (recall that P is the direct pricing function). Further, in equilibrium in this region not all of the loan supply will be lent out: realized aggregate lending ($\int_0^L BdG(B)$) will be smaller than loan supply (R).

Consider now a potential equilibrium liquidation value L that satisfies $L \geq \bar{B}(R)$. Since by the definition of $\bar{B}(R)$, realized demand at a zero interest rate will be greater than the supply of loanable funds, R, in equilibrium the interest rate will be greater than zero, and supply and demand for loanable funds will equate. Thus, the marginal firm borrowing will have a borrowing requirement of $B = \bar{B}(R)$. The interest rate associated with L will then simply be that r solving $\bar{B}(R) = B^*(r)$ where $B^*(r) = min[L/(1 + r^*), (X_1 + X_2 - I)/r^*]$.
A direct consequence of Proposition 2 which we will use in the next section is:

Corollary 1. *Fix an exogenous loan supply $R \leq \int_0^I BdG(B)$. The pricing function $p(L;R)$ is increasing in L over the region $L < \bar{B}(R)$ and decreasing in L over the region $L > \bar{B}(R)$.*

Holding R constant, increasing L has two opposing effects on the price of collateral in period 1, $p(L;R)$. The first effect is that as L increases, more firms are able to raise external finance which increases liquidity in the corporate sector and therefore raises the market price of collateral in period 1. The second effect is that as L increases, more firms are able to borrow. Effective demand for intermediated loans increases, which implies that the equilibrium interest rate of loans rises. An increase in the interest rate reduces liquidity in the corporate sector in period 1, which tends to push down the period-1 price of collateral.[17] When L is low the first effect dominates, while when it is high the second dominates. $p(L;R)$ is therefore non-monotonic in L.

Figure 3 provides an example of the pricing function p for a given level of loanable funds R. As described in Proposition 2, p is increasing up to $\bar{B}(R)$ and decreasing following that. The equilibrium liquidation value is that L^* where $p(L^*;R) = L^*$. Rational expectations is satisfied under this condition as the implied price of collateral when the liquation value is L^* and loan supply is R, $p(L^*;R)$, indeed equals L^*.

4.1. Monetary Policy, Liquidation Values, and Lending

We now turn to the main point of our paper which is to understand the effect of monetary policy on bank lending behavior. We analyze the effect of changes in R, the supply of loanable funds, on liquidation values, interest rates, and lending when liquidation values are determined endogenously. This is done by considering the effect of changes in R on the pricing function $p(L;R)$. We say that monetary policy is 'ineffective at R' if a marginal increase in the supply of funds by the central bank above R does not change the equilibrium amount of lending by banks to firms. Similarly, we say that monetary policy is fully effective if there exists a value of loan supply, R, such that in the associated equilibrium aggregate lending from banks to firms achieves its maximal possible value – $AL^{max} = \int_0^I BdG(B)$.

As a first step in analyzing the impact of changes in R, it is easy to see from Proposition 2 that $p(L;R)$ is non-decreasing in the loan supply R: i.e., adding liquidity to the economy does not decrease the date 1 price of liquidated assets.Figure 4 illustrates this by presenting the impact of

[17] This effect is similar to the analysis of Diamond and Rajan (2001) which shows that an adverse effect of liquidity provision is to raise real interest rates which may lead to more bank failures and lower subsequent aggregate liquidity.

an increase in the supply of funds from R^1 to R^2. By Proposition 2, the pricing function $p(L; R^2)$ is identical to $p(L; R^1)$ on the interval $L \leq \bar{B}(R^1)$, with both equal to $P(L, 0)$. For L between $\bar{B}(R^1)$ and $\bar{B}(R^2)$, by Proposition 2 again, the pricing function $p(L; R^2)$ is also equal to $P(L, 0)$. Finally, for $L > \bar{B}(R^2)$, the new pricing function is decreasing in L and equal to $P(\bar{B}(R^2), (B^*)^{-1}(\bar{B}(R^2)))$. As can be seen in the figure, $P(L, 0)$ therefore serves as an envelope of $p(L; R)$: the two functions are equal up to the point $\bar{B}(R)$, while $P(L, 0)$ is greater than $p(L; R)$ for L greater than $\bar{B}(R)$. The behavior of $P(L, 0)$ turns out to be crucial in understanding the effect of changes in the loan supply on lending, liquidation values and interest rates. Indeed, we have that:

Corollary 2. *Consider a loan supply R. Banks will lend out R in loans if and only if $P(\bar{B}(R), 0) \geq \bar{B}(R)$.*

Corollary 2 is a direct result of Proposition 2 and is quite intuitive. First, in order to extract R in loans from the banking sector, the value of collateral must be at least $\bar{B}(R)$. Otherwise, if the value of collateral, L, is less than $\bar{B}(R)$, no firm will be able to borrow more than L, so that the maximal effective demand will be $\int_0^L BdG(B)$ which is less than the loan supply R $(= \int_0^{\bar{B}(R)} BdG(B))$. On the other hand, if R is indeed lent out, the marginal firm obtaining financing will have a borrowing requirement of $\bar{B}(R)$ (by definition of $\bar{B}(R)$). Thus, the *maximal* value of collateral when R is lent out is $P(\bar{B}(R), 0)$, i.e. when R is lent out at an equilibrium interest rate is zero. Corollary 2 states that if the maximal value of collateral conditional on R being lent out $(P(\bar{B}(R), 0))$ is smaller than the minimal amount of collateral required to extract R $(\bar{B}(R))$, then R will not be lent out. In contrast, R will be lent out if the maximal collateral value implied by a liquidity injection of R is greater than the minimal value of collateral required to extract R: the equilibrium interest rate and liquidation value will adjust to equate effective loan demand to loan supply, R.

Based on Corollary 2 and Proposition 2, we can analyze the general equilibrium effects of the supply of loanable funds. Proposition 3 provides a formal characterization of the three types of equilibria that arise.

Proposition 3. *Consider the pricing function $P(L, 0)$.*

(i) **The conventional equilibrium:** If $P(L, 0) > L$ for all $0 < L \leq I$ then aggregate lending increases one-for-one with increases in the loan supply R on the range $0 \leq R \leq ALmax$. Thus, monetary policy is effective at any level of reserves $R \leq ALmax$.

(ii) **The credit trap equilibrium:** If $P(L, 0)$ and L intersect at L^*, with $P(L, 0) > L$ for $0 < L < L^*$ and $P(L, 0) < L$ for $L > L^*$, monetary policy is effective up to the loan supply R^* satisfying $\bar{B}(R^*) = L^*$. Beyond R^*, monetary policy is ineffective: rather than lending to firms, banks invest any excess reserves beyond R^*, and maximal aggregate lending is therefore R^*.

(iii) **The jump-start equilibrium:** Assume that $P(L, 0) < L$ for all $0 < L < L^*$ and $P(L, 0) = L$ for L=0 and $L = L^*$. Then, monetary policy is not effective up to the loan supply R^* satisfying $\bar{B}(R^*) = L^*$ and is effective at the loan supply R^*.

