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Maturity shortening and market failure

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Abstract:
Motivated by the financial crisis of 2007-2009 several papers have provided explanations for why liquidity may dry up during market stress. This paper also looks at this issue but focuses on the question as to why the liquidity crunch was not uniform across maturities. As funding pressures were felt particularly severe at longer maturities, central banks saw a high need to provide longer-term liquidity. The paper asks what market failure central banks were addressing by intervening and whether they took on unwarranted credit risk by providing other than ultra-short liquidity. I propose a model in which financial firms' expectations about the availability of longer-term liquidity in the future may affect their investment decisions today, even though they have full access to borrowing at the onset. These investment decisions may in turn impact on the willingness of lenders to provide future long-term liquidity. Central banks, by promising to provide long-term liquidity, can rule out the inefficient rational-expectations equilibrium in which firms choose short-term projects or prefund a future potential liquidity need out of fear of not being able to receive long-term funding in the future. The model shows that firms of high credit quality may be particularly prone to choosing inefficient investment decisions for this very reason.

Keywords:
Liquidity, Asymmetric Information, Debt maturity

JEL-Classification:
D82, G21, G32

Non-technical summary

During the financial crisis of 2007-2009, liquidity abruptly dried up for many financial institutions and securities markets. This liquidity crunch was, however, not uniform across maturities. Whereas financing was generally available at the very short end of the maturity spectrum, liquidity shortages were felt most severely at longer maturities. Among the measures central banks took to fight the crisis, several were particularly aimed at easing liquidity shortages at longer maturities.

This paper asks what market failure central banks were addressing by intervening and whether they took on unwarranted credit risk by providing other than ultra-short liquidity. I identify an expectations channel by which expectations about the availability of longer-term finance in the future may impact on financial firms' investment decisions today. More specifically, with imperfect knowledge about borrowers' investment decisions impatient lenders may at times only be willing to lend short-term out of fear that borrowers may not adequately compensate them for the provision of longer-term liquidity. If borrowers anticipate lenders' behavior they may choose investment projects that mature early and generate a low return, validating lenders' expectations. This may be true even if firms are able to prefund any future reinvestment need.

The model therefore allows for multiple rational expectations equilibria: In the good (efficient) equilibrium, firms expect to be able to get longer-term liquidity if they face a reinvestment need in the future. This makes them choose high-return but illiquid investment projects today. Lenders, in turn, correctly assume that high-return projects were chosen, making them willing to provide longer-term liquidity indeed. In the bad (inefficient) equilibrium, however, firms expect that only short-term liquidity will be available and they will therefore choose a low-return (but liquid) investment project. Lenders, on the other hand, are only willing to provide short-term finance since they correctly assume that firms chose the low-return project. Central banks can induce the efficient equilibrium if they credibly commit to provide long-term liquidity in the future.

Central bank intervention in the model is, however, only necessary if a reinvestment need is highly likely. Otherwise, firms will choose the high-return project no matter what maturity they expect to obtain. In addition, it is important to note that the model abstracts from the problem of moral hazard whereby central bank interventions weaken agents' incentives to develop funding arrangements that prove resilient during financial crises.

Nicht-technische Zusammenfassung

Während der Finanzkrise von 2007-2009 kam es bei vielen Finanzinstituten und auf diversen Wertpapiermärkten zu erheblichen Liquiditätsengpässen. Diese Engpässe waren allerdings nicht über alle Laufzeitensegmente hinweg gleich ausgeprägt. Während Liquidität über sehr kurze Laufzeiten im Allgemeinen noch zu bekommen war, waren Mittel über längere Laufzeiten kaum mehr verfügbar. Unter den diversen, von Zentralbanken ergriffenen, Krisenmaßnahmen zielten einige deshalb auf eine Lockerung der längerfristigen Refinanzierungsbedingungen ab.

Das vorliegende Papier geht der Frage nach, welches Marktversagen Zentralbanken adressierten und ob sie durch die Bereitstellung längerfristiger Refinanzierungsmittel unvertretbare Risiken in Kauf genommen haben. Dabei wird ein Erwartungskanal ausgemacht, nach dem Erwartungen über die künftige Verfügbarkeit längerfristiger Refinanzierungsmittel die Investitionsentscheidungen von Firmen beeinflussen. Bei unvollkommener Information über die von Schuldnern getätigten Investitionen werden Gläubiger mitunter die Laufzeit vergebener Kredite begrenzen aus Sorge, nicht angemessen für die Bereitstellung längerfristiger Mittel entlohnt zu werden. Wenn Schuldner dieses Verhalten antizipieren, werden sie Investitionsprojekte wählen, die eine kurze Laufzeit und eine geringere Rendite aufweisen, womit die Sorge der Gläubiger ex-post gerechtfertigt erscheint. Diese Dynamik kann selbst dann auftreten, wenn Firmen die Möglichkeit haben, einen potentiellen zukünftigen Liquiditätsbedarf vorzufinanzieren.

In dem vorgestellten Modell können folglich multiple rationale Erwartungsgleichgewichte auftreten. Im guten (effizienten) Gleichgewicht erwarten Firmen, dass sie bei einem etwaigen künftigen Refinanzierungsbedarf längerfristige Mittel zur Verfügung gestellt bekommen. Daraufhin wählen sie höher rentierliche, aber illiquide, Investitionsprojekte. Gläubiger sind in diesem Gleichgewicht bereit, bei Bedarf tatsächlich längerfristige Mittel bereitzustellen, da sie korrekt erwarten, dass die Firmen aufgrund der höher rentierlichen Investition in der Lage sind, sie angemessen zu entlohnen. Im schlechten (ineffizienten) Gleichgewicht erwarten Firmen demgegenüber, dass sie nur kurzfristige Mittel zur Verfügung gestellt bekommen. Deshalb wählen sie weniger rentierliche, dafür aber liquide, Investitionsprojekte. Gläubiger sind auf der anderen Seite tatsächlich nur bereit, kurzfristige Mittel bereitzustellen, da sie richtigerweise unterstellen, dass das Investitionsprojekt mit geringer Rendite gewählt wurde und sie folglich für die Bereitstellung längerfristiger Refinanzierung nicht angemessen entlohnt werden würden.

Zentralbanken können im Rahmen des Modells nunmehr das effiziente Gleichgewicht herbeiführen, indem sie glaubhaft versichern, bei Bedarf längerfristige Refinanzierungs-

mittel zur Verfügung zu stellen. Firmen werden daraufhin in höher rentierliche Projekte investieren, während private Gläubiger zu einer längerfristigen Mittelvergabe bereit sind. Eine tatsächliche Kreditvergabe durch die Zentralbank kann damit mitunter gar nicht erforderlich werden.

Eine Zentralbankintervention in Form der Ankündigung längerfristiger Liquiditätsbereitstelllung ist im vorliegenden Modell allerdings nur notwendig, wenn ein künftiger Refinanzierungsbedarf sehr wahrscheinlich ist. Andernfalls werden Firmen ohnehin in höher rentierliche Projekte investieren, selbst wenn sie nicht von einer längerfristigen Refinanzierung ausgehen. Des Weiteren ist zu bedenken, dass das Modell nicht andere Kanäle berücksichtigt, durch welche Zentralbanken das Verhalten von Firmen bzw. Investoren beeinflussen. Insbesondere vernachlässigt das Papier die Frage des moralischen Risikos, wonach eine Zentralbankintervention den Anreiz von Privatagenten schwächen kann, selbst für stabile Refinanzierungsquellen zu sorgen.

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Maturity Shortening and Market Failure[1]

1 Introduction

During the financial crisis of 2007-2009, liquidity abruptly dried up for many firms and securities markets. In particular, many financial institutions were able to borrow in the money markets only at prohibitive rates, if at all. This liquidity crunch was, however, not uniform across maturities. Whereas financing was generally available at the very short end of the maturity spectrum, liquidity shortages were felt most severely at longer maturities. The development of spreads between the London interbank offered rate (LIBOR) and the overnight index swap rate (OIS) at different maturities provides evidence for this.[2] During the crisis, spreads increased by more for longer maturities than for shorter ones whereas before the crisis there was little difference in the spreads across terms (Buiter (2008) and Thornton (2009)).

