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Barriers to liquidity in market-based intermediation

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Summary

The overarching goal of my work is to understand barriers to liquidity in market-based finance. Understanding the implications of market-based finance is important because an increasing share of maturity transformation and capital allocation is performed outside of the traditional banking sector. While regulators of traditional banks can rely on an extensive body of scientific studies, our understanding of shadow banking and other financial institutions lacks such a complete academic underpinning. My thesis produces insights to guide policy on matters related to collateralized lending, repo markets and liqudity in corporate bond markets.

In the first chapter, I study how and when transparency can be disadvantageous given multiple (symmetric) counterparties. Many secured lending markets are opaque, allowing borrowers potentially to conceal multiple borrowing relationships. The policy debate has proposed transparency to curtail hidden risk. In this paper, I show that transparency may backfire due to increased credit rationing under multiple borrowing. In a transparent market, an opportunistic lender can easily coordinate with the borrower at the expense of a pre-existing lender. This becomes more difficult in an opaque market, as an opportunistic lender may more easily find himself at the receiving end of a different opportunistic move by the borrower. Lenders are therefore more cautious in an opaque market. This can restore the second-best allocation. I show that over-collateralization plays a key role in this mechanism as it constrains the borrower's ability to increase leverage op-

portunistically. Finally, I provide a clear characterization of when opacity achieves allocations that dominate those that can be achieved under market transparency in terms of welfare.

In my second chapter, I study how some lenders protect against a winner's curse in the repo market. Security dealers finance their inventories through repurchase agreements, using inventory securities as collateral. They face a variety of counterparties of varying degrees of sophistication regarding their ability to value the securities. Theoretically, less sophisticated counterparties should fear the winner's curse of receiving worse collateral. In my model, a dealer seeks a more sophisticated lender because the sophisticated lender cherry-picks collateral and finances at lower rates. The less sophisticated lender cannot observe the dealer's behaviour and charges higher interest rates to compensate. I provide empirical evidence in support of my theory, showing that the compensation increases in the number of contacts that dealers have with sophisticated lenders. The increase in uncertainty during the Covid-19 pandemic serves as an exogenous variation in the informational advantage of more sophisticated lenders. My work suggests that opacity exacerbates fragility for well-connected borrowers, as less sophisticated lenders charge higher rates to compensate for the possibility of hidden cherry-picking.

In my third chapter, titled "Dynamic Liquidity Provision for Corporate Bonds under Capital Constraints", I study how capital constraints can delay bilateral trades. After the financial crisis, corporate bond practitioners lamented a poor state of market liquidity for large corporate bond trades, while academic research painted an inconclusive picture of liquidity conditions. Motivated by this tension, I find theoretically that scarce capital, together with market incompleteness, can delay trades. The market incompleteness stems from restrictive investment mandates that prohibit agents to trade derivative contracts, in particular forward contracts. Due to the absence of forward contracts, the agents must trade bundles of state-contingent claims. When the buyer's capital is scarce, the buyer wants to minimize capital used on the purchase of claims without gains from trade. Waiting unbundles claims, allowing for more productive use of capital. Therefore, I argue that scarce capital after the financial crisis may explain a deterioration in the time dimension of liquidity that may cause differences in opinion. My model relates the trade timing to the scarcity of capital, the bargaining power distribution and the dynamics of gains from trade. It also explains that investment funds with restrictive mandates, who are therefore limited to spot trades, are more affected by scarce capital.

I dedicate this work to my parents.

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Contents

Chapter 1

Transparency of Collateralized Lending without Commitment

Abstract

Many secured lending markets are opaque, allowing borrowers potentially to conceal multiple borrowing relationships. The policy debate has proposed transparency to curtail hidden risk. In this paper, I show that transparency may backfire due to increased credit rationing under multiple borrowing. In a transparent market, an opportunistic lender can easily coordinate with the borrower at the expense of a pre-existing lender. This becomes more difficult in an opaque market, as an opportunistic lender may more easily find himself at the receiving end of a different opportunistic move by the borrower. Lenders are therefore more cautious in an opaque market. This can restore the second-best allocation. I show that over-collateralization plays a key role in this mechanism as it constrains the borrower's ability to increase leverage opportunistically. Finally, I provide a clear characterization of when opacity achieves allocations that dominate those that can be achieved under market transparency in terms of welfare.

1.1 Introduction

Firms typically raise debt from multiple lenders. Bizer and DeMarzo (1992) show that an agency friction creates spillovers across lenders even when debt claims are perfectly prioritized. Furthermore, when the borrower cannot commit to an exclusive lending relationship, the spillovers harm equilibrium lending. The following examples highlight that the lack of commitment to an exclusive lender has practical relevance under different market structures:

Mortgage lending: Haughwout, Tracy, and van der Klaauw (2011) suggest that buyers of multiple houses have fuelled the 2008 financial crisis by "*apparently misreporting their intentions to occupy the property*". Lenders expect a mortgage borrower who occupies a residential property to preserve it. Therefore they stipulate lower interest rates and downpayments. When a new lender extends a new mortgage on a new house, he will not consider how it affects the value of the legacy mortgage lender. Non-exclusivity matters, since the marginal loans affect the legacy loan through the agency friction.

Prime brokerage: In 2021 the failure of a hedge fund, Archegos, caused losses of several billion USD among some of its lenders (prime brokers). Without informing its lenders, Archegos had established mirrored positions in separate leveraged investment accounts. Lenders extended too much leverage in their bilateral negotiations because they did not consider the incentive of Archegos to bet on a small selection of stocks. The exposure to the same financial assets as collateral created spillovers across lenders through fire-sale prices at the time of default.

Repurchase agreements: Repurchase agreements (repos) are secured loans with an agreed sale and repurchase of collateral. They are bilateral contracts that do not prevent the borrower from dealing with multiple counterparties. Lehman Brothers used borrowing from a subset of its counterparties to conceal the true state of its leverage to others. To conceal leverage, Lehman Brothers designed their repo contracts to circumvent disclosure rules[1]. The commissioned bankruptcy examiner of Lehman Brothers suggested that due to the special design, counterparties were aware of the intent to conceal and would charge higher interest rates[2]. In this example, non-exclusivity allowed opportunistic counterparties to lend at excessive interest rates that distorted other lenders' pricing of risk through incomplete leverage information.

In these examples, all debt contracts stipulate collateral, but the respective market structures differ in their degree of transparency. While mortgages are recorded in credit registries that are accessible to lenders, prime brokerage and repo lenders have little oversight over a borrower's other lending relationships. In the context of the Archegos failure, "[s]enior finance executives acknowledge that a crackdown of some form, whether on borrowing or transparency or both, is inevitable"[3]. The repo market is large and plays a crucial role in providing liquidity to market-makers and other financial institutions. In its 2013 report on the mitigation of shadow banking risks, the Financial Stability Board recommends extended disclosure requirements for financial institutions and investment funds. The report argues that greater disclosure of repos and securities lending is necessary "to monitor the build-up of systemic risk [...][and to] improve investors' and authorities' visibility into financial institutions' activities". While the call for more transparency is an instinctive reaction to many financial market disturbances, it is unclear whether transparency helps. In particular, I argue that the literature

[1] Lehman Brothers coined the term "Repo 105" for a method that allowed it to declare repos as asset sales instead of secured loans. Declaring repos as asset sales allows to reduce leverage in accounting measures while increasing economic leverage. Rigid accounting rules were tailored to the industry standard of repurchase prices between 98 and 102% of the collateral value. Therefore, only repos that fell within that bandwidth had to be declared as secured loans. Lehman Brothers deliberately agreed on contractual terms outside of this bandwidth to be able to misreport and to hide leverage.

[2] The bankruptcy report states that "witnesses who have knowledge on the subject uniformly advised the Examiner that Repo 105 trades generally were more expensive to Lehman than ordinary repos" and that "[E]veryone knows [Repo] 105 is an off-balance sheet mechanism, so counterparties are looking for ridiculous levels to take them."

[3] Bloomberg, *Leveraged Blowout: How Hwang's Archegos Blindsided Global Banks*

on non-exclusive lending does not provide guidance on the optimal degree of transparency when *collateral is a contractual choice*.

To study the role of transparency, I set up a model of a borrower with a scalable investment project. To scale up investment beyond his initial capital, the borrower can raise funds from lenders. The success probability of the project increases when the borrower behaves (e.g. chooses high effort or avoids pet projects). However, since behaving is not observable, the borrower needs to be incentivized by a sufficiently large share of the project to exert it. Lenders compete by offering menus of contracts, from which the borrower can choose contracts sequentially. The borrower cannot commit on subsequent borrowing. Importantly, the cash invested into the project generates an investment good that lenders can use strategically as a part of their contract to mitigate the non-exclusivity problem[4]. I consider two market designs, transparency and opacity, that govern whether the borrower's sequential choice is public information. In the transparency case, lenders observe which contract the borrower has signed and offer contingent menus. Opacity is the opposite, lenders cannot observe which contracts have been signed and therefore can only offer a single menu.

Under transparency, there can be increased credit rationing in equilibrium. When opportunistic lenders observe moderate leverage, they can seize the opportunity to offer a low collateral at a high interest rate. This contract benefits the opportunistic lender and the borrower, but it hurts the prior lender because the borrower exerts less effort at increased leverage. In equilibrium, lenders preempt opportunistic lending by demanding that the borrower owns a larger share of the project. Increasing leverage and misbehaving thus becomes less attractive. On the downside, it also reduces the scale of the (valuable) project.

Opacity, paradoxically, can mitigate the non-exclusivity issue of further

[4]Real world examples in which borrowers use their project as collateral are market-makers who use their inventory assets as collateral or real estate developers who assign mortgage liens on their properties

leverage by opportunistic lenders without a decrease in the project scale. Lenders include an additional contract with high leverage in their menu so as to threaten opportunistic lenders with overborrowing. Such overborrowing is a threat because it expropriates the under-collateralized opportunistic lender. The overborrowing contract, however, would be loss-making for the issuing lender if it were accepted by the borrower. To make the threat of overborrowing credible, it cannot be withdrawn at the time of need. Opportunistic lenders foresee that under transparency the over-borrowing contract would be withdrawn, precisely when needed. Opacity helps with credibility because it renders withdrawing a contract impossible. Importantly, the credibility of the threat suffices such that it is never used in equilibrium and therefore cost-less[5].

The main result of my paper cautions against an increase in transparency since it invites the entry of opportunistic lenders. While I insist that this finding does not hinge on any unconventional assumption, I acknowledge that reasons outside of my model can favour transparency. Therefore, I interpret my result as a call for a bundle of reforms: Greater transparency should be implemented *together* with rules that prevent opportunistic lending.