Proof. In the Appendix.

To understand Proposition 3 we consider each of the three equilibrium types in turn.

First, consider the conventional equilibrium in case (i) in which $P(L, 0) > L$ for all $0 < L \leq I$ (as will be discussed in section 3.3, this is the case of relatively high liquidity in the corporate sector). Since for any R, we have that $P(\bar{B}(R), 0) \geq \bar{B}(R)$, by Corollary 2 R is lent out. Monetary policy, in this equilibrium, is therefore fully effective: increases in R are matched one to one with increases in aggregate lending.

Figure 4 demonstrates this conventional equilibrium. Increases in R shift up the pricing function $p(L; R)$ as described in Proposition 2. This increase in $p(L; R)$ implies that the equilibrium liquidation value – i.e. the price of assets – shifts up as well (from L_1^* to L_2^* in the figure). The overall chain of events of an increase in loan supply can be summarized as follows: The increased loan supply is lent out to the corporate sector; the increased liquidity in the corporate sector increases collateral values; and finally, the increase in collateral values increases firm debt capacity and enables the increase in loan supply.

The effect on equilibrium interest rates of a shift in loan supply is less clear cut. This is best demonstrated in Figure 5 which graphs loan supply and demand as a function of interest rates, r. The main point is that *effective* demand for loans is not just a function of the loan interest rate, but is also influenced by collateral values; Firm borrowing in the model is determined both by their desire to borrow as well as their ability to do so. Loan demand can thus be represented by the function $D(r; L^*)$, where L^* is the equilibrium collateral price. As can be seen in the figure, an increase in R has two effects. First, loan supply shifts out. Second, effective loan demand shifts out as well – as discussed above, equilibrium liquidation values increase, thereby increasing firm borrowing capacity. The outward shifts in both loan supply and loan demand cause aggregate lending to unambiguously increase, but the net effect on the interest rate is ambiguous. If loan demand shifts out sufficiently – due to a large increase in collateral prices – there can be situations in which the interest rate remains constant or even rises as loan supply R increases. Put differently, in a conventional equilibrium large changes in aggregate lending and investment can be associated with small changes in interest rates. This is consistent with evidence that monetary shocks have large real effects, even though empirical studies show that components of aggregate spending are not very sensitive to cost-of-capital variables (see e.g. Bernanke and Gertler 1995).

Consider now the credit trap equilibrium represented in case (ii) of Proposition 3. In this equilibrium, monetary policy is ineffective at any point after R^*. To see this formally note that for any $R < R^*$, $\bar{B}(R) < \bar{B}(R^*) = L^*$. Thus, the condition stated in case (ii), $P(\bar{B}(R), 0) \geq \bar{B}(R)$ in the region $R < R^*$: i.e. in this region, the implied value of collateral conditional on R being lent out is larger than the minimum required collateral value to actually extract R. By Corollary 2 this implies that banks will successfully lend R out. In contrast, for any $R > R^*$, $P(\bar{B}(R), 0) < \bar{B}(R)$, which means that in this region, the implied value of collateral conditional on R being lent out is *smaller* than the minimum required collateral value to actually extract R. By the same corollary, any $R > R^*$ will therefore not be lent out.

The equilibrium is depicted in Figure 6a. If the central bank sets reserve level at $R < R^*$, there is a positive equilibrium liquidation value in which aggregate lending is R (L_1 in the figure). However, monetary policy is completely ineffective at any point beyond R^*. As can be seen in the figure, as R increases beyond this point, the sole positive equilibrium liquidation value where p intersects the 45 degree line remains L^*. Realized demand thus does not change as R increases above R^*. The equilibrium collateral value remains at L^*, realized lending remains at R^* (with the difference $R - R^*$ invested by banks), and, based on Theorem 2(i), the equilibrium interest rate is constant at zero.

The intuition of this credit trap equilibrium is that for any additional loan supply above R^* to actually be lent out by banks, liquidation values need to be sufficiently high. However, when the implied pricing function p is comparatively low (as depicted in Figure 6a), the increase in date-1 liquidation values associated with a marginal increase in the amount of aggregate lending beyond R^* is not sufficient to induce banks to actually lend the additional funds at date 0. Monetary policy thus becomes ineffective above the loan supply R^*: the only equilibrium has liquidation values equal to L^* and aggregate lending fixed at R^*.

As an extreme case of a credit trap, when $P(L, 0) < L$ for all $L > 0$ monetary policy is completely ineffective: no matter the level of loan supply held by banks, the only equilibrium is one in which liquidation values are zero, and hence aggregate lending is zero as well. This can be seen in Figure 6b, where regardless of the level of R, the only point where P intersects the 45 degree line is at zero. Again, the intuition is that for any level of loan supply R, the price of liquidated assets which results when R is lent out by banks is smaller than the minimum liquidated value required to actually extract R in loans from banks.

Consider now the jump-start equilibrium depicted in case (iii) of Proposition 3. By Corollary 2, banks will not lend out any amount of loan supply $0 < R < R^*$, since for any such R, $P(\bar{B}(R), 0) < \bar{B}(R)$ – the value of collateral assuming that R is lent out is smaller than the minimum value needed to extract R. In contrast, if the level of loan supply is R^* then $P(\bar{B}(R^*), 0) = \bar{B}(R^*)$. This implies that the collateral value $L^* = \bar{B}(R^*)$ satisfies the rational expectations equilibrium requirement and that the entire loan supply R^* will be lent out. Thus, only if the central bank raises the loan supply to R^* will banks lend out funds. The jump-start equilibrium therfore demonstrates how a policy of 'quantitative easing' may successfully reignite bank lending. As exhibited in Figure 7, for any loan supply $R_1 < R^*$, the only equilibrium has a liquidation value of $L = 0$ and no lending – banks hoard all reserves.[18]. Over the region $[0, R^*)$ monetary policy is thus completely ineffective. In contrast, when the central bank acts forcefully enough – i.e. by injecting R^* in reserves into the banking sector – another equilibrium arises in which liquidation values are high (L^* in the figure) and lending is jump started. This equilibrium arises due to the feedback effect between lending and collateral values: lending is high precisely because collateral values are large enough to support it, while collateral values are high because lending increases liquidity in the corporate sector. Note that the efficacy of 'quantitative easing' depends crucially on the behavior of the pricing function P – i.e. on how collateral prices vary with corporate liquidity. Indeed, following a policy of 'quantitative easing' in a credit trap equilibrium (where P satisfies the conditions in 3(ii) rather than those in 3(iii)) will be fruitless.

[18] To see this note that for any $R < R^*$, the only value where $P(L; R)$ equals L is $L = 0$

4.2. Exogenous Changes in Corporate Liquidity: Fiscal Policy and Productivity Shocks

In this subsection we examine the effects of an exogenous change in corporate liquidity by analyzing shocks to date 1 cash flow X_1. Changes in X_1 can be viewed in two ways. The first is simply as representing a productivity shock – which, since there is no asymmetric information in the model – both firms and banks observe. The second reason for a change in date-1 corporate liquidity is changes in fiscal policy. For example, if the government reduces the corporate tax rate, τ, date-1 cash flow of firms will increase to $(1-\tau)X_1$. Alternatively, government changes in the size of an investment tax credit would change date-1 corporate liquidity as well. This can be thought of as varying θ in firm cash flows $(1-\tau)(X_1-\theta I)$.