Among the measures central banks took to fight the crisis, several were particularly aimed at easing liquidity shortages at longer maturities. For example, the Eurosystem conducted exceptional long-term refinancing operations in August and September 2007. Starting in September 2008, it increased the number and frequency of operations with maturities of three and six months. Finally, it conducted fixed rate full-allotment refinancing operations with maturities of up to 12 months starting in June 2009. The Federal Reserve, for its part, extended the maturity of loans at the discount window from overnight to up to one month in August 2007. In December 2007, it started the Term Auction Facility (TAF) with loans of a 28-day maturity and extended the maturity to 84 days in August 2008. After the collapse of Lehman Brothers, it also created the Commercial Paper Funding Facility (CPFF) through which it purchased three-month commercial paper (CP) directly from eligible issuers.

The responses by central banks were motivated not least by concerns about the impact of liquidity shortages on the real economy. For example, in its press release announcing the creation of the CPFF the Federal Reserve stated: "[...] this facility should encourage investors to once again engage in term lending in the commercial paper market. Added

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[2]LIBOR rates are interest rates for unsecured, longer-term interbank lending, while OIS rates are a measure of secured, short-term interbank lending, often used as proxy for expectations of future Federal Reserve policy.

investor demand should lower commercial paper rates from their current elevated levels and foster issuance of longer-term commercial paper. An improved commercial paper market will enhance the ability of financial intermediaries to accommodate the credit needs of businesses and households."

To put the responses by central banks into perspective, it is important to keep in mind that emergency funding arrangements were already in place when the crisis hit. In particular, the discount window had prevented major disruptions in previous stress episodes. To the extent that banks saw a stigma to borrowing from the discount window, emergency lending operations could have been adjusted to make borrowing more anonymous (which the TAF did). And if institutions other than banks needed to be provided with emergency funding, the discount window or, for that matter, the TAF could have been opened up to accommodate their needs (which e.g. the Primary Dealer Credit Facility did). All in all, it is not obvious why the maturity of emergency lending operations also needed to be extended. In fact, if private lenders decreased the maturity of lending because credit risk had increased, central banks may have taken on too much risk by extending the maturity of their loans.

This paper looks at the behavior of providers of short-term liquidity such as money market funds. It is argued that these lenders may not cut the maturity of lending primarily out of concern about their own lack of funding sources (as some commentators have argued in the case of US money market funds). Instead, with imperfect knowledge about borrowers' investment decisions they may only be willing to lend at very short maturities out of fear that borrowers may not adequately compensate them for the provision of longer-term liquidity.[3] If borrowers anticipate lenders' behavior they may choose investment projects that mature early and generate a lower return, validating lenders' expectations. This may be true even if firms have full access to credit at the onset and would hence be able to prefund any potential future liquidity need. The model therefore allows for multiple equilibria: In the good (efficient) equilibrium, firms expect to be able to get longer-term liquidity if they face a reinvestment need in the future. This makes them choose high-return but illiquid investment projects today. The fact that they choose these projects, in turn, makes lenders willing to provide longer-term liquidity. In the bad (inefficient) equilibrium, however, firms expect that only short-term liquidity will be available and they will therefore choose a low-return (but liquid) investment project. This, in turn, makes lenders only willing to provide short-term finance. Central banks can induce the efficient equilibrium if and only if they credibly commit to provide long-term

[3]The paper only looks at short-term credit / liquidity provision and tries to give a reason as to why lenders may not be willing to provide 3-12 month credit but only credit with a materially shorter maturity.

liquidity in the future.

The types of firm for which the model appears to be particularly relevant are financial institutions. The balance sheets of these firms are all too often very opaque making it difficult for their lenders to verify investment decisions. In addition, financial firms often turn to wholesale funding to refinance a significant part of their balance sheet. Money market funds as buyers of short-term paper typically do not engage in a thorough analysis of investment decisions taken by the issuers of such paper. However, the model could also be applied to non-financial firms (e.g. big corporations) who often directly tap wholesale funding markets as well.

Related Literature. My paper is related to several strands of the literature. In relation to the risks arising from short-term financing, Acharya, Gale, and Yorulmazer (2010) explain why short-term borrowing may not be rolled over even when there is no credit risk. In their model the price of an asset falls unless some good news arrives. But if the debt needs to be rolled over frequently, the probability of receiving good news is low. Hence, borrowing may freeze. Similarly, He and Xiong (2009) show that rollover risk may lead to dynamic bank runs. In contrast to these two models, this paper argues that a firm may want to avoid a future maturity mismatch in its balance sheet for the very reason that it fears to get liquidated otherwise.

In this sense, the paper is also related to models in which the fear of a market freeze in the future makes agents choose actions that make a freeze more likely, such as Diamond and Rajan (2010), Bolton, Santos, and Scheinkman (2009), and Malherbe (2010).

For example, Diamond and Rajan (2010) argue that the overhang of illiquid securities and the seizing up of term credit in the financial crisis of 2008/09 had common causes. When there are few potential buyers and banks hold a significant quantity of assets, a liquidity shock may trigger fire sales in the future. The prospect of a fire sale of the bank's assets depresses their current value. As a consequence, a bank may prefer holding on to illiquid assets and risking future insolvency rather than selling the asset today and ensuring its own stability. However, by gambling on a recovery the bank exacerbates the potential insolvency in the future and the associated price decline.

Bolton, Santos, and Scheinkman (2009) show that financial intermediaries may over-invest in liquid assets if they expect to sell only a small fraction of risky assets at close to fair value should they be hit by a liquidity shock in the future. Potential buyers ("long-run investors") will then hold little liquid funds to buy up those assets as they only expect a small discount relative to fair value. In fact, the authors show that an alternative, more efficient equilibrium may exist in which financial intermediaries are more heavily invested in the risky asset and long-run investors hold more cash in anticipation of a larger future

supply of assets at more favorable cash-in-the-market pricing. The authors show that public provision of liquidity can act as a complement for private liquidity under certain conditions.

Finally, and most similar to my model, Malherbe (2010) develops a model in which the fear of a market breakdown may induce banks to take actions that would in fact cause such a breakdown. When banks expect a market to be illiquid their best response is to self-insure through the hoarding of liquid assets. However, this makes the underlying adverse selection problem more severe. In particular, if the market expects banks to hoard substantial liquidity, it suspects that the motive for any bank selling assets at a later stage must be that the assets are of low quality, not that the bank really needs cash. In the end, this may lead to a market breakdown. In such a multiple-equilibria environment, a government can prevent the underlying coordination failure and rule out the bad equilibrium by introducing a public liquidity insurance scheme that renders self-insurance unreasonable. Agents will then fully invest in the long-run technology and participate in the secondary market ex-post, boosting overall liquidity in the market. Whereas in his model productive long-term investment hence crucially depends on expectations about future (secondary) market liquidity, long-term investment in my model depends on expectations about future funding liquidity.[4] More specifically, my model looks at how expectations about the availability of wholesale funds at different maturities may impact current investment decisions. Public provision of liquidity per se does not solve the underlying coordination problem in my model unless it is of long-term duration.

Holmström and Tirole (1998) also consider liquidity demand on the corporate borrowers' side rather than on depositors' side. Similar to their model, public provision of longer-term maturity funds is also a pure public good in my model, causing no moral hazard. The reason is that liquidity shocks are modeled as exogenous events and the magnitude of the reinvestment need is not determined by the firm's investment choice. The interaction between corporate firms and financial institutions is also covered in Bebchuk and Goldstein (2010). However, the source of inefficiency in their model is a coordination failure among lenders themselves, not a coordination failure between borrowers and lenders. They argue that it is the interdependence among firms in the real economy that makes the investment in a firm profitable only if other firms are able to receive funding. Financial institutions may thus rationally avoid lending to nonfinancial firms out of self-fulfilling fear that other lenders withhold loans.

In general, the model presented here does not rely on strategic complementarities

[4]For an explanation of the two concepts of funding and market liquidity see Tirole (2010), for example.

among lenders.[5] Nor does it rely on strategic complementarities among depositors as in bank-run models such as Diamond and Dybvig (1983). By contrast, the inefficient market outcome is driven by a coordination failure between borrowers and short-term lenders. Key to this result is the absence of full information (the lender cannot observe the borrower's choice of project) and the assumption that short-term investors are assumed to be impatient. Furthermore, contrary to Diamond and Rajan (2010) and Malherbe (2010), there is no wasteful liquidity hoarding assumed.[6] Rather than the lending market breaking down completely, only the market for longer-term funds breaks down in the inefficient equilibrium in the model.