In the model, opportunistic lenders offer low collateral contracts with high interest rates. A minimum collateral value relative to the loan amount could prevent such inefficient contracts from opportunistic lenders in the model. In 2014, the Financial Stability Board issued a report that recommends haircut floors on repo contracts. A positive haircut refers to the amount that the collateral value exceeds the loan amount. Consequently, a haircut floor imposes a minimum amount that the collateral has to exceed the loan amount. It is precisely such a minimum collateral value that would prevent the entry of opportunistic lenders in my model.

The Financial Stability Board describes the purpose of haircut floors to be

[5] Arnott and Stiglitz (1991) and Attar, Mariotti and Salanié (2011) discuss the role of latent contracts in the context of non-exlusive contracts.

a "backstop in a benign market environment". In my model, a "backstop" is needed when entry of the opportunistic lender creates gains from trade between the opportunistic lender and the borrower. Proposition 1 states that this happens under transparency when the low effort project is profitable. In real-world markets, such gains from trade might arise under different market conditions. In some cases, like the mortgage lending market, opportunistic lending is arguably enticing in boom periods with high price growth, because it renders such house purchases profitable in which the buyer is not the occupant. In other cases, however, like market-making or arbitrage trading by investment funds, opportunistic lending is likely the most enticing when markets are in turmoil. My work, therefore, suggests that regulators should apply haircut floors in response to different market conditions, not only when the wider economy is booming.

1.1.1 Related Literature

A number of papers have studied the problem of non-exclusive lending[6]. However, this literature did not consider the role of collateral in contracts to resolve the non-exclusivity issue. One exception is Donaldson, Gromb and Piacentino (2020) who have recently highlighted that in the context of non-exclusive lending, collateral serves to exclude other lenders. Hence, it plays a different role than in the literature in which collateral usually guarantees cash flows that are pledgeable vis-à-vis the borrower[7]. In contrast to Donaldson, Gromb and Piacentino (2020), I study a setting in which the pledgeability of cash flows is endogenous. Due to the endogenous pledgeability problem,

[6] Other contributions include e.g. Kahn and Mookherjee (1998), Bisin and Guaitoli (2004), Leitner (2012), Admati, DeMarzo, Hellwig and Pfleiderer (2018), DeMarzo and He (2020),Green and Liu (2021) and van Boxtel, Castiglionesi and Ferriozi (2021)

[7] Donaldson, Gromb and Piacentino (2020) write that the "*two roles of collateral correspond to the two components of property rights that accrue to secured creditors upon default: the right of access (a creditor's right to seize collateral) and the right of exclusion (a creditor's right to stop other creditors from seizing collateral)*"

lenders have to ensure that all accepted contracts induce a sufficiently large residual claim for the borrower. The need to induce the right incentives for the borrower gives rise to *overcollateralized* contracts, i.e. contracts that have positive collateral haircuts in equilibrium. To my knowledge, this is the first paper that studies the role of haircuts in mitigating the non-exclusivity friction. I show that such high collateral contracts play a novel role under opacity; they are *pro-competitive*. Collateral encumbers the borrower's capital: When the demanded collateral value is large relative to the loan amount, the borrower must invest own capital that becomes encumbered. This implies that two high collateral contracts are mutually exclusive for the borrower to accept in equilibrium, while low collateral contracts are not. Importantly, due to mutual exclusivity of acceptance, multiple competing contracts can be *offered* in equilibrium. It is precisely the impossibility of competing offers to be offered in equilibrium that generally prevents zero-profit equilibria.

The transparency regime of my sequential lending model reproduces some findings of Bizer and DeMarzo (1992). In their model and mine, indirect dilution of prior lenders occurs because the borrower exerts less effort when he continues to borrow. To prevent the borrower from engaging in further borrowing, lenders have to adjust their contract relative to the exclusive competition allocation. The inability to commit to exclusive lending gives rise to an additional moral hazard problem in the acceptance of further contracts. Therefore, contracts need to satisfy an additional incentive constraint that ensures no further borrowing. To satisfy the additional constraint, lenders have to reduce their lending in my model, while the opposite is true in Bizer and DeMarzo (1992)[8]. My main contribution to this strand of literature is to show that the assumption on the observability of prior lending determines whether the additional constraint affects allocations.

The opaque version of my sequential model speaks to the literature on

[8]Furthermore, in my model the project scale is variable, while it is fixed in Bizer and DeMarzo (1992)

simultaneous non-exclusive lending like Parlour and Rajan (2001) and Attar, Casamatta, Chassagnon and Décamps (2019). Compared to this strand of literature, I show that the set of equilibria is markedly different when lenders can demand collateral. A common theme in this literature is that the competitive equilibrium with lender zero profits is not generally sustainable. I show that this finding is not robust to the inclusion of collateral. In particular, bilateral contracts suffice to ensure the existence of a competitive equilibrium. Furthermore, I show that contracts can only make positive profits in equilibrium if they stipulate low collateral. Since only low collateral contracts can make positive profits, their corresponding loan amount is limited in equilibrium. Otherwise, opportunistic lenders enter, offering a high collateral contract at high interest rate that dilutes profit-making contracts.

Two related papers on the role of transparency under non-exclusivity are Acharya and Bisin (2014) and Bennardo, Pagano and Piccolo (2015). I differ from both papers by modelling collateral as an investment good and the lenders' ability to write contracts on the collateral. While Bennardo, Pagano and Piccolo (2015) show that transparency can lead to credit rationing, they do not focus on the benefit of referencing collateral explicitly under opacity. I show that the extended contracting space makes it always possible to reach the second-best allocation under opacity.

My paper also relates to the literature that studies the role of information or transparency in financial markets. While Hirshleifer (1971) shows that information can prevent socially beneficial insurance trades, Dang, Gorton, Holmström and Ordoñez (2017) explain that the opacity of a bank's balance sheet can increase welfare when it prevents inefficient information production. Relative to these papers, I focus on the role of transparency with respect to the contracts that a borrower accepts[9]. In such a nonexclusive setting, I highlight that opacity can prevent lenders from offering socially inefficient

[9] Asriyan and Vanasco (2021) also study the role of transparency in a non-exclusive setting, but they focus on hidden types instead of moral hazard.

contracts in situations in which it comes at the expense of prior lenders.

Several papers study the role of collateral in lending. Early contributions by Stiglitz and Weiss (1981) and Bester (1985) focus on environments with adverse selection in which collateral signals the borrower's risk type. Duffie and DeMarzo (1999) show that collateralized debt emerges as the optimal security design when sellers have private information about the collateral. Two recent contributions study the implication of contractual features of repo contracts: Gottardi, Maurin and Monnet (2019) model the re-use of transferred collateral by the lender and Bigio and Shi (2020) show that the option value of the repurchase promise for the borrower can prevent credit rationing. In my work collateral in over-collateralized contracts restricts the borrower in his choice of further contracts, thereby mitigating excessive borrowing.

1.1.2 Road map

Section 2 introduces the model. Section 3 and 4 study non-exclusive competition under transparency and opacity, respectively. Section 5 discusses implications. Section 6 concludes. Proofs are in the appendix.

1.2 The model

1.2.1 The borrower's project

As in Holmström and Tirole (1997), I consider a single risk-neutral borrower with a variable size investment project with constant returns to scale. There are two goods, cash and an investment good. The borrower has an endowment A in cash. Moreover, he can transform cash into the investment good. There are three dates: At date 0 the borrower transforms I units of cash into I units of the investment good, at date 1 the borrower chooses effort and at date 2 the investment good generates a random cash flow equal to $\tilde{v}I$. The project's random cash flow $\tilde{v}$ follows a binary distribution:

$$\tilde{v} = \begin{cases} v & \text{with probability } p_e \\ 0 & \text{otherwise,} \end{cases}$$

where p_e depends on the borrower's unobservable effort choice, $e \in \{H, L\}$. The outside option for a cash investment yields a net return of 0.

Investing I and exerting high effort produces an expected cash flow of $p_H vI$ and yields a net return on investment (ROI) of $u_H \equiv p_H v - 1$. Similarly, low effort produces expected cash flows of $p_L vI$ but also generates a private benefit to the borrower that scales in the investment size, bI. Hence, the ROI of the low effort project including the private benefit is u_L and equals $(p_l v + b) - 1$.

Assumptions 1 (ROI): I consider two versions of assumptions on the ROIs.

$$\mathcal{A}1: \quad u_H > 0 > u_L$$
$$\mathcal{A}1^*: \quad u_H > u_L > 0$$

As will be seen later, the problem of non-exclusivity becomes severe under $\mathcal{A}1^*$. Since the project has always a positive ROI under high effort, the borrower would like to invest more than his limited capital. In the first best, the optimal project scale is infinite. To increase the scale of the project beyond his own capital, the borrower can raise outside funding from lenders.

1.2.2 Lenders

There are $n \geq 2$ risk-neutral lenders with deep pockets. A typical lender $i \in \{1, .., n\}$ offers a menu $\mathcal{M}_i$ that can contain several loan contracts $\mathcal{L}_{ik}$:

$$\mathcal{M}_i = \{\mathcal{L}_{i1}, .., \mathcal{L}_{ik}\}$$

from which the borrower can choose one. Each contract $\mathcal{L}_{ik}$ is a tuple (D_{ik}, R_{ik}, C_{ik}) that stipulates a loan size, repayment and collateral[10]. The loan size and the repayment are denominated in units of cash, while the collateral is denominated in units of the investment good. To accept contract $\mathcal{L}$, the borrower must transfer the required collateral to the lender at the moment of acceptance. Therefore, the borrower can only accept an additional contract, if he has sufficient funds to produce the required collateral. Importantly, the cash that the borrower transforms into an investment good can be pledged to lenders *while* it is invested in the project.

Collateral directly determines the priority of claims between lenders when full repayment of lenders is impossible. In case of default, any lender who owns collateral has first priority over cash flows stemming from his collateral up to full repayment. The remaining cash flows are distributed according to time priority that prescribes contracts accepted earlier to be repaid first[11].

Observe that collateral not only *directly* prevents other lenders from establishing competing claims on the collateral's cash flows, $C\tilde{v}$, but it limits *indirectly* which additional contracts the borrower can accept at date 0. When the borrower accepts a contract that is *over-collateralized* $C > D$, he has to invest $C - D$ of his own funds along with the loan size D to produce the required collateral. I say that $C - D$ is the amount by which the contract encumbers the borrower's capital A. Therefore, the required collateral constrains the borrower's acceptance of additional contracts by limiting the amount of unencumbered capital[12]. When the borrower transfers the investment good as collateral, the money

Lenders compete in a sequential financing stage that occurs within date 0.