Since we are now interested in the effects of changes in X_1, we rewrite the indirect pricing function, p, as $p(L,R;X_1)$. In the appendix we show that holding constant the liquidation value, L, and loan supply, R, an increase in X_1 increases date-1 liquidity in all firms.[19] Assuming that collateral prices can only increase when date-1 corporate liquidity increases in all firms, we have that $p(L,R;X_1)$ is increasing in X_1.[20]

Consider the conventional equilibrium case described in Case (i) of Proposition 3. We have:

Proposition 4(i). *Assume that the conditions in Proposition 3(i) hold. For any level of loan supply R, an increase in X_1 increases the equilibrium liquidation value L, increases the equilibrium interest rate r, but does not affect the equilibrium amount of loans provided by the banking sector.*

The intuition of Proposition 4(i) is quite simple: In the conventional equilibrium of Proposition 3(i), any loan supply is lent out in full. The main effect of an increase in X_1 is to increase date-1 corporate liquidity and hence to raise the equilibrium collateral value of assets. (This is exhibited in Figure 8 where as a result of the increase in X_1, $p(L;R,X_1)$ rises, implying a higher liquidation value.) As the equilibrium liquidation value of assets rise, effective demand for loans increases which, in turn, increases the equilibrium interest rate. Thus, in a conventional equilibrium, an increase in X_1 caused, say, by expansionary fiscal policy, does not increase aggregate lending. However, to the extent that collateral values are determined by liquidity in the corporate sector,

[19] This statement is not completely trivial, as increases in X_1 are associated with higher equilibrium interest rates which, all else equal, reduce the amount of liquidity in firms.

[20] For simplicity, we make the assumption that p is *strictly* increasing in X_1. Alternatively, we could assume that p is increasing in X_1 in a region $[0,\bar{X}_1]$. With the latter assumption, all of the following propositions should be interpreted as confined to this region of X_1.

such expansionary fiscal policy will increase liquidation values and interest rates.

Consider now the effect of an increase in date-1 cash flow, X_1, in the case of a credit trap equilibrium as described in Proposition 3(ii). We have the following proposition:

Proposition 4(ii). *Assume that the conditions in Proposition 3(ii) hold so that the economy is in a credit trap. An increase in X_1 increases the maximal aggregate loan supply which the banking sector can successfully lend to firms.*

The intuition for Proposition 4(ii) is that an exogenous increase in date-1 liquidity increases asset values. This increase in liquidation values, in turn, supports higher lending by banks. The increased lending by banks further increases corporate liquidity and so collateral values increase further. Thus, a multiplier effect arises, where liquidity-induced increases in collateral values and lending amplify one another. By circumventing banks and directly injecting liquidity into the corporate sector, fiscal policy can therefore ease a credit trap equilibrium.

This process is demonstrated in Figure 9. First note that in a credit trap equilibrium the maximal liquidation value of assets is the L^* satisfying $P(L, 0; X_1) = L$. The corresponding maximal aggregate amount of loans that banks will be willing to provide to firms is then $\bar{B}^{-1}(L^*)$. Consider now a shift from X_1^L to X_1^H arising from an expansion in fiscal policy (such as a cut in corporate tax rates). In the original equilibrium, the top liquidation value was L_1^* satisfying $P(L_1^*, 0; X_1^L) = L_1^*$. The exogenous increase in corporate liquidity from X_1^L to X_1^H will raise the collateral pricing function P. This means that the implied value of assets, assuming a liquidation value of L_1^* and an interest rate of zero, rises from $P(L_1^*, 0; X_1^L)$ to $L_2^* := P(L_1^*, 0; X_1^H)$. This higher level of collateral values will support a higher level of lending (equal to $\bar{B}^{-1}(L_2^*)$) which will imply a still higher liquidation value level of $L_3^* := P(L_2^*, 0; X_1^H)$. The initial increase in collateral values due to the increased liquidity provided by the expansionary policy is multiplied in the feedback loop between lending, liquidity, and collateral values. The process converges at the point L_H^* where $P(L, 0; X_1^H) = L$.

This multiplier effect can also cause small exogenous changes in corporate liquidity to have large, discrete effects on lending. Consider the credit trap case depicted in Figure 10. The maximal collateral value is L_1^* and the corresponding maximal loan amount is $\bar{B}^{-1}(L_1^*)$. An increase in X_1 due to expansionary fiscal policy increases the pricing function to $P(L, 0; X_1^H)$, causing a jump in the maximal collateral value and maximal loan amount to be L_2^* and $\bar{B}^{-1}(L_2^*)$, respectively.

By circumventing financial intermediaries and providing direct liquidity injections, fiscal policy increases the maximal borrowing capacity of firms – as exhibited in the increased maximal liquidation value from L_1^* to L_2^* – and enables liquidity to be pulled out of banks. With fiscal policy in place, monetary policy serves to *push* out liquidity from the banking sector to the corporate sector (in the example, by increasing loan supply from $\bar{B}^{-1}(L_1^*)$ to $\bar{B}^{-1}(L_2^*)$) employing in the process the positive feedback loop between lending, liquidity and increased collateral values. Lending is therefore jump-started through a push/pull mechanism, where monetary policy serves to push and fiscal policy serves to pull out liquidity from financial intermediaries into firms.

As a final point, interpreting changes in X_1 as productivity shocks leads to a 'sudden stop' effect: small changes in productivity can cause a large reduction in both collateral prices and aggregate lending. Indeed, reducing date 1 cash flow from X_1^H to X_1^L reduces equilibrium collateral values from L_2^* to L_1^* and aggregate lending from $\bar{B}^{-1}(L_2^*)$ to $\bar{B}^{-1}(L_1^*)$ (see Figure 10). The intuition is that a small reduction in date-1 liquidity (X_1 decreasing) reduces collateral values, which reduces lending, which further reduces collateral values. This process reinforces itself until it reaches a low collateral value and low lending equilibrium.

4.3. The Effects of Initial Liquidity

In this subsection we analyze how the initial level of liquidity in the corporate sector affects successful monetary policy interventions. We show that if date-0 corporate liquidity is sufficiently low when the central bank decides to intervene, such interventions will not be successful in that banks will not increase lending – put differently, credit traps are likely to arise when initial corporate liquidity is low.

Formally, we analyze the model's comparative statics with respect to the distribution of borrowing requirements, G. Since each firm's borrowing requirement B is equal to $I - A$, the difference between its internal wealth and the required investment outlay, increases in firm borrowing requirements are associated with decreases in initial corporate liquidity, all else equal. Thus, if G and G' are two distributions of firm borrowing requirements with G' first order stochastically dominating G, liquidity in the corporate sector is higher under the distribution G as compared to the distribution G'. Further, we denote for every distribution G, the aggregate date-0 liquidity in the corporate sector as $W(G) := \int_0^I (I - B) dG(B)$.