The paper proceeds as follows. Section 2 presents the model, sections 3 and 4 derive the different equilibria that may occur including the inefficient short-maturity Nash equilibrium and the inefficient "prefunding" equilibrium, section 5 allows for different types of firms in the model, section 6 performs some comparative statics, section 7 focuses on policy intervention, and section 8 concludes.

2 The Model

Consider an economy with three types of agents: firms, long-run investors, and short-run investors (or liquidity providers) and four dates: 0, 1, 2, and 3. All agents are risk-neutral and protected by limited liability. Firms and long-run investors are indifferent about consuming early or late, i.e. their utility is a linear function of the sum of (undiscounted) consumptions at all dates on or before date 3. By contrast, short-run investors have preferences

$$u(C_1, C_2, C_3) = C_1 + C_2 + \delta C_3,$$

where C_t is the short-run investor's date-t consumption and $\delta \in (0, 1)$ is the discount factor. These assumptions are quite standard and are a simple way of capturing the idea that some investors may be impatient.[7] Long-run and short-run investors each have one unit of endowment at $t = 0$ and no endowment at subsequent dates.

Firms are run by entrepreneurs with no initial wealth who need to raise outside funds to cover their investment outlays. Investors provide funds and behave competitively in the sense that a loan, if any, just covers investors' opportunity cost of capital, i.e. there is

[5] Apart from Malherbe (2010), another adverse-selection-driven endogenous liquidity model that relies on strategic complementarities is Eisfeldt (2004).

[6] See also Diamond (1997).

[7] Bolton, Santos, and Scheinkman (2009) and Diamond and Rajan (2005) make similar assumptions, for example.

a shortage of investment opportunities relative to endowments of goods. In what follows I refer to short- and long-run investors as SRs and LRs respectively.

2.1 Firms' Projects

Firms can invest in either one of two indivisible projects that each require one unit of investment at $t = 0$:

1. A short-term, low-return ("L") project that yields $Y_2 \geq 1$ at date 2 per unit of date-0 investment which can be fully reinvested to yield $Y_3 \geq 1$ at date 3 per unit of date-2 investment, or

2. A long-term, high-return ("H") project that yields $Y_H > 1$ at date 3 per unit of date-0 investment, and nothing at date 2.

Both projects do not generate a return at date 1. Liquidity is costly as long-term projects generate a higher yield, i.e. $Y_H > Y_2 \cdot Y_3 \equiv Y_L$. Without loss of generality, I assume that $Y_3 = 1$ so that $Y_2 = Y_L$.

Projects may, however, be hit by an economy-wide liquidity shock at $t = 1$ which needs to be withstood in order for the projects to be completed, similar to Holmström and Tirole (2000). The liquidity shock can be interpreted as a reinvestment need (or an investment cost overrun). More specifically, with probability λ each firm in the economy faces a reinvestment need $k < 1$ at $t = 1$. If an individual firm does not reinvest k, then its project is liquidated. The liquidation value is zero for both projects.[8] If an individual firm reinvests k, then its project has the same (gross) return profile as in the absence of the liquidity shock. The timing of events is described in Figure 1. It is important to note that in contrast to Holmström and Tirole (2000) a potential reinvestment need occurs before any project generates a return, i.e. even before the L project generates Y_L.[9] Hence the firm must fully resort to outside finance at $t = 1$ or, if possible, prefund its need at $t = 0$.

Crucially, a firm's project choice is information private to the firm and cannot be signalled to the broader public. An investor therefore has to base her decision of providing long-term or, alternatively, short-term finance at $t = 1$ on her *belief* about the firm's project choice, not on the firm's *actual* choice. This assumption lies at the heart of the

[8] The liquidation value for the H project at $t = 2$ is also assumed to be zero.

[9] This assumption guarantees that the firm's project choice cannot be verified when it faces a reinvestment need.

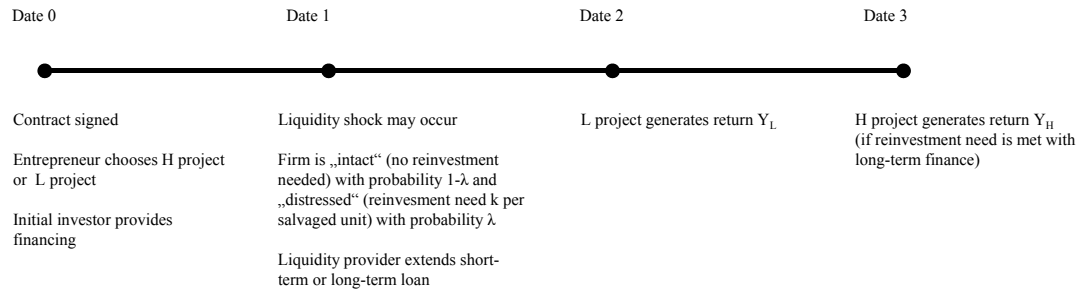

Figure 1: Timeline

model as it may give rise to a coordination problem whereby the firm chooses the low-return project simply because it believes that the liquidity provider believes that it will do so.

2.2 Firms' Financing Options

For simplicity, I assume that the two types of investors face different opportunity costs of investing in the firms' project similar to Bolton, Santos, and Scheinkman (2009). LRs can also invest in a long-maturity asset at $t = 0$ that yields $R > 1$ at $t = 3$ per unit of investment. By contrast, SRs only have the alternative of investing in cash with a gross per period return of 1 per unit of investment. This assumption could be justified by current regulatory restrictions in the US, for example. Whereas banks and other long-run investors can invest in long-maturity assets, such as those with a remaining maturity of greater than one year, or in asset classes of considerable credit risk, one of the most significant group of liquidity providers in the US, money market funds (MMFs), cannot.[10] In what follows I refer to a loan extended at $t = 0$ as an initial loan, a loan extended at $t = 1$ and maturing at $t = 2$ as a short-term ("ST") loan and a loan extended at $t = 1$ and maturing at $t = 3$ as a long-term ("LT") loan. Both ST and LT loans are assumed to be in the form of money market instruments or instruments typically held by SRs such as money market funds.

[10]US MMFs are strictly regulated by the SEC, both as mutual funds generally and pursuant to Rule 2a-7 under the Investment Company Act of 1940. These regulations prohibit a money market fund from acquiring any investment that is not (1) short-term, (2) determined to present minimal credit risks, and (3) either highly rated or determined to be comparable in quality to highly rated securities. "Short-term" means that the money market fund can receive its full principal and interest within 397 days. Moreover, regulations prohibit the average maturity of the fund's investments from exceeding 60 days.

Given that a loan just covers an investor's opportunity cost of capital, liquidity providers will charge $R_{ST} = 1$ for a short-term loan and $R_{LT} = 1/\delta$ for a long-term loan. For the moment, I assume that SRs can only provide financing at $t = 1$ and are unable to do so at $t = 0$. This can be easily justified by assuming that the first period is longer than each of the two following periods and a loan covering the first period surpasses the maximum allowable maturity for a security that a liquidity provider may invest in.[11]

For SRs to be able to offer attractive financing rates at $t = 1$, LRs' opportunity cost of investing in the firm must be sufficiently high. In particular, LRs' opportunity cost must be at least as high as the long-term rate offered by SRs at $t = 1$, i.e. $R \geq R_{LT}$, for firms to borrow from SRs no matter how high λ. Otherwise, and for a sufficiently high λ, LRs would find it attractive to hoard liquidity and provide long-term finance at $t = 1$ at a rate below that offered by SRs.[12] For simplicity and without loss of generality, I assume that $R = R_{LT} = 1/\delta$.[13]

In this setting, initial financing at $t = 0$ will be provided by LRs only and subsequent financing will be provided by SRs only. The initial interest rate solely depends on LRs' opportunity cost of investing in the firm and not on expectations about the firm's choice of project. The firm's project choice in turn only depends on the likelihood of the liquidity shock and the firm's expectations about the availability of long-term liquidity in the future. Given that the initial interest rate is determined by LRs' (exogenous) opportunity cost, we can hence focus on the net return that each project offers to determine the firm's optimal choice of project or the project's return after repaying LRs. I denote this net return by $\hat{Y}_i = Y_i - R$, $i \in \{L, H\}$.

[11] Without this assumption, the firm may resort to SRs for initial financing at $t = 0$. The initial interest rate that liquidity providers charge will then depend on their expectation about the firm's project choice. In practice, corporates do not receive long-term financing from MMFs.