[10]I will drop the indices in the text to improve readability.

[11]The time priority assumption is not important. I could also assume some pro-rata of investment rule.

[12]Note that collateral does not per se constitute additional pledgeable income as described in Tirole (2006). I make this modelling choice to tease out the specific role of collateral in the context of non-exclusive lending.

$t=0$	$t=1$	$t=2$
• Investment and financing stage.	• The borrower chooses effort.	• Uncertainty is resolved and lenders are repaid.

1.2.3 Sequential financing stage

The sequence of accepted contracts is recorded by credit history $\mathcal{H}_j$ with the index j counting the number of accepted contracts. At each instance j of the credit history, lenders compete and the borrower can accept one contract. Transparency makes the credit history public, allowing lenders to adjust their offers at each instance. Under opacity lenders cannot observe the credit history, preventing them from adapting their menu offers.

More formally, the transparency regime governs whether the current credit history is contained in the public information set of lenders, $\mathcal{I}$. The strategy of lender i maps the public information set $\mathcal{I}$ into a menu $\mathcal{M}_i$. When the public information set is always empty, lenders can only offer one menu.

Definition 1.2.1 (Transparency) *Transparency reveals the borrower's credit history to lenders, hence $\mathcal{I} = \mathcal{H}_j$ at any instance j.*

The structure of the financing stage under transparency is:

Transparency	$\mathcal{H}_0$	$\mathcal{H}_1$	$\mathcal{H}_2$
	• The public information is $\mathcal{I} = \{\}$. • Lenders post menu $\mathcal{M}_i(\mathcal{I})$. • Borrower accepts first contract $\mathcal{L}_1$.	• The public information is $\mathcal{I} = \mathcal{H}_1 = \{\mathcal{L}_1\}$ • Lenders post $\mathcal{M}(\mathcal{I})$. • Borrower accepts second contract.	• ... • Financing stage ends after the borrower accepts the null contract.

Definition 1.2.2 (Opacity) *Opacity hides the borrower's credit history from lenders, such that $\mathcal{I} = \{\}$ at any instance j.*

Under opacity, lenders cannot adjust their menu offers and the structure of the financing stage is:

Opacity

$\mathcal{H}_0$	$\mathcal{H}_1$	$\mathcal{H}_2$
• The public information is $\mathcal{I} = \{\}$. • Lenders post menu $\mathcal{M}_i(\mathcal{I})$. • Borrower accepts first contract $\mathcal{L}_1$.	• The public information is $\mathcal{I} = \{\}$. • Borrower accepts a second contract.	• ... • Financing stage ends after the borrower accepts the null contract.

1.2.4 Second best: Exclusive competition benchmark

Suppose first that the borrower can commit to a modus with one lender only. This provides a second-best benchmark against which to compare the non-exclusive case. The central concepts of my paper, collateral and the transparency regime, are only relevant in the context of non-exclusive lending. Collateral is redundant since there is no need to exclude competing claims or limit the borrower in his choice of additional contracts. The observability of prior lending is redundant since there can only be one active lender. Therefore, I abstract from collateral and the transparency regime in the analysis of the second-best case of exclusive competition.

Under exclusive competition, each lender simultaneously posts one contract, $\mathcal{L} = (D, R)$, and the borrower can choose one such contract. This is a standard moral hazard problem, except that the low effort project can be profitable. This requires an additional assumption $\mathcal{A}3$ that ensures that the high effort project is better in a second-best sense that considers the limited pledgeability due to the moral hazard friction. To ensure high effort, the loan contract must make the borrower exert high effort voluntarily. This limits the amount the borrower can borrow and thus the project scale. The borrower can commit to investing his capital A which he will do. Hence, the investment is $I = A + D$.

Incentive compatibility constraint (1) describes all combinations of loan size and repayment to the lender for which the borrower prefers to exert high effort (LHS) compared to low effort (RHS):

$$IC: \quad p_H(v(A+D) - R) \geq p_L(v(A+D) - R) + b(A+D) \tag{1.1}$$

The borrower makes a non-negative profit when the expected repayment recoups his initial loan. The zero-profit condition of the lender describes all combinations of loan size and repayment for which this is the case. Since the repayment occurs in the success state only, the zero-profit condition depends on the borrower's effort choice:

$$ZP_e: \quad p(e)R \geq D \tag{1.2}$$

In the high effort case, the incentive constraint limits the lender's repayment to be at most $R = (v - \frac{b}{\Delta p})(A+D)$ in order to induce high effort, where $\Delta p \equiv p_H - p_L$. The lender cannot ask for a higher repayment without inducing the borrower to choose low effort. Therefore, the minimum payoff of the borrower due to the agency friction, the *agency rent*, reduces the pledgeable cash flow per unit of investment by $p_H \frac{b}{\Delta p}$.

Assumption 2 (Pledgeable income gaps):

$$\mathcal{A}2: \quad p_H(v - \frac{b}{\Delta p}) - 1 < 0 \quad , p_L v - 1 < 0$$

$\mathcal{A}2$ implies that the amount of outside funding is limited by the borrower's cash even though there is always a positive ROI project.

Contract $\mathcal{L}^* = (D^*, R^*)$ solves the system of connstraints consisting of the binding incentive constraint and the lenders' zero-profit constraint under high effort:

$$D^* = \frac{p_H(v - \frac{b}{\Delta p})}{1 - p_H(v - \frac{b}{\Delta p})}A$$
$$R^* = \frac{D^*}{p_H}$$

Contract $\mathcal{L}^L = (D^L, R^L)$solves the system of equations consisting of the binding feasibility constraint, $R \leq (A + D)v$, and the lenders' zero-profit constraint under low effort:

$$D^L = \frac{p_L v}{1 - p_L v}A$$
$$R^L = \frac{D^L}{p_L}$$

$U_b(\mathcal{L}, e)$ is borrower's expected profit from accepting contract $\mathcal{L}$ and choosing effort e. When accepting $\mathcal{L}^*$ the borrower exerts high effort and his expected profit is:

$$U_b(\mathcal{L}^*, H) = p_H((A + D^*)v - R^*) - A$$
$$= \frac{A}{\frac{p_H b}{\Delta p} - u_H}u_H \equiv V_H$$

When accepting contract $\mathcal{L}^L$ and exerting low effort the borrower receives expected profit:

$$U_b(\mathcal{L}^L, L) = p_L((A + D^L)v - R^L) - A$$
$$= \frac{A}{b - u_L}u_L \equiv V_L$$

In both cases, under high and low effort, the scale of the project is determined by the size of the pledgeable income gap. In the high effort case, the pledgeable income gap per unit of investment can be expressed as $p_H \frac{b}{\Delta} - u_H$. The ratio of the borrower's capital to the pledgeable income gap determines the size of the maximal leverage. The capital multiplier, i.e. the ratio of the total investment relative to the borrower's capital, is the inverse of the pledgeable income gap:

$$\frac{A + D^*}{A} = \frac{1}{p_H \frac{b}{\Delta p} - u_h}$$

If the ROI of the low effort project is negative it is immediate that the borrower does not want to accept a contract that induces low effort. When the ROI of the low effort project is positive, $u_L > 0$, both V_L and V_H are positive. A third assumption guarantees that the value to the borrower of the leveraged high effort project is higher than the leveraged low effort project. This assumption ranks the two projects in a second-best sense that considers the limited pledgeability due to the agency friction. The relevant assumption guarantees that the product of the capital multiplier and the ROI under high effort is larger than the corresponding product under low effort:

Assumption 3 (Second Best):

$$\mathcal{A}3 : \frac{u_H}{p_H \frac{b}{\Delta p} - u_H} > \frac{u_L}{b - u_L}$$

Under these three assumptions, it follows that in any pure strategy equilibrium the borrower accepts contract (D^*, R^*). The corresponding allocation is unique, since in any other case there exists a profitable deviation to offer a contract arbitrarily close to (D^*, R^*) that gives the inactive lender positive profits and is preferred by the borrower.

Lemma 1 *Under exclusive competition, lenders compete and offer* (D^*, R^*) *in equilibrium. Social welfare is equal to* V_H.

Since lenders make zero profits in equilibrium, the borrower's profit corresponds to social welfare. Social welfare is maximal under exclusive competition in the second-best sense. A social planner who respects the agents' participation constraints and maximizes social welfare chooses to implement the allocations that correspond to contract (D^*, R^*).

Figure 1.1 plots the lender's repayment on the vertical axis and the loan size on the horizontal axis. Any allocation below the black IC line induces the borrower to exert high effort. The lender's zero profit constraint under high effort is drawn as a dashed line in blue. Its slope equals to $\frac{1}{p_H}$. Any allocation above this line and below the IC line yields a positive profit to the lender. The borrower's participation constraint is depicted as a dotted red line. It marks all allocations that give the borrower the same expected profit as investing his own capital only. The shaded area describes the set of allocations that the social planner can implement and that induce high effort. The allocation under exclusive competition, (D^*, R^*) is at the intersection of the IC constraint and lender's zero profit constraint. It maximizes social welfare because it maximizes the scale of the project.