Clearly, the smallest level of aggregate corporate liquidity in date 0 is zero – this is the situation in which all firms have zero internal wealth, and thus all firms have a borrowing requirement of I. For what follows, it turns out useful to define P_0 to be the date-1 price of collateral assuming that (1) Aggregate liquidity was zero at date 0 and (2) In date 0 all firms were provided financing at a zero interest rate, so that in date 1 all firms have liquidity $X_1 - I$.

The next proposition shows that if X_1 is sufficiently small, low levels of date-0 aggregate corporate liquidity necessarily involve credit traps:

Proposition 5. *Assume that X_1 is sufficiently small so that $P_0 < I$. Then there exists a threshold level of aggregate liquidity $\bar{W}$ such that for all aggregate liquidity levels $W < \bar{W}$, the economy is in a credit trap equilibrium.*

The intuition of Proposition 5 is as follows. In providing liquidity to the corporate sector, banks need to rely on the aggregate liquidity in the corporate sector, as this determines, in part, the value of collateral and hence the strength of firms' balance sheets. Therefore, when injecting liquidity into the banking sector in the hope of increasing bank lending and jump starting the feedback loop between lending and collateral, the central bank must rely on the initial level of liquidity in the corporate sector. Essentially, the central bank is leveraging the initial level of aggregate liquidity to inject additional liquidity into the corporate sector. Proposition 5 then states that if this initial level of aggregate liquidity is sufficiently low, the central bank's ability to leverage existing liquidity to increase lending will be limited – i.e. the economy will be in a credit trap equilibrium where banks will not increase lending beyond a certain point, regardless of shifts in the loan supply.

The next proposition states that if an economy is in a credit trap, decreases in date-0 corporate liquidity intensify the severity of the credit trap: The maximal level of lending and the maximal value of collateral both decrease.

Proposition 6. *Consider an economy with a date-0 distribution of borrowing needs G_1 which is in a credit trap equilibrium. Denote by R_1^* the maximal aggregate lending provided by banks and L_1^* the maximal collateral value in the credit trap equilibrium. If G_2 stochastically dominates G_1 (implying that date-0 liquidity in the corporate sector is higher under G_1) then under the distribution G_2:*

(i) The economy will be in a credit trap equilibrium.

(ii) The maximal aggregate level of loans provided by banks, R_2^*, will be smaller than R_1^*.

(iii) The maximal value of collateral, L_2^*, will be smaller than L_1^*.

Proposition 5 and 6 make clear the importance of initial aggregate liquidity when the central bank tries to intervene and inject liquidity into the banking sector. Proposition 5 states that if aggregate liquidity is too low at the point of intervention, the economy will be stuck in a credit trap, while Proposition 6 states that as aggregate liquidity decreases, this credit trap becomes more severe.

5. Summary and Policy Implications

This section summarizes the main results of our model and discusses some of the attendant policy implications. Our model generates three types of equilibria, each with its own implications. The underlying theme in all three equilibria is a feedback loop between increased loan provision by banks and increased liquidation values of assets.

5.1. The Conventional Equilibrium

In the first, conventional equilibrium, monetary policy can successfully influence aggregate lending activity. The chain of linked events, which combines the lending and balance sheet channels of monetary policy, unfolds as follows: When the Fed eases monetary policy, bank reserves rise. The increased liquidity in the banking sector enables banks to increase lending, and hence serves to increase liquidity in the corporate sector. This, in turn, improves collateral values of real assets and therefore strengthens firms' balance sheets. The expected improvement in firms' balance sheets reduces financial frictions and justifies the banks' initial decision to convert the (Fed induced) increase in reserves into additional corporate lending. The rational expectations equilibrium thus makes a full circle: (1) increased liquidity in the banking sector leads to (2) increased lending to the corporate sector, which causes (3) improved firm balance sheets, which justifies (4) the increased bank lending. In this conventional equilibrium, an easing of monetary policy is therefore translated into three effects: an increase in lending, an increase in collateral values, and a change in the interest rate associated with bank lending.

The effect of monetary policy in a conventional equilibrium is nicely demonstrated by considering the market for loanable funds (see Figure 5) where an expansion in monetary policy has two effects. The first is an outward shift in the supply of intermediated loans. The second is an outward shift in loan demand – as described above, collateral values rise, which increases firm borrowing capacity, thereby raising the effective demand for loans. The outward shift in supply and demand for loans associated with a monetary expansion increases aggregate lending unambiguously. However, the effect on the interest rate of loans is ambiguous. This is because the increase in collateral values and the associated outward shift in the effective demand schedule for loanable funds places upward pressure on the equilibrium interest rate. Indeed, if loan demand shifts out significantly, interest rates may remain constant (or even rise) as loan supply increases. Thus, in a conventional equilibrium large changes in aggregate lending and investment can be associated with small monetary policy induced changes in interest rates. This is consistent with empirical evidence showing that monetary shocks have large real effects, even though components of aggregate spending are not very sensitive to cost-of-capital variables (see e.g. Bernanke and Gertler 1995).[21]

5.2. The Credit Trap Equilibrium

The second type of equilibrium is characterized by credit traps – beyond a certain level, any easing of monetary policy is completely ineffective in increasing lending – banks simply hold on to the additional reserves created by the Fed. In this equilibrium lending is constrained by low collateral values. To increase collateral values, the Fed would need to induce banks to inject liquidity into the corporate sector so as to increase firms' ability to purchase the assets of other industry participants. A credit trap arises when for any given level of loan supply (above a certain threshold), the collateral value implied by that loan supply being lent out is less than the minimum collateral value required to actually extract the loan supply in the first place.

As an example, consider the case where a central bank is trying to inject liquidity (through the banking system) into the corporate sector. Without any additional loans, aggregate liquidity in the corporate sector is \$1,500B. Assuming that the aggregate value of collateral is worth one tenth of aggregate liquidity, this implies an aggregate collateral value of \$150B. By the same assumption, any incremental dollar of loans to the corporate sector will increase aggregate collateral by \$0.1. Finally, assume that to inject \$x in loans, aggregate collateral values need to be equal \$0.3x. In this example it is easy to see that the maximum amount of lending that can be injected into the economy is that amount R which equates the level of collateral implied by R being lent out with the level of collateral required to extract R. Put differently, it solves the equation $150 + R/10 = 0.3L$,

[21] Indeed, the difficulty in finding a quantitatively important costs-of-capital effect is what gave rise to the credit-channel literature.

implying a maximal level of lending of \$750B. At this level, the implied collateral value is \$225B which exactly equals the amount required to extract \$750B in loans from the banking sector. Any additional amount of reserves above and beyond this amount will simply be held by the banks. Thus, for example, \$800B will not be lent out: the required collateral value to extract \$800B is $0.3 * 800 = \$240B$ while the implied level of collateral assuming that \$800B is actually lent out is only $150 + 0.1 * 800 = \$230B$.