[12] In fact, given our assumptions, LRs would drive down the long-term interest rate until the expected return from hoarding liquidity equals the initial interest rate, which in turn equals the LR's opportunity cost of investing. More precisely, for any given λ, LRs' opportunity cost must satisfy

$$\begin{aligned} R &\geq (1-\lambda)1 + \lambda\left(\frac{1}{\delta}\right) \\ &\geq 1 + \lambda\left(\frac{1-\delta}{\delta}\right) \end{aligned}$$

I assume that this inequality is satisfied for the whole range of λ, i.e. $R \geq 1/\delta$.

[13] It is important, however, to keep in mind that LRs, in contrast to liquidity providers, are not assumed to be impatient. If they were impatient, the initial interest rate demanded by LRs would depend on LRs' expectation about the firm's project choice.

2.3 The Role of the Discount Factor

The discount factor δ takes on crucial importance in the model. To see why, note that for the SR to provide long-term finance at $t = 1$ in case a liquidity shock occurs, it must be that the net return of a firm's project is greater than the SR's opportunity cost of investing, i.e. $\hat{Y}_i \geq k/\delta$, $i \in \{L, H\}$. I argue that liquidity providers may at times be highly impatient, or, equivalently, their discount factor quite low, so that the net return of a project may not be sufficient to compensate them for the opportunity cost of providing long-term finance.

In particular, I assume that the H project always generates enough net income to satisfy investors that provided the firm with *long-term* finance to withstand the liquidity shock, i.e.

$$\hat{Y}_H - k/\delta \geq 0 \tag{1}$$

The H project, however, does not generate enough income if it is abandoned prematurely which will be the case if the firm only received *short-term* finance at $t = 1$ to withstand the liquidity shock. This follows straight from the previous assumption that the liquidation value is zero at $t = 1, 2$.

By contrast, the L project only generates enough income for subsequent investors if and only if they provided *short-term* finance at $t = 1$ to withstand the liquidity shock, i.e.

$$\hat{Y}_L - k \geq 0 \tag{2}$$

$$\hat{Y}_L - k/\delta < 0 \tag{3}$$

Notice that the above assumptions ensure that initial lenders do not bear any risk by investing in a given firm provided that the H project is refinanced long-term and the L project is refinanced short term. I next show that in equilibrium this will always be the case.[14]

[14]It is important to note that for these assumptions to hold it is irrelevant as to whether renegotiation with initial investors is feasible or not. In this sense, the model differs from the debt overhang literature (e.g. Myers (1977), Hart and Moore (1995)). For example, assume that the firm could renegotiate with initial investors at $t = 1$. The firm may now want to lower LRs' claims whenever it has chosen the L project. If this was achievable, SRs would always be willing to provide long-term finance at $t = 1$ (no matter what project the firm chooses). The firm would in turn always choose the (first-best) H project. However, the problem is that initial investors would never consent to lower their stakes ex post if firms chose the L as it would make them worse off. Hence, it is irrelevant whether the firm is able to renegotiate with initial lenders or not.

3 No Prefunding Option

For expositional purposes only, assume for the time being that the firm cannot obtain more than one unit of investment from LRs at $t = 0$, i.e. the firm cannot prefund any potential future reinvestment need that may occur at $t = 1$. Any reinvestment need must therefore be financed by liquidity providers. Also, assume that the firm does not consider a short term loan that is rolled over at $t = 2$ a viable alternative to a long-term loan extended at $t = 1$. In the next section I will qualify both of these assumptions.

3.1 Socially Optimal Project Choice

Because both types of investors do not earn a profit (taking into account their opportunity cost), the social surplus generated by either project is simply the firm's expected profit.

In general, it is possible that the L project is socially optimal even though it generates a lower return at $t = 3$. This is so because the cost of refinancing the L project is also lower as SRs do not need to be compensated for late consumption. However, for simplicity and without loss of generality, I henceforth focus on situations in which the long-term project always generates a higher social surplus. Lemma 1 states the condition under which this is the case.

Lemma 1: The H project whose reinvestment need is financed long-term always generates a higher social surplus than the L project whose reinvestment need is financed short-term provided $Y_H > Y_L + (R_{LT} - R_{ST})k = Y_L + (1/\delta - 1)k$.

Proof: The H project generates a higher social surplus than the L project for all

$$\lambda < \frac{\delta(Y_H - Y_L)}{(1-\delta)k}$$

The H project generates a higher social surplus for the entire range of λ whenever $\frac{\delta(Y_H - Y_L)}{(1-\delta)k} \geq 1$ or

$$Y_H \geq Y_L + (1/\delta - 1)k \;\hat{=}\; Y_H^{\min}$$

In words, the return of the H project must not only be greater than the return of the L project but must also compensate for the extra cost of financing the reinvestment need long-term.

3.2 Equilibrium Project Choice

This section focuses on the firm's optimal project choice and asks whether the social optimum will be implemented in equilibrium. It is important to keep in mind that a firm's choice is information private to the firm and cannot be signalled to investors. SRs therefore have to base their decision of providing either long-term or short-term finance at $t = 1$ on their belief about the firm's project choice, not on the firm's actual choice. The interaction between the firm and the SR can hence be modeled as a game with imperfect information similar to Repullo and Suarez (1998). In this game, the firm first chooses the type of investment project (H or L). Subsequently, and only if the firm is hit by a liquidity shock, SRs choose to either provide long-term finance or short-term finance without observing the firm's project choice.

Let y be an indicator variable that takes the value 1 if the firm chooses the H project and 0 if it chooses the L project and m be an indicator variable that takes the value 1 if the liquidity provider chooses to provide long-term finance and 0 if it provides short-term finance. We are looking for a Nash equilibrium (y^*, m^*) such that

$$m^* \left[y^* R_{LT} k + (1 - y^*)\hat{Y}_L - k/\delta \right] + (1 - m^*) \left[(1 - y^*) R_{ST} k - k \right] \geq 0 \tag{4}$$

and

$$m^* \left[y^* \hat{Y}_H + (1 - y^*)\hat{Y}_L - \lambda k R_{LT} \right] + (1 - m^*) \left[y^*(1 - \lambda)\hat{Y}_H + (1 - y^*)(\hat{Y}_L - \lambda k R_{ST}) \right] \geq 0 \tag{5}$$

Equations (4) and (5) are participation constraints for the SR and the firm, respectively. In any Nash equilibrium (NE) the SR needs to be compensated for its opportunity cost of investing and the entrepreneur has to be provided with an expected utility of greater or equal to zero.

To find a Nash equilibrium, notice that we can restrict attention to pure strategy equilibria. This is so because for any given probability of the SR providing long-term finance, the payoff to the firm if it either chooses the H or the L project with certainty is higher or equal to the payoff from mixing strategies. But given that the firm therefore never mixes strategies, the SR will not mix strategies either as its participation constraint (equation (4)) will otherwise be violated. The following result characterizes the existence of Nash equilibria in the model.

Proposition 1: There exists a critical λ, denoted by $\underline{\lambda}^{L>H}$, such that, for any $\lambda < \underline{\lambda}^{L>H}$, there is only one NE, i.e. $(1, 1)$, where the firm chooses the H project and the SR provides LT finance if the liquidity shock occurs. For $\lambda \geq \underline{\lambda}^{L>H}$ there exist two NE, $(1, 1)$ or $(0, 0)$,

i.e. the firm may either choose the H project and be refinanced long-term or it may choose the L project and be refinanced short-term.

Proof: First note that the only two candidates for Nash equilibria are $(1,1)$ and $(0,0)$. The two remaining alternatives, $(1,0)$ and $(0,1)$, both violate the lender's participation constraint given the model's assumptions.

Next, assume that the lender chooses to lend short-term at $t=1$. The firm's optimal strategy in this case is to choose the H project whenever $(1-\lambda)\hat{Y}_H > \hat{Y}_L - \lambda k R_{ST}$ or

$$\lambda < \frac{Y_H - Y_L}{\hat{Y}_H - k} = \underline{\lambda}^{L>H} \tag{6}$$

But given that the firm chooses the H project, the lender's optimal strategy is to lend long-term. Hence for $\lambda < \underline{\lambda}^{L>H}$ the only NE is $(1,1)$. By contrast, if $\lambda \geq \underline{\lambda}^{L>H}$ the firm's optimal strategy is to choose the L project if it expects the lender to lend short-term. However, if it expects the lender to lend long-term, the firm is better off choosing the H project which is obvious from equation (5). Therefore both $(1,1)$ and $(0,0)$ constitute Nash equilibria if $\lambda \geq \underline{\lambda}^{L>H}$.