In this paper, I will study when and how this allocation can arise when competition between lenders is *non-exclusive.*

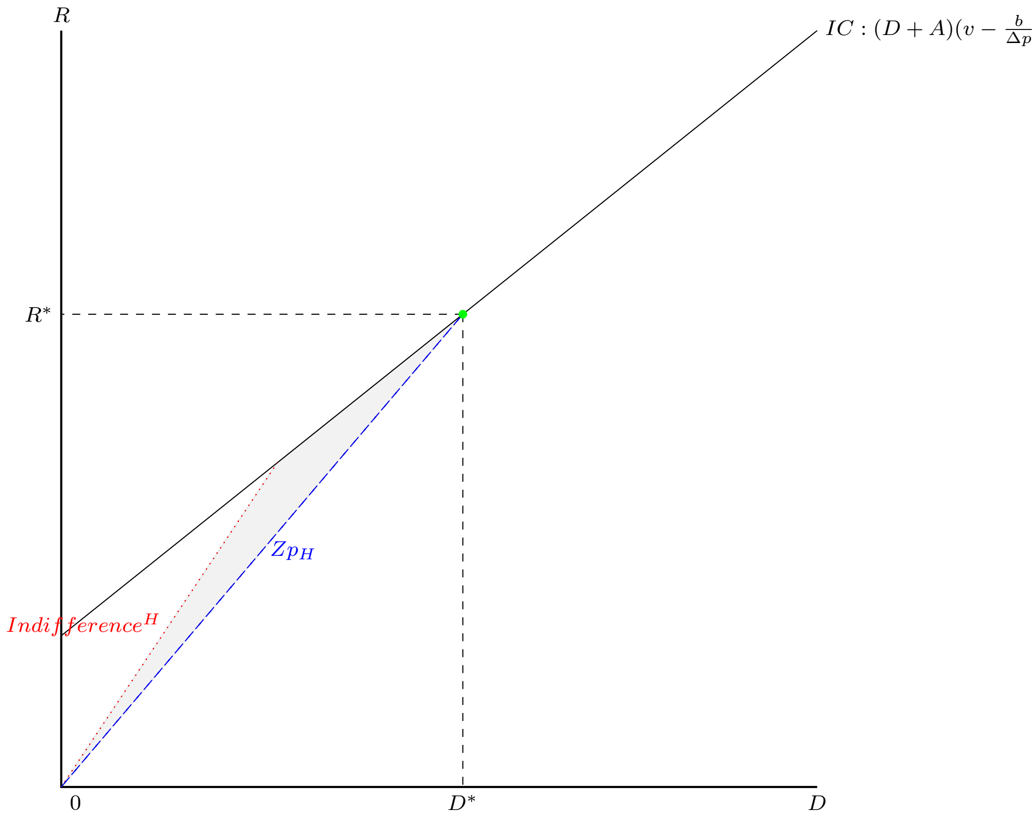

Figure 1.1: Exclusive competition

1.2.5 Equilibrium Definition for Non-exclusive Competition

I study subgame perfect equilibria that exclude equilibrium strategies with non-credible threats off the equilibrium paths. This means that the equilibrium cannot feature menu offers that are not optimal given a public information set. Each lender's strategy maps the public information $\mathcal{I}$ into a menu. The borrower's strategy is a sequence of contract acceptances and an effort choice. Since the borrower has to transfer the collateral when accepting a contract, a collateral constraint exists for any additional contract.

Definition 1.2.3 (Subgame Perfect Equilibrium) *In the subgame perfect equilibrium lenders offer menus $M(\mathcal{I})$ and the borrower chooses contracts and effort such that:*

1. *each lender's strategy maximizes his profit given the other lenders' strategies and the borrower's strategy.*

2. *The borrower chooses contracts sequentially and effort to maximize his profit given the lenders' strategies.*

3. *Sequence of contract acceptances $\mathcal{H}_j$ is feasible given the evolution of the information set of lenders and corresponding menu offers.*

4. *Any accepted contract j satisfies the collateral constraint:*

$$A + \Sigma_{k=0}^{j} D_k - \Sigma_{k=0}^{j-1} C_k \geq C_j$$

1.3 Non-exclusive competition under transparency

I proceed by discussing a candidate equilibrium strategy for lenders that is supposed to implement the allocation that would arise under exclusive competition and that yields the maximal social welfare V_H. To be consistent with the non-exclusive lending literature, I will refer to this allocation as the competitive allocation, since it yields zero profits to lenders and maximizes the scale of the project in the second-best environment.

In the candidate equilibrium strategy each lender offers a menu at $\mathcal{I} = \{\}$ that contains a null contract, $(0, 0, 0)$ and a contract $\mathcal{L}^*$ that implements the competitive allocation with maximal collateral:

$$(D, R, C) = (D^*, \frac{D^*}{p_H}, D^* + A).$$

The borrower has to use all his funds to produce the necessary collateral to accept one contract from the candidate menu with a positive loan amount. Let credit history $\mathcal{H}_1^* = \{\mathcal{L}^*\}$ record the acceptance of such a contract from the candidate menu. The public information reveals the credit history to the lenders and they can post a new menu, $\mathcal{M}(\mathcal{I})$. Since the borrower has no funds left, lenders cannot ask for collateral that exceeds the loan amount. Furthermore, as the project is not self-financing, lenders cannot offer an additional loan that, if accepted, guarantees $e = H$ and ensures that the lender breaks even. Therefore, any additional loan has to induce low effort as it is at least partly repaid with the agency rent from contract $\mathcal{L}^*$. Suppose lenders offer a contract $\mathcal{L}^s$ that yields zero profits for a small amount d:

$$(D, R, C) = (d, \frac{d}{p_L}, d)$$

Let history $\hat{\mathcal{H}}_2$ describe the final history in which the borrower accepts contract $\mathcal{L}^*$ and a second contract $\mathcal{L}^s$. $U_b(\mathcal{H}_j, e)$ evaluates the value of the final history $\mathcal{H}_j$ under the corresponding optimal effort choice for the borrower. The borrower prefers $U_b(\hat{\mathcal{H}}_2, L)$ to $U_b(\hat{\mathcal{H}}_1^*, H)$ when:

$$U_b(\hat{\mathcal{H}}_2, L) = V_H + du_L > V_H = U_b(\hat{\mathcal{H}}_1^*, H)$$
$$\iff u_L > 0$$

The borrower receives the same payoff V_H from contract $\mathcal{L}^*$ regardless of his effort choice and the full ROI of the low effort project. Therefore, under assumption $\mathcal{A}1^*$, all lenders different from the first lender can offer an additional *side-trading*[13] contract that is accepted by the borrower and admits a non-negative profit, provided that d is not too large. The maximal loan size d has to satisfy:

$$\frac{d}{p_L} + \frac{D^*}{p_H} \leq (A + D^* + d)v$$

Since the first lender makes a loss on his contract due to the *side-trade*, the candidate strategy cannot support an equilibrium when the low effort project is profitable. Figure 1.2 depicts the continuation at credit history $\mathcal{H}_1^*$ when the low effort project is valuable. Starting from the competitive allocation (D^*, R^*), the slope of the borrower's indifference line is steeper than the lenders' zero profit line, $v + \frac{b}{p_L} > \frac{1}{p_L}$. The shaded area describes *side-trades* that induce an allocation with positive gains from trade between the borrower and a *side-trading* lender, provided that the loan amount is below the feasibility line, $(D + A)v$.

[13] I use *side-trading* contract to describe a contract that induces negative profits for any previous lender.

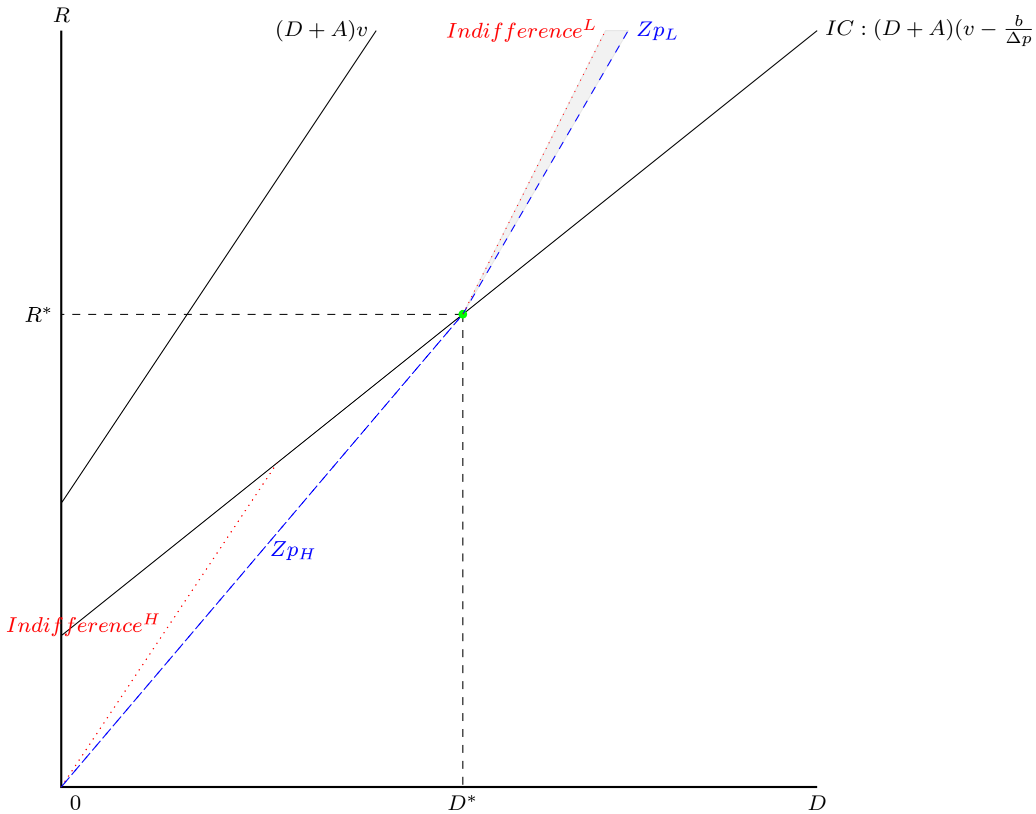

Figure 1.2: Continuation game at $\mathcal{H}_1$

Proposition 1 makes the relationship between social welfare and the profitability assumptions precise.

Proposition 1 *Under transparency, the competitive outcome attains social welfare of V_H if and only if the low effort project is not profitable.*

While the example above shows the impossibility of allocation (D^*, R^*) under $\mathcal{A}1^*$, this allocation is unique under $\mathcal{A}1$. If a different allocation $(\hat{D}, \hat{R})$ induced high effort and positive profits for some lenders in equilibrium, an inactive lender could deviate by offering any allocation on the line between $(\hat{D}, \hat{R})$ and (D^*, R^*) and ask for maximum amount of collateral.