More generally, when providing liquidity to the corporate sector banks need to rely on the aggregate liquidity already present in the corporate sector. This is because liquidity in the corporate sector determines, in part, the value of collateral and hence the strength of firms' balance sheets. Thus, when the central bank injects liquidity into the banking sector in the hope of increasing bank lending, it *too* must rely on the initial level of liquidity in the corporate sector. Essentially, the central bank is leveraging the initial level of aggregate liquidity to inject additional liquidity into the corporate sector. Proposition 5 in the previous section states that if this initial level of aggregate liquidity is sufficiently low, the central bank's ability to leverage existing liquidity to increase lending will be limited – i.e. the economy will be in a credit trap equilibrium where banks will not increase lending beyond a certain point, regardless of shifts in the loan supply. Further, Proposition 6 shows that reductions in initial aggregate liquidity will make this credit trap more severe. This result underscores the danger of a central bank beginning to ease monetary policy when existing liquidity in the corporate sector is too low. Since the central bank is leveraging preexisting liquidity to support additional lending, if preexisting corporate liquidity is too low, the maximal amount of lending which banks can be induced to lend will be low as well.

Khwaja, Mian, and Zia (2007) provide evidence from Pakistan that is consistent with a credit trap equilibrium. One of the consequences of the 9/11 events and Pakistan's ensuing corporation with the U.S. was a large inflow of capital into Pakistan, accompanied by a positive aggregate demand shock. However, despite the availability of abundant credit and investment needs, banks were reluctant to lend. Khwaja, Mian, and Zia (2007) argue that the reason for the lack of lending by banks is driven by the fact that Pakistanian banks relied heavily on pledgeable assets and historical cash flow rather than expected future cash flows. This explanation is consistent with our model in which the extent of lending volume is driven by collateral values and available liquidity in the corporate sector rather than expected cash flows.

The central role played by initial corporate liquidity in determining bank lending leads also to a multiplier effect of preexisting aggregate liquidity. This is best understood through the feedback loop between liquidity, collateral values and lending. The Fed is leveraging preexisting aggregate liquidity in the corporate sector to support additional lending. Since additional lending leads to an increase in collateral values and thus to *further* lending, a liquidity multiplier effect arises: increases in preexisting aggregate liquidity increase maximal corporate liquidity more than one-to-one. Returning to the example above, if W represents the initial level of aggregate liquidity, the maximal amount of lending solves $W/10 + L/10 = 0.3L$.[22] The maximal amount that can be lent out, therefore, is $W/2$. Thus, every dollar increase in starting aggregate liquidity, increases the maximal level of liquidity by \$1.5.

While easing monetary policy does not increase bank lending in a credit trap equilibrium, *fiscal policy* can serve a role in reviving lending. Expansionary fiscal policy circumvents financial intermediaries and injects liquidity directly into the corporate sector. The liquidity multiplier effect thus leads to a fiscal policy multiplier: Consider, for example, a reduction in the corporate tax rate or a corporate investment tax credit.Either policy involves an exogenous direct increase in corporate liquidity which will serve to increase collateral values. The increase in collateral values enables additional lending, which raises collateral values still further, enabling even further lending. By directly increasing corporate liquidity, changes in fiscal policy can therefore jump start lending to the corporate sector.[23]

In sum, in a credit trap equilibrium there is a benefit to monetary and fiscal policy acting in concert; Monetary policy serves to push liquidity out from the banking sector to the corporate sector, while fiscal policy, by directly increasing corporate liquidity and collateral values, serves to pull out liquidity from the banking sector to the corporate sector. Importantly, when used on its own, monetary policy is powerless in disgorging liquidity from intermediaries since firm borrowing capacity (as implied by collateral values) are too low.

This result show that the impact of fiscal policy will be state-contingent and will depend crucially on the level of liquidity in the corporate sector. In the context of our model, the benefit of fiscal policy lies in its ability to directly inject liquidity into the corporate sector. Banks (including the central bank) can then leverage this liquidity into additional lending. However, in the con-

[22]While the underlying foundation is altogether different, this equation is similar to that behind the 'Keynesian Cross' in the standard IS-LM model which gives rise to the fiscal policy multiplier.

[23]Indeed, as discussed in section 3.1 in an extreme case, fiscal policy can give rise to a large, discrete jump in lending due to the addition of a second high collateral value equilibrium.

ventional equilibrium, there is no lack of liquidity in the corporate sector. As we show in section 3.2, expansionary fiscal policy does not increase lending, holding constant loan supply. Rather, its sole effect is to increase the interest rate on borrowed loans (which is caused by the outward shift in effective demand.) In contrast, in a credit trap equilibrium, corporate liquidity is lacking and thus fiscal policy can increase lending, as described above. Our model thus predicts a liquidity-contingent multiplier effect of fiscal policy. Assessing the magnitude of the fiscal policy multiplier using an unconditional average of historic estimates may therefore provide a misleading result as to fiscal policy efficacy.[24]

A natural question to ask is which type of fiscal policy is most effective in increasing private sector lending to firms in a credit trap equilibrium: corporate tax reductions, direct transfer to consumers, or government expenditures. A formal answer is beyond the scope of this paper. However, in the context of the model provided, since the beneficial effect of fiscal policy on lending stems from its impact on collateral values, the comparison between these three methods ultimately rests on their relative effectiveness in directly injecting liquidity into the corporate sector. Here, it seems that reductions in corporate tax payments - be it through tax rebates, corporate tax investments or reduction in tax rates - are most efficient in increasing corporate liquidity, to the extent that firms continue to pay corporate taxes during a downturn associated with a credit trap. In contrast, similar to the standard IS-LM framework, a fraction of any transfer to consumers will be saved, and thus not end up in the corporate sector. While these savings may end up bolstering balance sheets of financial institutions, say in the form of additional deposits in banks, this will have no effect on lending in a credit trap.Indeed, the main problem in a credit trap equilibrium is not the lack of liquidity in the banking sector, but rather insufficient liquidity and low collateral values in the *corporate* sector. Similarly to direct transfers to consumers, a large fraction of any amount of government spending will take the form of payments to labor, and thus dollar for dollar, this method will also be less effective in increasing liquidity in the corporate sector as compared to direct transfers to firms.

[24]This topic became particular important during the debate regarding the fiscal stimulus passed in the first quarter of 2009.

5.3. The Jump-Start Equilibrium

In the third equilibrium, which we name the 'jump start' equilibrium, monetary policy becomes effective only when the Fed acts sufficiently forcefully in injecting reserves to the banking sector. If the Fed increases reserves by only a moderate amount, credit remains trapped in the banking sector and interest rates are stuck at zero. Similar to the credit trap equilibrium, banks rationally understand that when they can employ only a moderate amount of reserves to lend to firms, the implied collateral values are too small to justify any actual lending. In contrast, when the Fed eases monetary policy sufficiently, a high lending and high collateral values equilibrium arises: banks lend out their large amount of loan supply, corporate liquidity increases, and hence collateral values are sufficiently high to justify the large amount of lending.