Notice that $\underline{\lambda}^{L>H}$ is strictly less than 1 as $Y_L > R + k$ by assumption. There will hence always be a range of λ for which multiple equilibria are possible. Finally, we know from Lemma 1 that the NE $(1,1)$ is Pareto superior to $(0,0)$.

3.3 Numerical Example

Before extending the model to allow for asymmetric information, let us turn to a numerical example. Let $Y_H = 1.40$, $Y_L = 1.36$, $k = 0.2$, and $\delta = 0.87$. Given our assumptions, the initial interest rate equals the long-term interest rate, i.e. $R = R_{LT} = 1.15$. Next notice that the net return of the L project, $\hat{Y}_L = 0.21$, is high enough to provide SRs with an adequate return on funds lent short-term at $t=1$. However, it will not suffice to pay an adequate return on funds lent long-term at $t=1$ as $\hat{Y}_L < R_{LT} \cdot k = k/\delta = 0.23$. Likewise notice that the net return of the H project, $\hat{Y}_H = 0.25$, is high enough to provide SRs with an adequate return on funds lent long-term at $t=1$ since $\hat{Y}_H > R_{LT} \cdot k = 0.23$. But it will not suffice to provide them with an adequate return on funds lent short-term as the project would have to be liquidated and would generate a return of zero.

It is now obvious that the socially optimal outcome of the game is the firm choosing the H project and the SR providing long-term finance, no matter how likely the liquidity shock is. For example, if the liquidity shock occurs with certainty ($\lambda = 1$), the NE $(1,1)$

generates a social surplus of 0.02 whereas the NE $(0,0)$ generates a social surplus of only 0.01. Nonetheless, for $\lambda > 0.79$ $(= \underline{\lambda}^{L>H})$ the firm's optimal strategy is to choose the L project whenever it expects the SR provide short-term finance at $t = 1$. Given the firm's strategy, the SR indeed provides short-term finance. The economy may thus end up in a suboptimal equilibrium if the liquidity shock is highly likely.

4 Prefunding Option

In this section, it is assumed that the firm is able to obtain more than one unit of investment from LRs at $t = 0$, i.e. the firm can now prefund any potential future reinvestment need. Let us focus on three different options that the firm now has: 1) the H project combined with prefunding the potential reinvestment need (simply called "prefunding"), 2) the H project without prefunding (called "H project"), and 3) the L project.

Another option, financing a potential future reinvestment need by taking out a ST loan at $t = 1$ and rolling it over at $t = 2$, is assumed unattractive (ex-ante) from the firm's point of view due to a 'rollover cost'. This cost may simply consist of administrative fees or may reflect the expected cost of not being able to roll over the loan due to some external event outside the model. It is for this cost that a "rolled-over" short-term loan is not a perfect substitute for a long-term loan.[15] I assume that the rollover cost c is sufficiently high for the firm to either choose the L project or prefunding rather than choose the H project and fund any reinvestment need by a (rolled-over) short-term loan. Lemma 2 summarizes the condition under which this is the case.

Lemma 2: A firm that wants a reinvestment need to be financed long-term never considers taking out a short-term loan at $t = 1$ and rolling it over at $t = 2$ whenever the rollover cost c satisfies

$$c \geq \min \left\{ (Y_H - Y_L) \frac{\hat{Y}_H - R_{LT}k}{\hat{Y}_H - R_{ST}k}; k \left[R - 1 - (R_{LT} - 1) \frac{Y_H - Y_L}{\hat{Y}_H - R_{ST}k} \right] \right\}.$$

Proof: See the Appendix.

[15] If there was not a rollover cost, the firm would always choose the H project. To see why, notice that only if the firm chose the H project does it not generate any cashflow at $t = 2$. Hence, an SR observing no cashflow at $t = 2$ knows that the firm chose the H project. She would hence be willing to roll over any ST loan extended at $t = 1$ (albeit at a higher interest rate). The firm knowing this would therefore always choose the H project at $t = 0$, anticipating correctly that even a ST loan will be rolled over at $t = 2$.

With the three options, the key questions to answer is under what circumstances the firm chooses to prefund and whether prefunding is socially desirable. Having the option to prefund a potential reinvestment need, the firm can now decide whether or not to play the game with the liquidity provider. *Not prefunding* the reinvestment need is equivalent to deciding *to play* the game whereas *prefunding* is equivalent to deciding *not to play* in which case the market for liquidity provision at $t = 1$ ceases to exist. The firm's decision whether or not to play the game will depend on two factors: 1) its expectation about the SR's willingness to provide LT finance at $t = 1$ and 2) its expected return of prefunding relative to the expected return of the L project. The firm will decide not to play the game if and only if it expects the lender to be unwilling to provide long-term finance at $t = 1$ and prefunding generates a higher expected return than the L project. I henceforth assume that the firm's decision to prefund is observable but its project choice remains unobservable.

It turns out that in the simple model with the option to prefund, the firm will never choose the L project but may instead prefund the reinvestment need for a sufficiently high λ. To see this, note that if the firm expects the SR to only provide ST finance at $t = 1$ it will prefer prefunding to the L project whenever

$$\hat{Y}_H + (1 - \lambda)k - Rk > \hat{Y}_L - \lambda k$$

Solving for Y_H we get $Y_H > Y_L + (R - 1)k$ which is true by Lemma 1. In addition, under these circumstances prefunding will always be possible.[16] Hence, no matter how high the liquidity shock, the firm never chooses the L project. Instead, in equilibrium, it will choose the H project and either prefund the potential reinvestment need or rely on SRs to provide LT finance. As can be easily verified, the NE where the firm relies on SRs for LT finance is Pareto superior to the prefunding equilibrium.[17]

It is important to note, however, that the critical probability level beyond which there are multiple equilibria remains unchanged at $\underline{\lambda}^{L>H}$, i.e. the threshold level of λ is again solely determined by the relative attractiveness of the H project versus the L project. This may at first seem surprising. In particular, it could be that the firm preferred prefunding to the H project for some $\lambda < \underline{\lambda}^{L>H}$ if it believed to only get ST finance at $t = 1$ otherwise. However, this belief turns out to be unjustified. Whenever the SR observes that the firm did not prefund at $\lambda < \underline{\lambda}^{L>H}$, she knows that it must have chosen the H project. The

[16] Let $Y_H^{\text{Pre}} = (1 + k)R$ be the minimum Y_H for which prefunding is still possible. If Lemma 1 holds prefunding is always possible as long as $Y_H^{\min} > Y_H^{\text{Pre}}$ or $Y_L > R + k$ which is true by assumption 2.

[17] The NE generates a higher SS to the prefunding equilibrium whenever $Y_H - R - \lambda R_{LT} k \geq Y_H - R(1 + k) + (1 - \lambda)k$ or $\lambda \leq \frac{R-1}{R_{LT}-1}$. Since $R = R_{LT}$ this is satisfied for the entire range of λ.

lender is hence willing to lend long-term at $t = 1$ in this case. By contrast, suppose $\lambda \geq \underline{\lambda}^{L>H}$ and the firm believes that it will only be able to obtain short-term finance at $t = 1$. The SR knows that in this case the firm must have chosen the L project if it did not prefund its reinvestment need. The lender will hence indeed only provide short-term finance at $t = 1$.

5 Incorporating 'Bad' Firms into the Model

Prefunding may no longer always dominate the L project if we allow for different types of firms (and asymmetric information about these types). So far, there was just one type of firm in the model whose project produced a return of either Y_H or Y_L with certainty (provided the liquidity need was somehow met). The market failure occurred because the SR could not tell what project the firm actually chose and therefore had to place its decision of providing long-term versus short-term finance on her *belief* about the firm's choice.

In the following section, I extend the model to allow for another type of firm. This 'bad' firm can only invest in a project that neither yields a date 1 nor a date 2 return. However, it enjoys an infinitesimal small private benefit $B \geq 0$ at date $t = 2$ by undertaking the project. Furthermore, there is asymmetric information between the firm and investors in the sense that bad firms always disguise as good firms in order to receive financing. The model thus becomes a version of the standard privately-known-prospects model (see Tirole (2006)).