When the low effort project is profitable, social welfare has to be strictly lower than V_H under $\mathcal{A}1$. However, there can be still a high effort equilibrium, but lenders have to decrease their repayment to prevent the borrower from accepting contracts that induce low effort. Non-exclusivity gives rise to a *side-trading constraint* that prescribes that the borrower refuses to accept an additional *side-trading* contract. This condition can be written as:

$$U_b(\mathcal{H}_1, H) \geq U_b(\hat{\mathcal{H}}_2, L) \tag{1.3}$$

where $\hat{\mathcal{H}}_2$ contains the *side-trade* preferred by the borrower that gives non-negative profits to the *side-trading* lender. I denote by ϵ the additional payment to the borrower in the success state beyond $\frac{b}{\Delta p}$ in order to prevent a *side-trade*. The higher agency rent makes the borrower *strictly* prefer high effort over low effort on the first contract. Hence, ϵ satisfies inequality (3) when the loss on the first contract exceeds any gain on the additional contract:

$$\begin{aligned} & U_b(\mathcal{H}_1, H) - U_b(\hat{\mathcal{H}}_2, L) \geq 0 \\ \iff \; & \frac{\Delta p \epsilon}{\frac{p_H b}{\Delta p} - u_H + p_H \epsilon} A \geq \frac{u_L}{b - u_L} \frac{p_L(\frac{b}{\Delta p} + \epsilon)}{\frac{p_H b}{\Delta p} - u_H + p_H \epsilon} A \end{aligned}$$

Due to the higher agency rent, high effort yields the borrower a strictly higher profit from the first contract. When an $\epsilon \in [0, v - \frac{b}{\Delta p}]$ satisfies this constraint, then there is high effort in equilibrium. Proposition 2 makes this result precise:

Proposition 2 *Under assumption $\mathcal{A}1^*$ the unique equilibrium induces high effort and increased credit rationing provided that $u_H > \frac{u_L}{b - u_L}$. Lenders have to increase the agency rent to the borrower by $\epsilon^H = \frac{V_L p_L \frac{b}{\Delta p}}{\Delta p A - V_L p_L}$. Social welfare is equal to $\frac{u_H}{p_H(b/\Delta p + \epsilon^H) - u_H} A$. Otherwise, lenders offer only a contract that induces low effort and social welfare V_L.*

Figure 1.3 visualizes that an increase in the agency rent can allow sustaining a high effort equilibrium. While at the allocation (D^*, R^*) there are profitable side-trades, as discussed in Figure 1.2, reducing the allocation below the IC line induces the borrower to prefer high effort strictly to low effort. The figure depicts the strict preference for high effort through the rightward shift of the borrower's indifference line. The new candidate allocation (D^1, R^1) prevents *side-trades* when no additional loan can yield gains from trade to borrowers and the opportunistic lenders. This corresponds to the situation in which the borrower's indifference line and the lenders' zero profit line do not cross before they cut the feasibility line, $(D + A)v$.

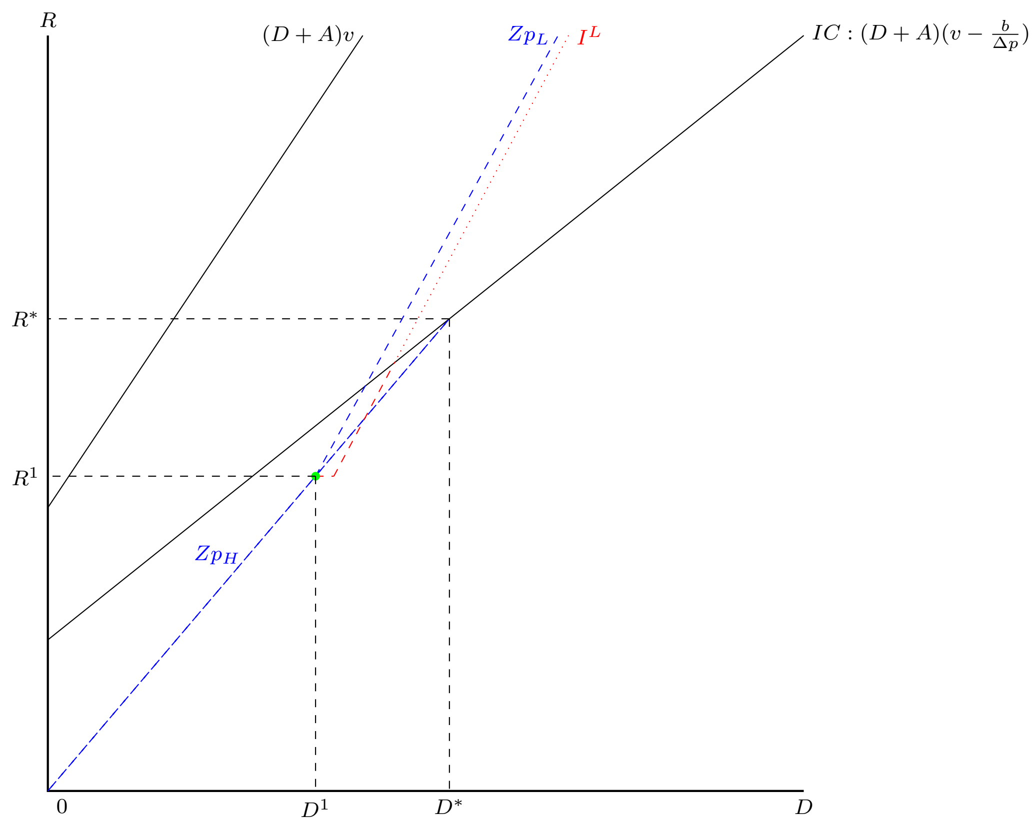

Figure 1.3: Continuation game under higher agency rent

In the relevant parameter region $u_H > \frac{u_L}{b-u_L}$ the lowest additional agency rent, denoted by ϵ^H, is equal to $\frac{u_L/(b-u_L)p_L\frac{b}{\Delta p}}{\Delta p - u_L/(b-u_L)p_L}$ and the corresponding menu offered by lenders contains the contract:

$$(D, R, C) = (D^\epsilon, \frac{D^\epsilon}{p_H}, D^\epsilon + A)$$
$$D^\epsilon = \frac{p_H(v - \frac{b}{\Delta p} - \epsilon^H)}{1 - p_H(v - \frac{b}{\Delta p} - \epsilon^H)} A.$$

Otherwise, in the unique equilibrium lenders offer a contract that induces low effort and yields social welfare equal to V_L:

$$(D, R, C) = (D^L, \frac{D^L}{p_L}, D^L + A)$$
$$D^L = \frac{1 + u_L - b}{b - u_L} A$$

Under the transparency regime, the equilibrium allocation is unique, but welfare is lower than in the competitive allocation whenever the low effort project is socially valuable. The transparency version of my sequential lending model reproduces the findings of Bizer and DeMarzo (1992) in a model with endogenous project size. In my model, the threat of opportunistic lending is relevant when the low effort project is valuable. In the next section, I will show that even in this case, the presence of multiple counterparties does not have to harm welfare, provided that the lending market is opaque.

Observe that it is not the collateral that prevents further lending under transparency but the lower repayment to lenders that makes the borrower unwilling to accept an additional contract. Collateral is therefore not uniquely determined. When the low effort project is valuable, a collateral that fully secures repayment, $C \geq \frac{R^*}{v}$, is necessary in equilibrium. Otherwise, a lender makes himself vulnerable to expropriation through subsequent secured lending. This effect has been previously discussed in Donaldson, Gromb and Piacentino (2020). Interestingly, the least amount of collateral is $\frac{R^*}{v}$ is smaller than D, hence the value of the collateral can be lower than the loan amount. On the contrary, under opacity collateral has to be larger than the loan amount, i.e. over-collateralization is crucial.

1.4 Non-exclusive competition under opacity

Under opacity, lenders cannot update their menus. Firstly, I will show that opacity always allows for an equilibrium that yields social welfare equal to V_H. This occurs because opacity allows lenders to include threats that deter other lenders from offering *side-trades*. The $pro-competitive$ role of collateral plays a crucial role in sustaining this equilibrium. I can show this role of collateral by contrasting my findings with Attar, Casamatta, Chassagnon and Décamps (2019), who study a similar model without collateral. Threats can be a two-edged sword, since lenders can (ab)use threats to lessen competition, paving the way for equilibrium multiplicity. I show that there is a lower bound on social welfare in equilibrium. To give a normative recommendation on the optimal transparency policy in the model, I compare the welfare under the lower bound to the transparency outcome.

1.4.1 Existence of V_H Equilibrium

Consider that at the beginning, $\mathcal{I} = \{\}$, lenders offer a null contract and a contract that induces the competitive allocation at maximal collateral:

$$(D, R, C) = (D^*, \frac{D^*}{p_H}, D^* + A).$$

The borrower can accept only one contract with a positive loan amount because the collateral required depletes his capital A. This constitutes an equilibrium under $\mathcal{A}1$ because no lender can deviate and offer a *side-trading* contract that is accepted by the borrower and yields positive profits. The reasoning is the same as in the transparency case. Therefore, the candidate strategy sustains an equilibrium with social welfare equal to V_H under $\mathcal{A}1$.

When $u_L > 0$, there exists a *side-trade* with gains from trade for the borrower and the *side-trading* lender. The lenders can, however, prevent the *side-trade* through a threat in their menu. This threat is a contract that remains inactive or *latent* but sustains the competitive allocation in equilibrium even under assumption $\mathcal{A}1^*$:

Proposition 3 *Under opacity, there always exists an equilibrium allocation that induces social welfare of V_H.*

To prevent a *side-trade* lenders add the following contract to their menus:

$$(D^l, R^l, C^l) = (d^l, (d^l + A)v, d^l + A)$$
$$d^l = \frac{V_H + A(1-b)}{b}$$

When accepted, the latent contract induces the borrower to exert low effort since he does not receive any payment in the case of success. The loan size d^l is chosen such that the borrower weakly prefer to accept $\mathcal{L}^*$ and to exert high effort compared to accepting the latent contract and exerting low effort, $U_b(\mathcal{H}_1^*, H) \geq U_b(\mathcal{H}_1^l, L)$. However, due to the large scale under the latent contract, the borrower weakly prefers receiving a large scale private benefit over the competitive allocation contract and exerting low effort, $U_b(\mathcal{H}_1^l, L) \geq U_b(\mathcal{H}_1^*, L)$. Therefore, the latent contracts have to satisfy the following two conditions:

$$U_b(\mathcal{H}_1^*, H) \geq U_b(\mathcal{H}_1^l, L) \geq U_b(\mathcal{H}_1^*, L).$$

The latent contract renders any *side-trade* unprofitable because the borrower would complement any *side-trade* with a latent contract. Firstly, any *side-trade* has to feature a collateral value equal to loan size, $C = D$, so that the borrower *can* accept it together with the competitive allocation. However, the low collateral value of the *side-trade* implies that it can be also accepted with the latent contract. Secondly, both the latent contract and the competitive allocation yield the same borrower profit, but the latent contract enables the borrower to expropriate the *side-trading* lender. Suppose that the *side-trading* lender offers a contract that affords a zero profit if it is fully repaid:

$$(D, R, C) = (d, \frac{d}{p_L}, d)$$

When this contract is accepted in conjunction with the latent contract, the *side-trading* lender is only repaid up to the cash flow stemming from his collateral, $d\tilde{v}$. Therefore, the borrower can expropriate the side-trading lender and earn a higher profit:

$$U(\mathcal{H}_2^l, L) - U(\mathcal{H}_2^*, L) = db - du_L = d(1 - p_L v) > 0$$

where the two histories record the respective addition of a side-trade. Importantly, this deterrence of an opportunistic lender is only possible under opacity. Since the latent contract would be *loss-making conditional on acceptance*, it would not be credible under transparency. Only when opacity prevents withdrawing the contract is it credible and hence, successfully deters entry. Furthermore, it can be part of an optimal strategy, as it is cost-less due to its credibility.