While this third type of equilibrium is similar to a credit trap equilibrium - over a certain range of loan supply, monetary policy is ineffective in spurring additional lending - the policy implications are quite different. In a credit trap equilibrium monetary policy cannot jump-start lending on its own and thus needs to rely on other actions such as expansive fiscal policy. In a 'jump-start' equilibrium the Fed can escape the credit trap and render monetary policy effective, but only if it acts forcefully enough. The 'jump-start' equilibrium provides, therfore, a justification for a quantitative easing strategy of monetary policy: The Fed increases the amount of reserves in the system while interest rates remain constant at zero, so that finally, when a reserve threshold is passed, the new equilibrium arises and lending commences.

Because of their different policy implications, determining in practice whether an economy is in a credit trap or jump-start equilibrium is a question of obvious importance. This question seems to be difficult to answer: As long as the Fed increases reserves only moderately, the two equilibria will be observationally equivalent, with both aggregate lending and equilibrium interest rates unresponsive to the easing in monetary policy. Thus, to make the distinction between the two equilibria, the Fed will have to rely on factors which are not easily observable. Indeed, as discussed in Section 3, the crucial factor determining which equilibrium arises is the level and shape of the collateral pricing function $P(L, 0)$ i.e. how does an exogenous increase in corporate liquidity affect the implied value of collateral (assuming an interest rate of zero). Proposition 5 shows that when aggregate liquidity in the corporate sector is low, the economy will be in a credit trap equilibrium, while Proposition 3 shows that if aggregate liquidity is sufficiently high, a jump-start equilibrium will tend to arise when P is convex in liquidation values.[25]

Determining the form of the collateral pricing function is difficult. Still, the existence of either of two factors will point towards convexity, and hence towards the jump-start equilibrium. The first is when the financial constraints of a relatively large fraction of firms are severe.[26] In such a situation, marginal increases in liquidation values will have an increasing impact on the quantity of firms able to obtain financing, and thus an increasing impact on corporate liquidity and collateral values. The second factor pointing towards convexity of the pricing function, and hence towards a jump-start equilibrium, is a positive correlation between a need for external finance and firm productivity. Under this condition, marginal increases in firm liquidation values will allow more productive firms to obtain financing, implying a greater ex-post amount of liquidity in the corporate sector. Hence, marginal increases in liquidation values will have a positive and increasing impact on collateral values, implying a convex collateral pricing function P.

6. Conclusion

We analyze the limitations of the 'credit channel' in transmitting monetary policy and identify three potential equilibria. The first equilibria is one in which monetary policy successfully influence aggregate lending activity. In this conventional equilibrium expansionary monetary policy translates into an increase in collateral values and lending. The second equilibrium is a 'credit trap' equilibrium, where any easing of monetary policy beyond a certain level is completely ineffective in increasing lending and aggregate lending is constrained by low collateral values. In the third equilibrium monetary policy becomes effective only when the central bank inject a large amount of reserves to the banking sector. The underlying mechanism in all three equilibria is a feedback loop between lending, corporate liquidity, and collateral values. We show that credit traps will arise when liquidity in the corporate sector is low. Under such circumstances there is room for joint action of monetary and fiscal policy in order to boost lending. While the 'jump-start' equilibrium provides theoretical justification for a policy of 'quantitative easing', we argue that differentiating between a credit trap and a jump-start equilibrium will be hard in practice.

[25] Although Proposition 3 does not require convexity, convexity is sufficient for a jump-start equilibrium, assuming that liquidity in the corporate sector is high enough (i.e. $P(I, 0) > I$).

[26] Formally, G, the density function of firm internal wealth is skewed to the right.

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Appendix

To be added.

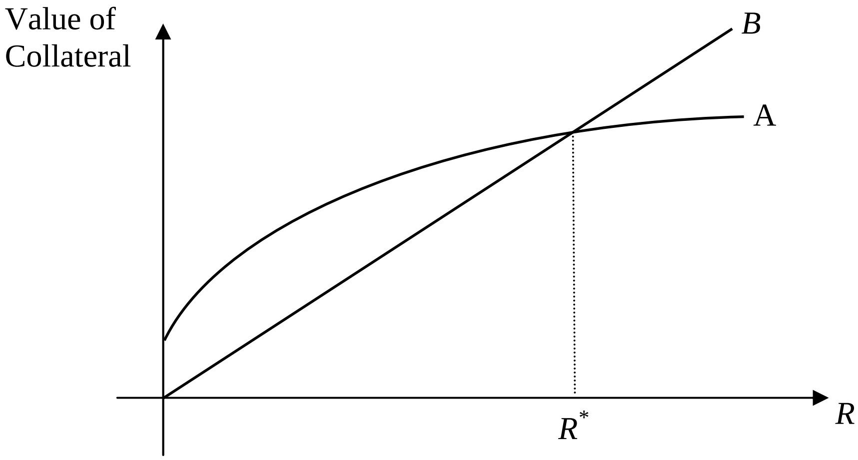

Figure 1a. A credit trap equilibrium: Curve A depicts the value of collateral assuming that an amount R is lent out by banks. Curve B depicts the minimum level of collateral needed to extract R in loans from banks. R^* is the maximal level of reserves that will be lent out in equilibrium.

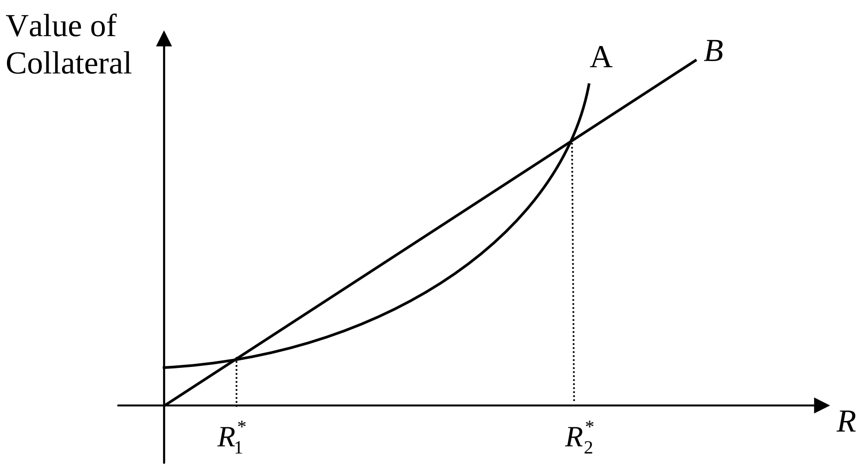

Figure 1b. A jump-start equilibrium: Curve A depicts the value of collateral assuming that an amount R is lent out by banks. Curve B depicts the minimum level of collateral needed to extract R in loans from banks. R^*_2 can be lent out in equilibrium, but no amount below it and above R^*_1 will be lent out.