The key question I try to answer is how the degree of asymmetric information about the firm's type affects the possibility of having multiple equilibria in the model. This should give an indication as to whether public intervention may be more or less justified in markets with a lower degree of asymmetric information. Somewhat surprisingly, it turns out that in markets with less asymmetric information firms may be more inclined to choose the L project or prefunding (i.e.the critical $\underline{\lambda}^{L>H}$ is lower). This supports the notion that public intervention may at times be particularly beneficial in markets for high quality debt with a low degree of asymmetric information.

To be more specific, assume that at the onset ($t = 0$) there is a fraction p_L of good firms that share all of the characteristics of the firms in the simple model. But there is now also a fraction $1 - p_L$ of bad firms that share the above mentioned characteristics. Furthermore, assume that information becomes less asymmetric at $t = 1$ in that SRs can now identify some bad firms. This means that SRs refinance a fraction p_H of good firms and a fraction $1 - p_H$ of bad firms at $t = 1$ ($p_H > p_L$). The interest rates charged by SRs

and LRs will hence now also reflect their respective agency costs, i.e. $R = \frac{1}{p_L \delta}$, $R_{LT} = \frac{1}{p_H \delta}$, and $R_{ST} = \frac{1}{p_H}$.

This assumption is supposed to reflect the fact that liquidity providers (SRs) are different from risk takers (LRs). Not only are liquidity providers such as MMFs barred from extending credit over an extended period of time, MMFs are also fundamentally opposed to assuming excessive credit risk. It is, however, crucial to keep in mind that although there is less asymmetric information about the firm's type at $t = 1$, there is still asymmetric information about the good firm's choice of project.

5.1 Socially Optimal Project Choice

Before I show that firms may now choose the L project or prefunding (crucially depending on the relative return of the H project), let us restate Lemma 1 to account for asymmetric information and the possibility of prefunding. Lemma 3 states the condition under which the H project without prefunding generates a higher social surplus than either the L project or prefunding.

Lemma 3: The H project Pareto dominates both the L project and prefunding for the entire range of λ provided $Y_H \geq Y_L + k(R_{LT} - R_{ST})$ and $p_L < p_H$.

Proof: As in Lemma 1, it is straightforward to show that the H project Pareto dominates the L project under the above condition. Furthermore, note that the H project returns a higher social surplus than prefunding whenever $p_L < p_H$ since the agency cost that the firm incurs if it prefunds is higher than if it waits for the reinvestment need to occur.[18]

Analogous to section 3.1, define $Y_H^{\min}$ as the minimum Y_H at which Lemma 3 just holds, i.e. $Y_H^{\min} \hat{=} Y_L + k(R_{LT} - R_{ST})$. We will see in the next section that whether or not the firm prefers prefunding to the L project crucially depends on whether Y_H is significantly above Y_H^{min}.

[18] The H project generates a higher social surplus than prefunding whenever

$$\begin{aligned} Y_H - R - \lambda R_{LT} k &> Y_H - R(1+k) + (1-\lambda)k \\ \lambda \frac{1}{\delta p_H} &< \frac{1}{\delta p_L} - 1 + \lambda \end{aligned}$$

The H project generates a higher SS for the entire range of λ if and only if $p_H > p_L$ which is true by assumption.

5.2 Equilibrium

The next section focuses on the firm's equilibrium project choice under asymmetric information about the firm's type. From Lemma 3 we know that neither the L project nor prefunding are optimal outcomes. Instead, it would be best if the firm always chose the H project and rationally expected to be refinanced long-term. However, we also know that under the expectation of only being able to receive short-term finance at $t = 1$, the firm will not choose the H project for a sufficiently high λ. As in section 3, under the expectation of future short-term finance the firm prefers the L project to the H project whenever

$$\lambda \geq \frac{Y_H - Y_L}{\hat{Y}_H - R_{ST}k} \quad \hat{=} \quad \underline{\lambda}^{L>H}.$$

Again, note that $\underline{\lambda}^{L>H} < 1$ as $Y_L > R + R_{ST}k$ by assumption. Furthermore, for the same reasons as in section 4, there is only one equilibrium whenever $\lambda < \underline{\lambda}^{L>H}$.

The key question now is whether the firm will choose the L project or prefunding whenever $\lambda > \underline{\lambda}^{L>H}$ and it expects to only be offered ST finance at $t = 1$. In general, for the firm to choose prefunding two conditions must be satisfied: 1) Prefunding must be possible and 2) Prefunding must be preferred to the L project. However, as Lemma 4 states it is sufficient to concentrate on what the firm prefers:

Lemma 4: If the firm prefers prefunding to the L project for some $\lambda \in (0, 1)$, then prefunding is possible.

Proof: The firm prefers prefunding to the L project whenever $Y_H + (1 - \lambda)k - Rk > Y_L - \lambda k R_{ST}$. Solving for λ we get

$$\lambda > \frac{R - 1}{R_{ST} - 1} - \frac{Y_H - Y_L}{k(R_{ST} - 1)} \quad \hat{=} \quad \underline{\lambda}^{Pre>L}.$$

Next, note that $\underline{\lambda}^{Pre>L} \leq 1$ for the firm to prefer prefunding at some $\lambda \in (0, 1)$. Solving for Y_H this is equivalent to $Y_H \geq Y_L + k(R - R_{ST}) \hat{=} Y_H^*$. However, we know that prefunding is possible whenever $Y_H \geq (1 + k)R \hat{=} Y_H^{\text{Pre}}$. For Lemma 4 to hold it must therefore be that $Y_H^* > Y_H^{\text{Pre}}$ or $Y_L + k(R - R_{ST}) > (1 + k)R$. Solving for Y_L we get $Y_L > R + kR_{ST}$ which is true by assumption.

Lemma 4 facilitates the analysis as we just have to ask whether the firm prefers prefunding or not, ignoring the question as to whether prefunding is feasible at all. That is, it could be that for some $Y_H < Y_H^*$ prefunding is not feasible. However, in this case the firm does not want to prefund anyway.

Let us now turn to the question of what the firm chooses to do if $Y_H \geq Y_H^*$ and it expects to only be able to receive short-term finance. Since $\underline{\lambda}^{pre>L}$ is decreasing in Y_H, we know that the higher Y_H the wider the range of λ for which the firm chooses to prefund the reinvestment need. However, as long as $\underline{\lambda}^{pre>L} > \underline{\lambda}^{L>H}$, there is still a range of λ for which the firm chooses the L project. That is, if $\underline{\lambda}^{pre>L} > \underline{\lambda}^{L>H}$, the firm chooses the L project for all $\lambda \in (\underline{\lambda}^{L>H}; \underline{\lambda}^{pre>L})$ and chooses to prefund for all $\lambda > \underline{\lambda}^{pre>L}$. Finally, it is obvious that there is a critical Y_H^{**} for which $\underline{\lambda}^{Pre>L} = \underline{\lambda}^{L>H}$. Whenever $Y_H > Y_H^{**}$ the firm will never choose the L project and always prefund the potential reinvestment need if $\lambda > \underline{\lambda}^{L>H}$. This critical Y_H^{**} is derived in the appendix. Hence, for a sufficiently high Y_H and under the expectation of short-term finance the firm will always prefer prefunding to the L project.

Proposition 2: There exists a critical $\underline{\lambda}^{L>H}$ such that for any $\lambda \leq \underline{\lambda}^{L>H}$ there is only one NE in which the firm chooses the H project and the SR provides LT finance if the liquidity shock occurs. For any $\lambda > \underline{\lambda}^{L>H}$ there exist two equilibria at each λ. One equilibrium is the NE where the firm chooses the H project and the SR provides LT finance. The other equilibrium depends on the return of the H project, Y_H. If $Y_H \leq Y_H^*$, the other equilibrium will always be the NE where the firm chooses the L project and the SR provides ST finance. By contrast, if $Y_H \geq Y_H^{**}$, the other equilibrium will always be the prefunding equilibrium. Finally, if $Y_H \in (Y_H^*, Y_H^{**})$ the other equilibrium depends on the likelihood of the liquidity shock.

Proof: Omitted.

However, neither the Nash equilibrium $(0, 0)$ nor the prefunding equilibrium constitute best outcomes. The highest social surplus will still be generated if the firm chooses the H project anticipating correctly that it will be refinanced long-term at $t = 1$.