Figure 1.4 shows the two contracts with positive loan amounts that sustain the V_H equilibrium. The borrower is indifferent between the two contracts but he strictly prefers to add any *side-trading* contract to the latent allocation, (D^l, R^l). This becomes clear visually, as the slope of the borrower's indifference line originating from the latent allocation is steeper than the one from the competitive allocation. Therefore, the borrower always prefers to "chain" the opportunistic loan to the latent allocation to receive a higher utility.

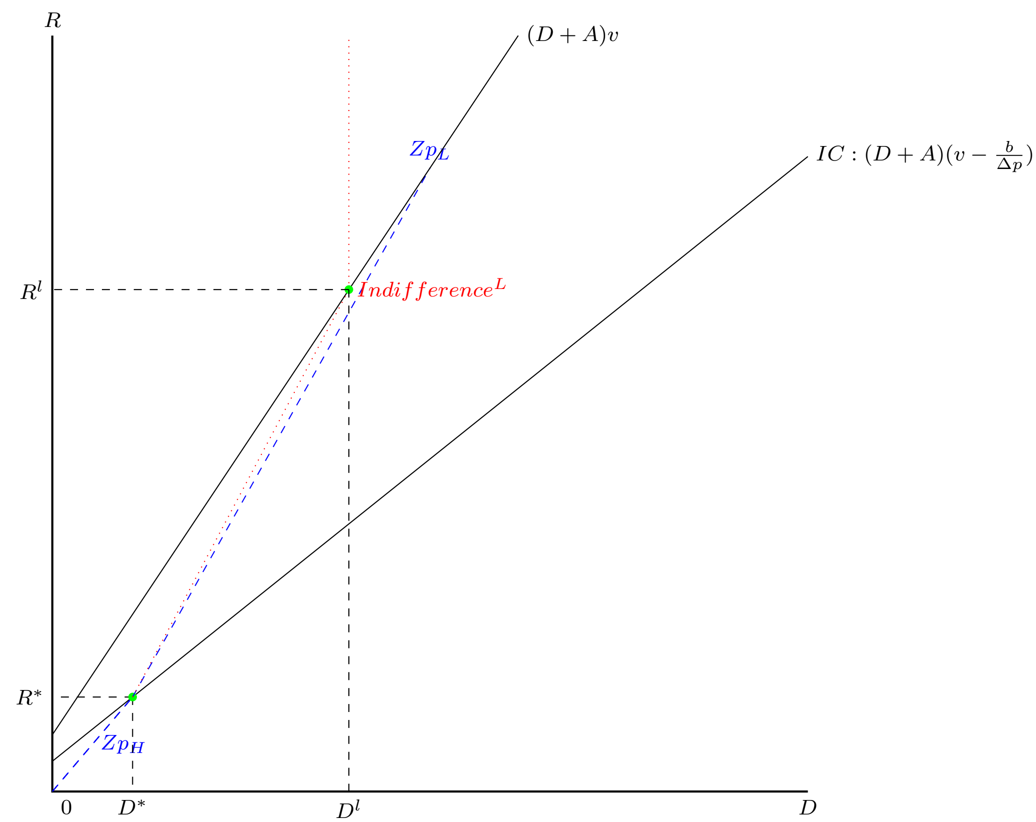

Figure 1.4: Menu with deterring contract (D^l, R^l)

1.4.2 The Role of Collateral

Collateral is crucial in sustaining the V_H equilibrium because it allows several lenders to offer the same contract that would induce the competitive allocation when accepted. These contracts are mutually exclusive when they stipulate a high collateral value. Consequently, an inactive competitive allocation contract can deter the active lender from deviating to offer a contract with slightly higher profits. Without collateral, the resulting lack of competing contracts that are offered in equilibrium prevents the competitive allocation from being sustainable in equilibrium in models of unsecured non-exclusive lending. For example, the equilibria characterized in Attar, Casamatta, Chassagnon and Décamps (2019) it is impossible that inactive contracts offer the equilibrium allocation, because the borrower prefers to accept these contracts. Therefore, in their analysis, a simple contracts that do not reference aggregate values cannot sustain V_H when the private benefit b is large. Similarly, in Parlour and Rajan (2001) the competitive allocation fails when it is impossible that offered competitive contracts remain inactive.

1.4.3 Multiplicity and the lower bound on welfare

Lenders can use threats to reduce competition. However, collateral bounds the profits lenders can make in equilibrium, as the monopolistic allocation with the maximal lender profits cannot be generally sustained. The intuition follows a two-step logic: Firstly, a contract that makes a positive lender profit cannot have a high collateral value, otherwise competitive pressure drives profits to zero. Secondly, when a contract has a low collateral value, it can be added to any other contract, in particular to contracts that induce low effort. The threat of *side-trading* a high collateral value contract bounds the maximal profit lenders can make through low collateral contracts.

Lemma 2 *No contract with $C > D$ can make a positive profit in equilibrium.*

Otherwise, there exists a deviation by an inactive lender to replicate the profit-making contract with a repayment that is reduced by an arbitrarily small amount δ such that the contract remains profitable. The borrower naturally prefers the slightly lower repayment and he "exchanges" the two contracts. Furthermore, now the borrower has more exposure to the success state, therefore is less inclined to accept a *side-trade*. This reasoning implies that high collateral contracts face competitive pressure that drives profits to zero. High collateral limits the borrower accepting all contracts, therefore it facilitates competing lenders to enter. This allows lenders to undercut any high collateral contract that gives positive lender profits.

Suppose that one *profit-making* lender offers a contract that makes a positive profit under high effort. Furthermore, this contract asks for the highest possible repayment that leaves the borrower indifferent between accepting or rejecting it:

$$(D, R, C) = (d^u, d^u v, d^u)$$

This contract, by itself, only gives the borrower his reservation, hence he would be inclined to accept a side-trade that induces low effort. It is in the best interest of the profit-making lender that the borrower accepts a complementary contract that induces a larger scale *and* high effort. Suppose the *profit-making* lenders or any other lender offer two contracts with a positive loan size: The first contract complements the profit-making contract to induce an allocation on the borrower's IC line, and the second contract complements the profit-making contract to induce a latent allocation that deters *side-trading*, i.e. offering a low collateral contract that induces low effort.

The first complementary contract $(d^c, d^c/p_H, d^c + A)$ induces high effort if it satisfies the borrower's IC constraint:

$$d^u v + d^c/p_H = (A + d^u + d^c)(v - b/\Delta p)$$

The second complementary contract $(d^l, r^l, d^l + A)$ remains inactive. It is issued to prevent a *side-trade* as seen before. To be effective, the second complementary contract has to threaten over-borrowing, by potentially inducing a large scale project. The borrower is exactly indifferent between the two complementary contracts when:

$$(d^u + d^l + A)b = (d^u + d^c + A)p_H b/\Delta p \quad r^l = (d^l + A)v$$

Due to the low collateral nature of the *profit-making* a new *side-trading* strategy arises for an opportunistic lender. He can offer a contract with a high collateral value that the borrower accepts together with the *profit-making* contract $(d^u, d^u v, d^u)$ and exerts low effort. Under such a high collateral *side-trade*, the borrower reaps the private benefit from a large project that is subsidized by the low collateral contract. The subsidy scales in the amount of the loan size of the low collateral contract. Therefore, the threat of an opportunistic lender imposes a limit on the amount of profit-making debt and lender profits in equilibrium. The following inequality determines the upper bound on the loan size of the *profit-making* contract as it ensures that the borrower does not accept a high collateral *side-trade*.

$$U_b(\mathcal{H}_2^u, H) = (d^u + d^c + A)p_H b/\Delta p - A \geq V_L + d^u b = U_b(\mathcal{H}_2^s, L) \tag{1.4}$$

The above inequality is a new *side-trading* constraint that arises because the profit-making contract cannot stipulate high collateral. Hence, the upper bound on the amount of the *profit-making* $\bar{d^u}$ depends on the amount of complementary debt d^c. The maximal amount of complementary debt follows from the borrower's IC constraint and equals:

$$d^c(\bar{d^u}) = V_H + A\frac{1 - p_H b/\Delta p}{p_H b/\Delta p - u_H} - d^u \frac{p_H b/\Delta p}{p_H b/\Delta p - u_H}$$

The maximal amount of the complementary debt together with the side-trading constraint (4) pin down the maximal amount of *profit-making* debt, $\bar{d^u}$:

$$\bar{d^u} = \frac{(V_H - V_L)(p_H b/\Delta p - u_H)}{b(bp_H/\Delta p) - u_H(b - bp_H/\Delta p)}$$

The total outside funding that the borrower receives in an allocation that yields the lower bound equals to

$$\bar{d^u} + d^c = D^* - \frac{u_H(V_H - V_L)}{b(bp_H/\Delta p) - u_H(b - bp_H/\Delta p)}$$

This equation reveals that the total outside funding is decreasing in the ROI of the high effort project but it is increasing in V_L. This is intuitive, as the *profit-making* allocation has to prevent that a lender can enter and offer a high collateral contract that yields the borrower at least V_L.

The amount of debt that yields the lower bound on the social welfare of any equilibrium under opacity can be rewritten as:

$$(\bar{d^u} + d^c(\bar{d^u}) + A)u_H = V_H - \frac{u_H(V_H - V_L)}{b(bp_H/\Delta p) - u_H(b - bp_H/\Delta p)} p_H b/\Delta p \equiv V_o$$

Identifying the lower bound V_o allows to pin down when it dominates the transparency outcome. The following proposition makes it precise:

Proposition 4 *The lower bound on welfare under opacity dominates the outcome under transparency when* $\frac{u_L}{b-u_L} \geq u_H$*. Under* $u_H > \frac{u_L}{b-u_L}$ *it depends on the model parameters whether the lower bound dominates. For* $u_H > 0 > u_L$ *transparency dominates opacity.*

Figure 1.5 shows the *profit-making* contract and the complementary contract, as well as the combination of the two contracts. I use a red and green colour to visualize that one contract has a low collateral value, $C = D$, while the other has a high collateral value, $C > D$.