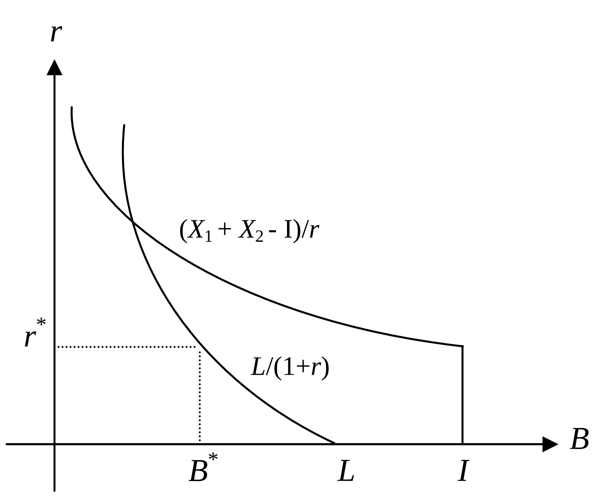

Figure 2. This graph shows the borrowing requirement, B, of the marginal firm able and willing to borrow funds at an interest rate, r.

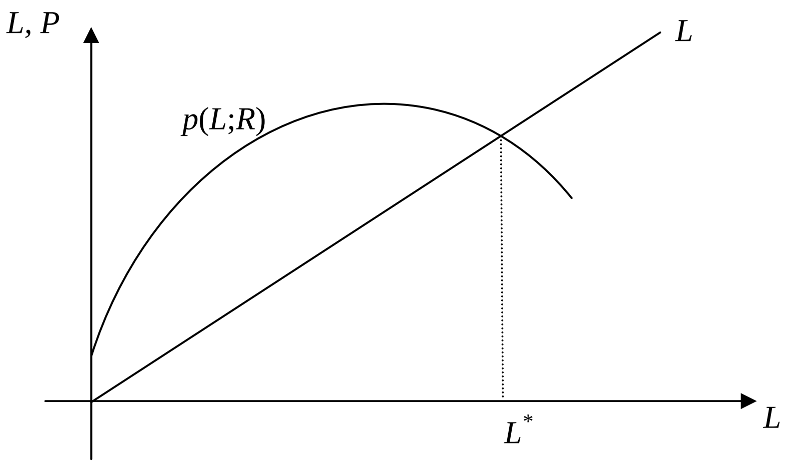

Figure 3. The pricing function $p(L;R)$ provides the implied price of assets assuming a liquidation value L and loan supply R. The equilibrium liquidation value is at L^*.

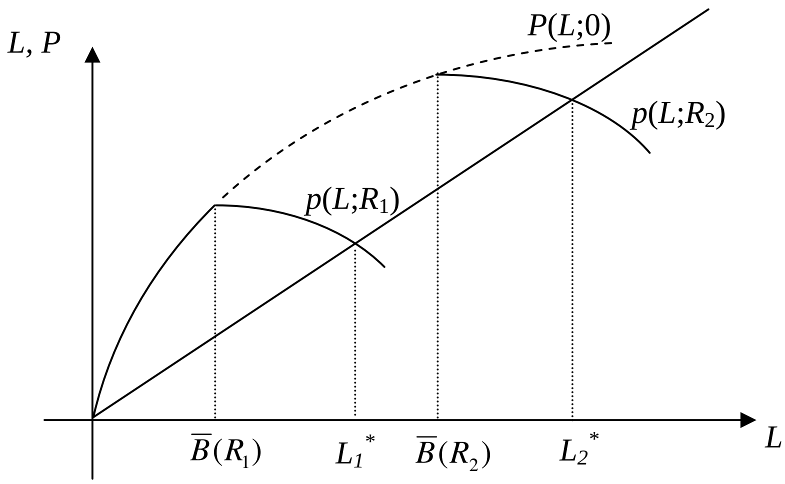

Figure 4. The conventional equilibrium. This figure presents the pricing function $p(L;R)$ for two levels of loan supply, R_1 and R_2. This pricing function represents the implied price of assets assuming a liquidation value L and loan supply R.

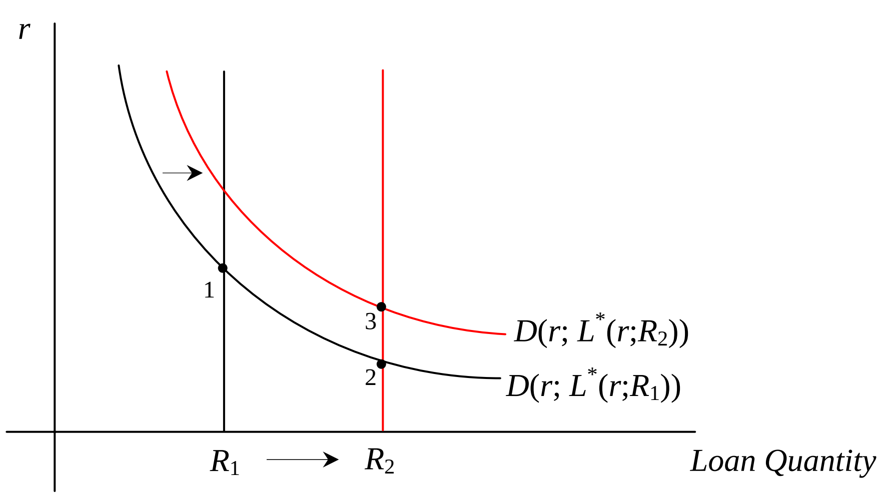

Figure 5. The market for loanable funds: aggregate loan supply and aggregate loan demand as a function of interest rate r for two levels of loan supply, R1 and R2. An increase in R shifts out both loan supply and effective loan demand.

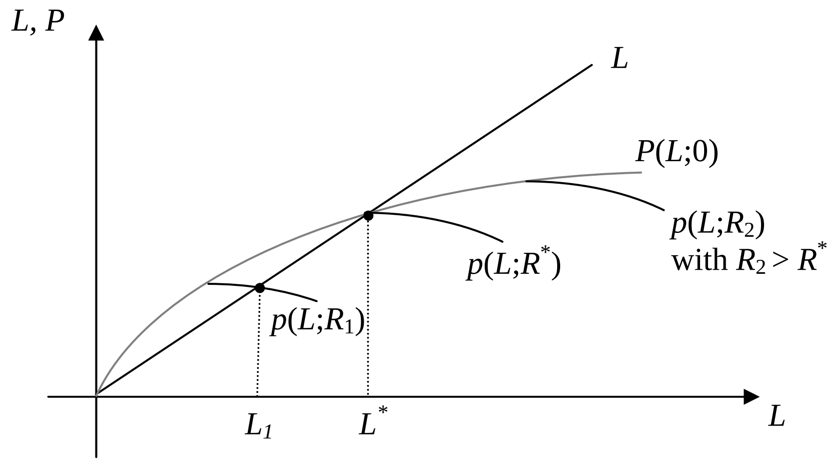

Figure 6a. The credit trap equilibrium. The pricing function $p(L;R)$ represents the implied price of assets assuming a liquidation value L and loan supply R.