5.3 Numerical Examples

Prefunding not possible

Let $Y_H = 1.40$, $Y_L = 1.38$, $k = 0.2$, $\delta = 0.95$, and $p_L = 0.9$ and $p_H = 1$. The initial interest rate now becomes $R = 1.17$ and the long-term and short-term interest rates are unchanged at $R_{LT} = 1.053$ and $R_{ST} = 1$, respectively.

Prefunding a potential reinvestment need is impossible as $Y_H^{\text{Pre}} = (1+k)R = 1.4035 >$

$Y_H = 1.40$. However, since SRs can perfectly distinguish between good and bad firms at $t = 1$ (since $p_H = 1$), good firms can fund any of the two projects at $t = 0$ and turn to SRs at $t = 1$ for financing the reinvestment need since $Y_H > R + R_{LT}k = 1.3801$ and $Y_L > R + R_{ST}k = 1.3696$. However, the H project only yields enough income if it is refinanced long-term at $t = 1$. Likewise, the L project only yields enough income if the firm receives short-term finance at $t = 1$.

Finally, as $Y_H > Y_H^{\min} = 1.3905$, the socially optimal outcome of the game always consists of the firm choosing the H project and the SR providing long-term finance at $t = 1$, regardless of the likelihood of the liquidity shock. Nonetheless, for $\lambda > \underline{\lambda}^{L>H} = 0.658$ the firm's optimal strategy is to choose the L project whenever it expects SRs to only provide short-term finance at $t = 1$. Given the firm's optimal strategy, SRs' optimal strategy is indeed to only offer short-term finance at $t = 1$.

Prefunding possible

Let $Y_H = 1.41$ and the other parameter values unchanged at $Y_L = 1.38$, $k = 0.2$, $\delta = 0.95$, and $p_L = 0.9$ and $p_H = 1$. Prefunding a potential reinvestment need is now possible as $Y_H = 1,41 > Y_H^{\text{Pre}} = (1 + k)R = 1.4035$. However, since $Y_H = 1.41 < Y_H^* = 1.4139$ the firm still chooses the L project for all $\lambda > \underline{\lambda}^{L>H} = 0.7424$ whenever it expects SRs to only provide short-term finance at $t = 1$. However, if $Y_H = 1.42$ (and the rest of the parameter values again unchanged), the firm will choose prefunding for all $\lambda > \underline{\lambda}^{L>H} = 0.7935$ whenever it expects SRs to only provide short-term finance at $t = 1$.

Finally, if we allow for some asymmetric information still being present at $t = 1$, it turns out that the firm's choice depends on the given probability of the liquidity shock. To see this, let $Y_H = 1.412$ and $p_H = 0.99$ and all other parameter values unchanged. The critical probability level beyond which there are multiple equilibria possible is given by $\underline{\lambda}^{L>H} = 0.7943$. However, with $\lambda^{Pre>L} = 0.9574$ the firm chooses the L project for all $\lambda \in (0.7943; 0.9574)$ and prefunding for all $\lambda > 0.9495$.

6 Comparative Statics

It is illuminating to perform comparative statics on the critical $\underline{\lambda}^{L>H}$ beyond which the firm prefers the L project over the H project whenever it believes that only ST finance will be available at $t = 1$. That is, we can determine how the threshold level beyond which multiple equilibria are possible responds to a change in parameter values. Since the intervention by the Federal Reserve was targeted at markets for short-term debt of the

highest quality, a natural question to ask is how $\underline{\lambda}^{L>H}$ responds to changes in parameter values that could be associated with an increase in firms' perceived credit quality. As we will see, the threshold $\underline{\lambda}^{L>H}$ in fact decreases with such changes. In this sense, there is a rationale for why central bank intervention may be particularly justified in markets for CP of the highest credit quality.

To see this, interpret a higher firm quality as either a higher p_L, i.e. a higher probability for being a good firm, or a lower k, i.e. a lower reinvestment need. Strictly speaking, p_L is not a measure of each firm's individual credit quality but a measure of the degree of asymmetric information. However, in the eyes of an initial lender there is conceptually no difference as she faces a return of zero if either she lends to a bad firm or to a good firm that turns out to be unsuccessful. If the firm always has a lower reinvestment need if a liquidity shock occurs it has a higher expected return and hence can be considered of higher quality.

It can easily be checked that the derivative of $\underline{\lambda}^{L>H}$ with respect to p_L is negative whereas the derivative of $\underline{\lambda}^{L>H}$ with respect to k is positive.[19] Hence, both tell the same story: an increase in firms' quality is associated with a lower threshold level of λ beyond which multiple equilibria are possible. What is driving this result? Rewrite the firm's expected profit from choosing the H project when it expects to only obtain short-term finance as $Y_H - R - \lambda(Y_H - R)$. Likewise the expected profit from choosing the L project is $Y_L - R - \lambda R_{ST} k$. Since a higher p_L leads to a lower initial interest rate R, the firm loses more profit for each small increase in λ when it chooses the H project (as opposed to the L project). Hence the level of λ at which the profits from each project are equal to one another is lower. On the other hand, a lower k also increases the relative attractiveness of the L project at each level of λ resulting again in a lower $\underline{\lambda}^{L>H}$ at which the profits of the two projects are equal. Key to the result is that the firm by choosing the H project is unable to withstand the liquidity shock and earn a profit.

7 Policy Intervention

The key problem in the model is that no private actor can credibly commit to follow a particular course of action when a liquidity shock is likely. The firm cannot commit to carrying out the H project as this will be a suboptimal choice whenever it believes it will only be able to obtain short-term finance at $t = 1$. And the SR cannot commit to lending

[19] Rewrite $\underline{\lambda}^{L>H}$ as $\underline{\lambda}^{L>H} = \frac{\delta p_L (Y_H - Y_L)}{\delta p_L (Y_H - R_{ST} k) - 1}$. The derivative with respect to p_L is $\frac{\partial \underline{\lambda}^{L>H}}{\partial p_L} = \frac{\delta (Y_H - Y_L)[\delta p_L (Y_H - R_{ST} k) - 1] - \delta p_L (Y_H - Y_L)[\delta (Y_H - R_{ST} k)]}{[\delta p_L (Y_H - R_{ST} k) - 1]^2}$. It can easily be checked that this term is always negative.

long-term at $t = 1$ since this will be suboptimal if she thinks the firm chose the L project at $t = 0$. If either the firm or the SR could commit to carrying out the H project or to lending long-term no matter what, the other party would choose the action that would result in the Pareto efficient outcome. The key question for policymakers is then how to ensure that the socially optimal equilibrium is depicted.

One approach might be to let the central bank extend long-term credit at $t = 1$ when the liquidity shock is highly likely. This could be done at some (slightly) punitive interest rate so that firms still prefer borrowing from private agents. But this raises the question of why the central bank should be able to credibly commit to provide long-term finance if private agents are unable to do so. In what follows I argue that this can be the case if the two agents face different relative costs of providing short-term vs. long-term finance at $t = 1$. For example, if the central bank faces high reputational costs of reneging on a previous promise to provide long-term finance, it may stick to that promise even if the firm chose the L project. However, the central bank will in fact not be at risk of a loss. Because the commitment is credible, the firm will choose the H project (and not the L project) which would leave enough income to compensate the central bank for its investment. In fact, if the interest rate is slightly punitive, the central bank will not even extend any credit because SRs will do so at more attractive terms.

To see this formally, let us return to the simple model of section 3, ignoring the option to prefund the potential future liquidity need. We will later see that ignoring prefunding as an option is justified. Let γ denote the central bank's extra cost of providing short-term credit at $t = 1$. In the context of the previous paragraph, this cost can be self-inflicted in the sense that if the central bank provides short-term credit when it promised not to do so it will incur a reputational damage. As in section 3.2 we are looking for a Nash equilibrium (y^*, m^*) such that

$$m^* \left[y^* R_{LT} k + (1 - y^*)\hat{Y}_L - k/\delta \right] + (1 - m^*) \left[(1 - y^*) R_{ST} k - k - \gamma \right] \geq 0 \tag{7}$$

and

$$m^* \left[y^* \hat{Y}_H + (1 - y^*)\hat{Y}_L - \lambda k R_{LT} \right] + (1 - m^*) \left[y^*(1 - \lambda)\hat{Y}_H + (1 - y^*)(\hat{Y}_L - \lambda k R_{ST}) \right] \geq 0 \tag{8}$$

Equation (7) is now the participation constraint of the central bank which is the same as the one for the SR except for the (reputational) cost γ. Equation (8) is the firm's participation constraint which is unchanged from section 3.2. The following proposition summarizes when the central bank's intervention will be successful.