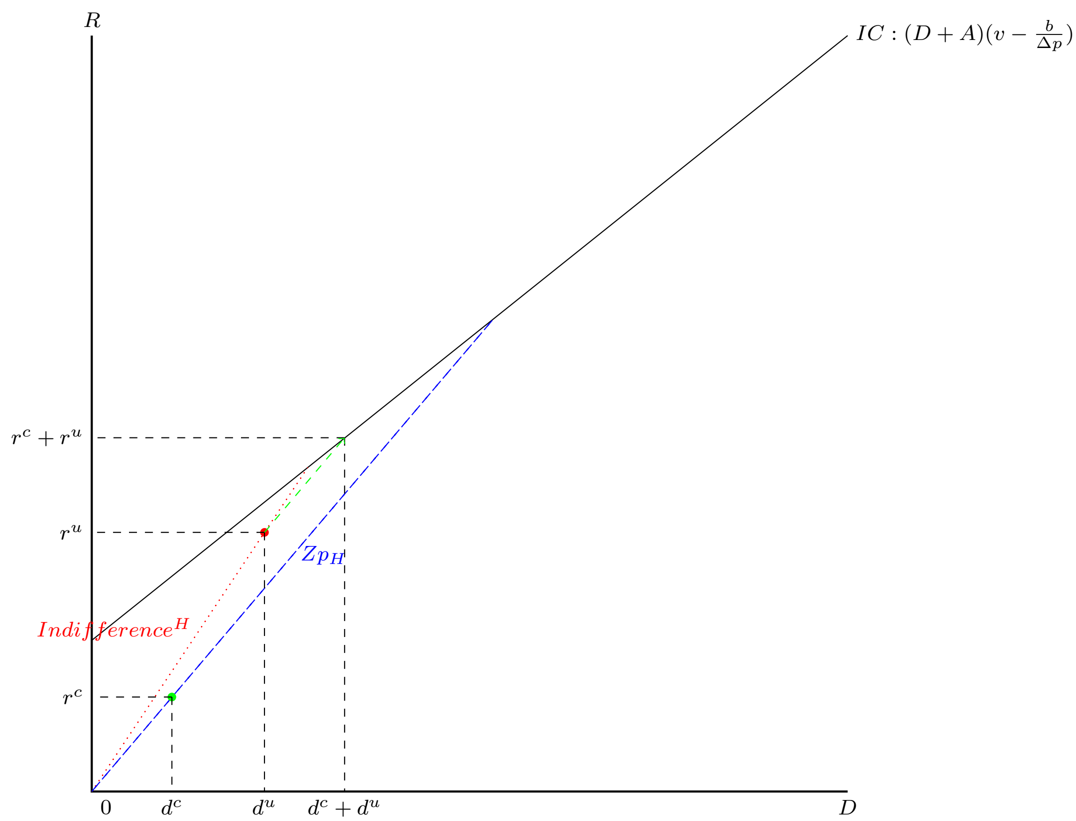

Figure 1.5: Active contracts in the *profit-making* equilibrium

1.5 Discussion

1.5.1 Implication for the policy debate

The main result of my paper cautions against an increase in transparency since it invites the entry of opportunistic lenders. A regulator in the model can prevent such opportunistic lending by enforcing a minimum collateral value of $C > D$. Such a regulatory tool is relevant as the Financial Stability Board recommends a corresponding floor on haircuts to national regulators of repo markets.

Haircut floors under transparency

A haircut floor that demands a positive haircut corresponds to a ban of contracts with $C \leq D$. This implies that lenders can prevent the entry of opportunistic lenders by requiring a collateral value that equals $C = D + A$. Even though opportunistic lenders would like to offer a contract when the low effort project is valuable, the borrower cannot produce the collateral for any admissible contract.

This produces the following counter-intuitive *empirical prediction*: Under transparency with a threat of opportunistic lending, i.e. assumption $\mathcal{A}1^*$, haircut floors lead to an increase in the amount of (valuable) lending as lenders are more protected from a subsequent increase in leverage by the borrower. On the other hand, under the assumption, $\mathcal{A}1$ an introduction of a binding haircut floor will lead to a reduction in leverage.

The novel empirical prediction can be tested in the context of loan-to-value (LTV) requirements for mortgage borrowers. LTV requirements are a macro-prudential policy tool that aims at preventing excessive mortgage leverage and house price growth. Interestingly, Igan and Kang (2011) report that LTV requirements impact speculators' loan demand but not first-time house buyers. Additionally, Kinghan, McCarthy and O'Toole (2019) report in their descriptive statistics that introducing a maximal LTV requirement increased the average observed LTV of loans in the Irish mortgage market. My model can rationalize these observations since it predicts that first-time buyers should have easier access to leverage when a regulator imposes borrowing constraints and speculation is a threat. Intuitively, when the LTV requirement mitigates the threat of leverage with opportunistic lenders, prudent first-time house buyers receive loans more easily. To the contrary, when speculation is not a threat, a binding LTV requirement will make it harder for first-time buyers to obtain leverage.

Haircut floors under opacity

Under opacity, there exist equilibria in which lenders can make positive profits with low collateral contracts. A requirement of positive haircut contracts would therefore eliminate these equilibria. This follows directly from lemma 2. The only equilibrium that prevails is the second-best efficient one.

1.5.2 Implication for collateral

Under transparency, the minimum collateral is not uniquely determined. It has to prevent direct dilution which lenders can achieve without over-collateralization. The following proposition specifies the minimum of collateral in aggregate that lenders have to demand to sustain an equilibrium under $\mathcal{A}1^*$:

Proposition 5 *When the low effort project is valuable, the minimum level of collateral under transparency is $C = R$ while it equals $C = D + A$ under opacity. Hence, when high effort can be sustained, there is a positive haircut under transparency $C < D$ and a positive haircut under opacity $C > D$.*

My model predicts that collateral protects against direct dilution under transparency, but under opacity, it also must protect against indirect dilution. The need to protect under indirect dilution requires over-collateralization. While providing collateral is cost-less in the model, it is reasonable to assume that collateral has a small transfer cost in reality (e.g. collateral has to be identified or monitored). Such a transfer cost of collateral would make the minimum level of collateral the unique equilibrium outcome. Hence, my model generates the empirical prediction that opaque lending markets should feature more overcollateralized lending than transparent lending markets.

1.6 Conclusion

I analyze a model of non-exclusive lending with collateral under different transparency regimes. On the policy side, I show that transparency can have drawbacks when it opens the door to opportunistic lenders. My model explains that policy recommendations on transparency and minimum haircut levels can be complementary. Therefore, I suggest that transparency reforms should be combined with rules that suppress opportunistic lending. With respect to the non-exclusivity literature, I show that collateral has a pro-competitive role. By creating mutual exclusivity between overcollateralized contracts, collateral allows Bertrand competition in model environments that often exhibit positive profit equilibria. Additionally, I show that overcollateralization plays an important role under opacity, as it limits the ability of the borrower to obtain hidden excessive leverage. My model produces novel empirical predictions. Firstly, policy interventions that limit leverage can increase socially valuable leverage when opportunistic lending is a problem. Secondly, opaque lending markets should exhibit more overcollateralized lending than transparent lending markets.

While in this paper all lenders have symmetric information about the collateral, in reality, some counterparties are more specialized in evaluating collateral than others. The knowledge of the identities of the other counterparties can therefore provide relevant information for lenders to infer the true value of the collateral. When opacity obfuscates this information, less sophisticated lenders might reduce or even withhold lending. I will address this question in future work about the role of opacity with asymmetrically informed lenders.

1.7 Proofs:

Proof of Lemma 1

By assumption 3, allocation (D^*, R^*) gives the highest profit to the borrower among allocations that satisfy the lenders' zero-profit constraint. Construct the following contract that depends on a parameter δ, $\mathcal{L}(\delta) = (D(\delta), R(\delta)) = (D^* - \delta, R^* - (v - b/\Delta p)\delta)$. Since all these contracts for $\delta > 0$ induce high effort, I can write the borrower's expected utility as a continuous function in δ, i.e. $U_b(\mathcal{L}(\delta), H) = p_H(A + D(\delta))v - R(\delta)) \equiv U_b(\delta)$. Observe that $U_b(0) = V_H$ and $U_b(\frac{D^*v - R^*}{b/\Delta p}) = u_H A$ which corresponds to the borrower's outside option. In any pure strategy candidate allocation $(\hat{D}, \hat{R})$ different from (D^*, R^*) the borrower's utility $\hat{U}_b$ has to be within $[u_H A, V_H)$. Since $U_b(\delta)$ is a continuous function, there must exist a $\delta \in (0, \frac{D^*v - R^*}{b/\Delta p})$ such that $U_b(0) > U_b(\delta) > \hat{U}_b$. This δ pins down a profitable deviation, because it gives a positive profit to the lender and a higher profit to the borrower.

Proof of Proposition 1

The lenders induces an allocation (D^*, R^*) with their candidate strategy. This candidate strategy prescribes to offer $(D^*, R^*, D^* + A)$ and the null contract for any history in which the borrower has either an empty credit history $\mathcal{H}_0$ or $\mathcal{H}_1 = \{(D^*, R^*, D^* + A)\}$. I show that there is no profitable deviation to this strategy after specifying lenders' strategies for any possible credit history $\mathcal{H}_j$.

Off equilibrium lender strategies

After any credit history $\mathcal{H}_j$ there can be up to three types of contracts offered by lenders: (i) a high effort contract, (ii) direct expropriation of an under-collateralized earlier contract (iii) or a null contract. Each contract is designed such that there is no further lending.

(i) Lenders can offer a high effort contract that induces an allocation on the borrower's IC line. Suppose that $\hat{D}$, $\hat{R}$, $\hat{C}$ are the debt, repayment and aggregate collateral from history of off-equilibrium path $\hat{H}_1$. A necessary condition for lenders to offer a high effort contract is:

$$(A+\hat{D})(v-\frac{b}{\Delta p})-\hat{R}>0$$

otherwise the borrower does not take high effort given additional funding. In this case, they can offer contract:

$$(D,R,C)=(d_c,\frac{d_c}{p_H},A+\hat{D}+d_c-\hat{C})$$
$$d_c=\frac{(A+\hat{D})(v-\frac{b}{\Delta p})-\hat{R}}{1/p_H-(v-\frac{b}{\Delta p})}$$

(ii) Expropriation of a prior lender might be more profitable through a contract that induces an allocation above the feasibility line, $(D+A)v$, such that the expropriated lender only gets repaid up to the cash flow stemming from his collateral. It is necessary but not sufficient that both $\hat{C}<\hat{R}$ and $p_L\hat{C}<\hat{D}$ hold for expropriation to create the highest value for the borrower. The first condition ensures that expropriation is possible, while the second condition ensures that earlier lending subsidizes later lending. The lenders offer a menu that contains:

$$(D,R,C)=(d_c,\frac{d_c}{p_L},A+\hat{D}+d_c-\hat{C})$$
$$d_c=\frac{(A+\hat{D}-\hat{C})v}{1/p_L-v}$$

. (iii) When both necessary conditions are not met, the lenders can only offer the null contract.