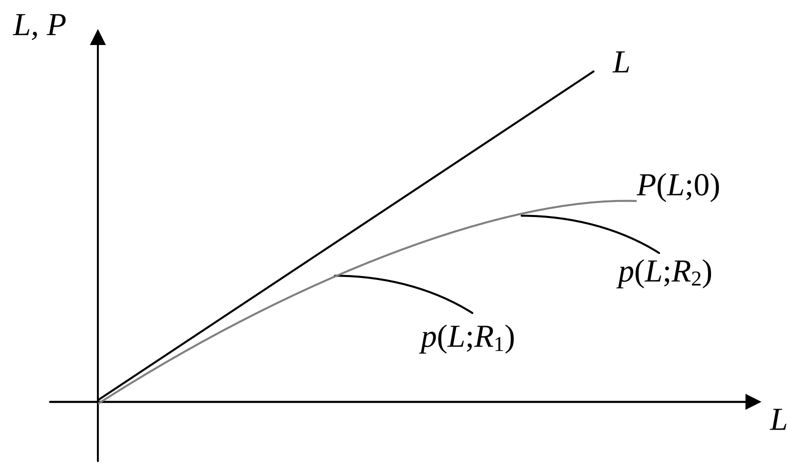

Figure 6b. A severe credit trap with no lending in equilibrium. The pricing function $p(L;R)$ represents the implied price of assets assuming a liquidation value L and loan supply R.

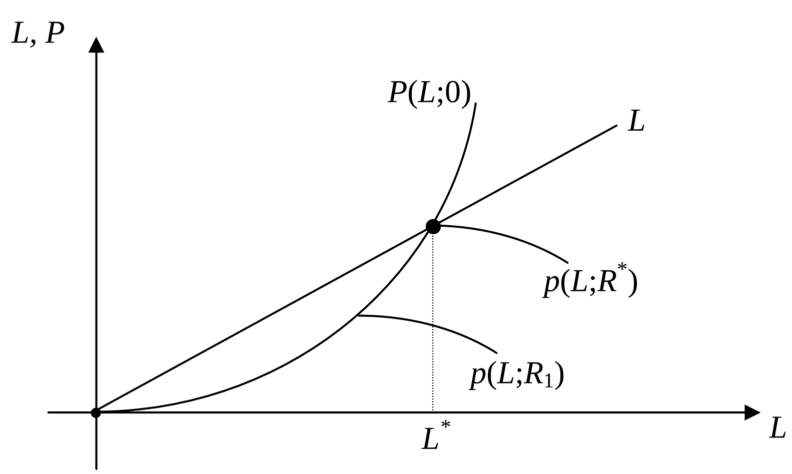

Figure 7. The jump-start equilibrium. The pricing function $p(L;R)$ represents the implied price of assets assuming a liquidation value L and loan supply R.

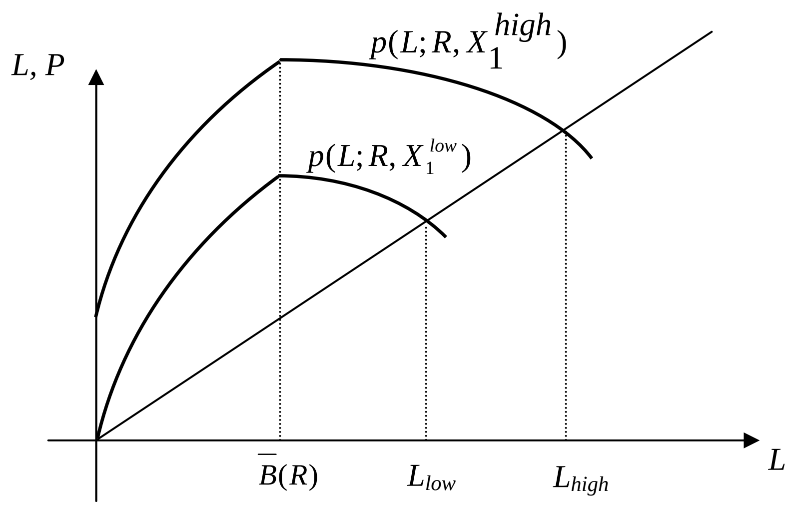

Figure 8. Exogenous shifts in date-1 liquidity, X_1. The pricing function $p(L;R, X_1)$ represents the implied price of assets assuming a liquidation value L and loan supply R.

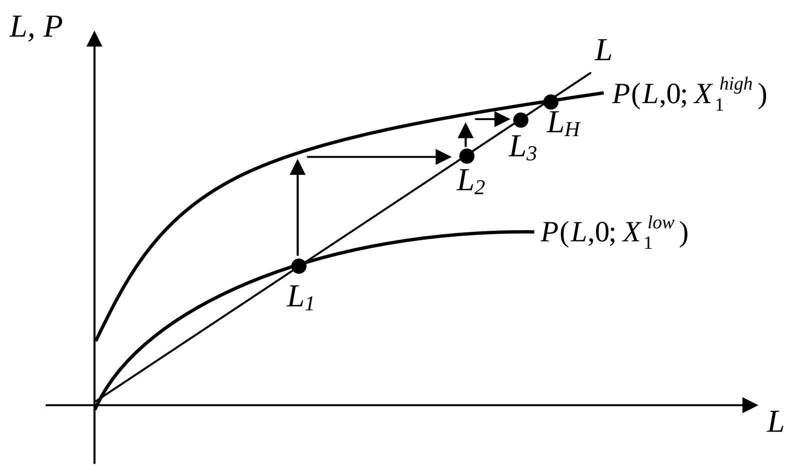

Figure 9. The effect of an exogenous increase in date-1 liquidity in a credit trap equilibrium.

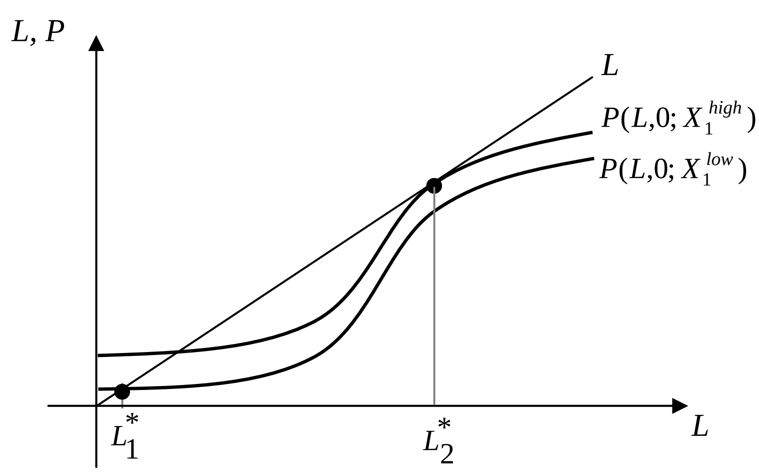

Figure 10. A large discrete effect implied by an exogenous increase in date-1 liquidity in a credit trap equilibrium.