Proposition 3: Central bank intervention in the form of promising to provide long-term finance at $t = 1$ will lead to implementation of the Pareto efficient equilibrium whenever the central bank's reputational cost is sufficiently high, i.e. $\gamma \geq k/\delta - \hat{Y}_L$.

Proof: The central bank provides long-term finance even if the firm chose the L project ($y = 0$) whenever $\hat{Y}_L - k/\delta \geq -\gamma$ which is equivalent to $\gamma \geq k/\delta - \hat{Y}_L$. Therefore we know that in equilibrium $m^* = 1$ whenever the reputational cost is higher than this threshold level. However, the firm's best response to $m^* = 1$ is $y^* = 1$ and the only NE is therefore the Pareto efficient equilibrium $(1, 1)$.

With this single solution to the game, we know that the firm will always decide to play the game instead of prefunding the potential liquidity need, which justifies ignoring prefunding as an option.

Key for its ability to commit is that the central bank incurs a higher loss if it provides short-term (instead of long-term) finance whenever the firm chooses the short-term project. Somewhat paradoxically, it is thus the willingness to incur additional losses in some states of the world that renders *any* losses for the central bank unlikely. This insight points to another possibility of intervening to ensure the implementation of the Pareto efficient equilibrium. As the relative attractiveness of providing short-term finance needs to be reduced, another solution would be to force SRs to incur (higher) losses if they provide short-term loans at $t = 1$. In fact, imposing a tax of $t \geq k/\delta - \hat{Y}_L$ on short-term loans would also guarantee an efficient outcome.

8 Conclusion

This paper explores why central bank intervention in the form of providing longer-term credit to financial firms may be justified at times. I identify an expectations channel by which expectations about the availability of longer-term finance in the future may impact firms' investment decisions today. These investment decisions in turn may justify lenders' decisions whether or not to supply longer-term credit.

Central banks, by promising to supply longer-term credit in the future, may stabilize firms' expectations and lead them to invest in projects that generate the highest social surplus. Through this form of intervention, central banks may, in fact, not assume any credit risk and may not even have to extend longer-term credit. Instead, private lenders, being more confident about firms' investment decisions, may instead be willing to provide longer-term financing themselves.

It is important to note that the model assumes that (short-term) wholesale funding markets are completely anonymous and that no communication between firms and liquidity providers takes place. Liquidity providers in the model have to place their lending decision solely on their belief about the firm's project choice without the firm being able to signal its true choice. In practice, this assumption may be seen as quite restrictive in normal times. However, it should be seen in the light of the recent crisis where events were unfolding rapidly and the usual communication channels between firms and investors were severely impacted.

As for the paper's policy conclusion, it is interesting to note that the new restrictions placed on US-Money Market Funds in January 2009 go into the opposite direction of what the model recommends as a solution to the market failure problem. In fact, the new rules make short-term loans comparatively *more* attractive for MMFs. Apparently, a key motivation for the new rules was to reduce the maturity mismatch between the assets and liabilities of US MMFs, thereby making the funds less susceptible to investor runs. The possibility of such runs and how to prevent them from occurring are beyond the scope of the paper. However, the model implies that these rules may have negative consequences in that they could make Pareto suboptimal outcomes more certain whenever firms are likely to be hit by liquidity shocks.

The simple model presented here just focuses on firms of the highest credit quality that issue short-term debt in markets with little asymmetric information. It shows that central bank intervention in these markets may be justified, in particular. However, the model does not account for other channels through which such interventions may impact on firms', or for that matter, investors' behavior. In particular, it abstracts from the problem of moral hazard. Private agents that know that central banks will intervene will have less incentive to develop private sector funding arrangements that prove resilient during financial crisis. In future research, it would be interesting to see how moral hazard concerns weigh against the benefits of stabilizing private sector expectations.

Appendix

A Proof of Lemma 2

We know that for $\lambda < \underline{\lambda}^{L>H}$ there is only one equilibrium where the firm always chooses the H project and the reinvestment need is financed long-term. Hence, the firm may only prefer the L project or prefunding for the range of λ for which multiple equilibria are possible, i.e. for $\lambda \geq \underline{\lambda}^{L>H}$.

For the firm to prefer the L project to the H project that is financed with a (rolled over) short-term loan it must be that $\hat{Y}_H - \lambda R_{LT} k - c \leq \hat{Y}_H - \lambda R_{ST} k$ or

$$c \geq Y_H - Y_L - \lambda(R_{LT} - R_{ST})k$$

As c is decreasing in λ, the condition will be satisfied for all $\lambda \geq \underline{\lambda}^{L>H}$ if it is satisfied at $\lambda = \underline{\lambda}^{L>H}$ which will be the case if

$$c = (Y_H - Y_L)\frac{\hat{Y}_H - R_{LT}k}{\hat{Y}_H - R_{ST}k} \quad \hat{=} \quad \underline{c}^L.$$

For the firm to prefer prefunding to the H project that is financed with a (rolled over) short-term loan it must be that $\hat{Y}_H - \lambda R_{LT} k - c \leq \hat{Y}_H - Rk + (1-\lambda)k$ or

$$c \geq k[R - 1 - \lambda(R_{LT} - 1)]$$

Again, as c is decreasing in λ, the condition will be satisfied for all $\lambda \geq \underline{\lambda}^{L>H}$ if it is satisfied at $\lambda = \underline{\lambda}^{L>H}$ which will be the case if

$$c = k\left[R - 1 - (R_{LT} - 1)\frac{Y_H - Y_L}{\hat{Y}_H - R_{ST}k}\right] \quad \hat{=} \quad \underline{c}^{\text{Pre}}.$$

It should be noted that $\underline{c}^L$ is increasing in Y_H whereas $\underline{c}^{\text{Pre}}$ is decreasing in Y_H. Furthermore, it can easily be checked that for $Y_H = Y_L + (R-1)k$ the two terms are equal. Hence, if the firm prefers prefunding to the L project, i.e. $Y_H \geq Y_L + (R-1)k$, the minimum rollover cost will be $c = c^{\text{Pre}}$ and the firm does not choose the H project with a (rolled over) short-term loan. Similarly, if the firm prefers the L project to prefunding, i.e. $Y_H < Y_H^*$ the minimum rollover cost will be $c = c^L$ and the firm also does not choose the H project with a (rolled over) short-term loan.

B Derivation of Y_H^{**}

We want to find the critical Y_H for which $\underline{\lambda}^{Pre>L} = \underline{\lambda}^{L>H}$ or

$$\frac{Y_H - Y_L}{Y_H - R - R_{ST}k} = \frac{R-1}{R_{ST}-1} - \frac{Y_H - Y_L}{k(R_{ST}-1)}$$

Rearranging we get

$$Y_H^2 + \underbrace{(-1)[Y_L + R(1+k)]}_{"b"} Y_H + \underbrace{Y_L(R+k) + k(R-1)(R_{ST}k + R)}_{"c"} = 0$$

This is a standard quadratic equation in Y_H. Solving for Y_H we get:

$$Y_H^{1,2} = \frac{-b \pm \sqrt{b^2 - 4c}}{2}$$

It is now straightforward to rule out one candidate as a solution. Given Lemma 4 we know that at Y_H^{**} prefunding is possible. Hence, if both Y_H^1 and Y_H^2 were solutions, both would have to be high enough to allow for prefunding. In particular, it must be the case that

$$Y_H^2 = \frac{-b - \sqrt{b^2 - 4c}}{2} > (1+k)R$$

Substituting the first b in the numerator but, for simplicity, keeping the term under the square root unchanged and rearranging we get

$$Y_L > (1+k)R + \sqrt{b^2 - 4c}$$

However, if $Y_L > (1+k)R$ then $Y_L > R + kR_{LT}$ as long as $p_H > p_L$ (which we assume). This violates one of the key assumptions of the model, i.e. that the L project does not provide a return high enough to compensate SRs for lending long-term at $t = 1$. Hence the only solution candidate is Y_H^1. Furthermore, since $\underline{\lambda}^{pre>L}$ is a continuous function of Y_H, we know that there must be at least one solution. This solution must therefore be Y_H^1 which we rename Y_H^{**}.

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