Remark: When both necessary conditions are met, then the lenders can include both contracts and let the borrower chooses his preferred contract among the, due to the required collateral, mutually exclusive contracts.

No profitable deviation for lender Given the off-equilibrium path strategies there does not exist a profitable deviation for any lender.

(i) Deviations that induce high effort: A lower interest rate given the same collateral level gives the lender negative profits and the borrower does not accept a higher interest rate contract. Decreasing the collateral is only valuable to the borrower if he wants to borrow more than would be compatible with high effort, thereby making a high effort contract deviation impossible.

(ii) Deviation that induce low effort: Under $\mathcal{A}1$ they are loss making for at least one party, since other lenders cannot be expropriated given that their equilibrium strategies contain menus with $C > R$. Under assumption $\mathcal{A}1^*$, the borrower is strictly better off to accept a secured high effort contract from the equilibrium strategy than any contract that induces low effort. This follows immediately from $V_H > V_L$.

Uniqueness Any equilibrium allocation has to entice high effort. By contradiction, suppose $(\hat{D}, \hat{R}, \hat{C})$ is an equilibrium allocation with positive lender profits and borrower profit equals to $U_b(\hat{\mathcal{H}}_1, H) = p_H((\hat{D} + A)v - \hat{R}) \equiv \hat{U}_b$. This has to be strictly lower than V_H and weakly higher than the borrower's outside option of no borrowing, $u_H A$. Let the contract parameter δ trace all allocations on the borrower's IC line: $(D^* - \delta, R^* - \delta(v - b/\Delta p), A + D^* - \delta)$. I can write the borrower's utility from such an allocation on the IC line as a function of δ with $U_b(0) = V_H > \hat{U}_b \geq U_b(\frac{D^* v - R^*}{b/\Delta p}) = u_H A$. Firstly, any contract on the IC line does not induce further lending. Since $U_b(\delta)$ is a continuous function, there must exist a δ such that $U_b(0) > U_b(\delta) > \hat{U}_b$. This δ describes the contract that yields a profitable deviation for an inactive lender at $\mathcal{H}_0$ and that will be accepted by the borrower.

Proof of Proposition 2

When $u_H > \frac{u_L}{b - u_L}$, lenders offer the null contract and the following contract:

$$(D,R,C) = (D^\epsilon, \frac{D^\epsilon}{p_H}, D^\epsilon + A)$$

$$D^\epsilon = \frac{v - \frac{p_H b}{\Delta p} - p_H \epsilon^H}{1-(v - \frac{p_H b}{\Delta p} - p_H \epsilon^H)} A$$

$$\epsilon^H = \frac{u_L/(b-u_L) p_L \frac{b}{\Delta p}}{\Delta p - u_L/(b-u_L)p_L}.$$

as long as $\mathcal{H}_0$ and $\mathcal{H}_1 = (D^\epsilon, \frac{D^\epsilon}{p_H}, D^\epsilon + A))$.

When $u^H < \frac{u_L}{b-u_L}$, lenders offer the null contract and the following contract:

$$(D,R,C) = (D^L, \frac{D^L}{p_L}, D^L + A) D^L = \frac{p^L v}{1-p^L v} A$$

ϵ^H **satisfies side-trading constraint** When the borrower accepts an additional contract, he can pledge all his agency rent to the second lender. This agency rent replaces the borrower's capital that is necessary to raise funds under low effort. The value of pledging the agency rent is therefore:

$$\frac{u_L}{b-u_L} \frac{p_L(\frac{b}{\Delta p} + \epsilon)}{\frac{p_H b}{\Delta p} - u_H + p_H \epsilon} A$$

The least amount of agency rent ϵ^H therefore solves:

$$U_b(\mathcal{H}_1^*, H) = U_b(\hat{\mathcal{H}}_2, L) \iff$$

$$\frac{u_H}{\frac{p_H b}{\Delta p} - u_H + p_H \epsilon^H} A = \frac{u_H - \Delta p \epsilon^H}{\frac{p_H b}{\Delta p} - u_H + p_H \epsilon^H} A + \frac{u_L}{b-u_L} \frac{p_L(\frac{b}{\Delta p} + \epsilon^H)}{\frac{p_H b}{\Delta p} - u_H + p_H \epsilon^H} A$$

A relevant ϵ^H exists when it is lower than $v - b/\Delta p$, otherwise there will be no positive lending. This is satisfied as long as $u^H \geq \frac{u^L}{b-u^L}$ because then the borrower strictly prefers a small high effort project without borrowing to a low effort project with borrowing and ϵ^H is larger than $v - b/\Delta p$.

Off-equilibrium strategies under assumption $\mathcal{A}1^*$:

(i) If $u_H < \frac{u_L}{b-u_L}$ then there exist no high effort equilibrium and lenders offer:

$$(D, R, C) = (d_c, \frac{d_c}{p_L}, A + \hat{D} + d_c - \hat{C})$$
$$d_c = \frac{(A + \hat{D})v - min(\hat{C}v, \hat{R})}{1/p_L - v}$$

(ii) If $u_H > \frac{u_L}{b-u_L}$ then lenders can offer a contract that induces a high effort allocation if $(A + \hat{D})(v - \frac{b}{\Delta p} - \epsilon^H) - \hat{R} > 0$. Otherwise, they only offer a contract that induces low effort.

$$(D, R, C) = (d_c, \frac{d_c}{p_H}, A + \hat{D} + d_c - \hat{C})$$
$$d_c = \frac{(A + \hat{D})(v - \frac{b}{\Delta p} - \epsilon^H) - \hat{R}}{1/p_H - (v - \frac{b}{\Delta p})}$$

$$(D, R, C) = (d_c, \frac{d_c}{p_L}, A + \hat{D} + d_c - \hat{C})$$
$$d_c = \frac{(A + \hat{D})v - min(\hat{C}v, \hat{R})}{1/p_L - v}$$

No profitable deviation for lender

Given the off-equilibrium path strategies there does not exist a profitable deviation for any lender.

(i) Deviations that induce high effort: A lower interest rate given the same collateral level gives the lender negative profits and the borrower does not accept a higher interest rate contract. Decreasing the collateral is only valuable to the borrower if he wants to borrow more than would be compatible with high effort, thereby making a high effort contract deviation impossible. **(ii) Deviation that induce low effort:** Under assumption

$\mathcal{A}1^*$, the borrower is strictly better off to accept a secured high effort contract from the equilibrium strategy than any contract that induces low effort. This follows immediately from $V_H > V_L$.

Uniqueness For the case that $u_H < \frac{u_L}{b-u_L}$: Denote the value under the alternative equilibrium allocation as $\hat{U}_b$ which is weakly lower than V_L if it induces low effort. Let the contract parameter δ trace all allocations on the borrower's *side-trading constraint* line: $(D^\epsilon - \delta, \frac{D^\epsilon}{p_H} - \delta(v - b/\Delta p - \epsilon^H), A + D^\epsilon - \delta)$. Let $U_b(\delta) = p_H(D^\epsilon - \delta + A)(v - b/\Delta p - \epsilon^H) - A$. There must exist a $\delta > 0$ such that $U_b(0) > U_b(\delta) > \hat{U}_b$. This δ pins down the profitable deviation for an inactive lender.

When $u_H < \frac{u_L}{b-u_L}$ there cannot be a high effort equilibrium. Any alternative equilibrium allocation has to induce low effort and yield a utility to the borrower that is weakly lower than V_L.

Proof of Proposition 3

Follows from the text.

Proof of Lemma 2

Follows form the text.

Proof of Proposition 4

For $u_H < \frac{u_L}{b-u_L}$, the social welfare under transparency according to proposition 2 is equal to V_L. The minimum social welfare under opacity is V_o is greater than V_L as:

$$V_o - V_L = (V_H - V_L)\frac{b(p_H b/\Delta p) - u_H b}{b(bp_H/\Delta p) - u_H(b - bp_H/\Delta p)} > 0$$

For $u_H < \frac{u_L}{b-u_L}$ the welfare under transparency is equal to:

$$\frac{u_H}{p_H(b/\Delta p + \frac{V_L p_L \frac{b}{\Delta p}}{\Delta p A - V_L p_L}) - u_H} A$$

In this region the welfare under transparency can be smaller or larger than V_o.

For $0 > u_L$ social welfare is V_H under transparency. The lower bound under opacity is strictly lower when evaluated at $V_L = 0$. Any decrease at in u_L will decrease V_o as the threat of the second side-trade is less problematic.

Proof of Proposition 5

Case: $u_H > \frac{u_L}{b-u_L}$. In the transparency case, collateral only prevents direct dilution. The side-trading constraint that pins down the additional agency rent ϵ^H implicitly assumes that the borrower can only pledge his agency rent to the opportunistic lender. This is exactly the case when collateral secures the repayment of the first lender, i.e. $C \geq R$. Suppose, $C_1 < R_1$, in that case the borrower can pledge more than his agency rent to the opportunistic lender:

$$U_b(\mathcal{H}_1, H) - U_b(\hat{\mathcal{H}}_2, L) \geq 0$$
$$\iff \frac{\Delta p \epsilon}{\frac{p_H b}{\Delta p} - u_H + p_H \epsilon} A \geq \frac{u_L}{b - u_L} \frac{p_L(\frac{b}{\Delta p} + \epsilon + (R_1 - C_1))}{\frac{p_H b}{\Delta p} - u_H + p_H \epsilon} A$$

The ϵ that solves the above inequality is strictly larger than ^{H}. Hence, there would be gains from trade between the borrower and the opportunistic lenders and $C < R$ cannot happen in equilibrium. The minimum level of collateral under transparency is therefore $C = R = \frac{D}{p_H v} < D$.

Under opacity, suppose that lenders offer a menu in which the active and the latent contract are:

$$
\begin{aligned}
&(D, R, C) = (D^*, R^*, D + A - \delta)\\
&(D^l, R^l, C^l) = (d^l, (d^l + A)v, d^l + A - \delta)\\
&d^l = \frac{V_H + A(1-b)}{b}
\end{aligned}
$$

The demanded collateral is arbitrarily smaller than maximum with $\delta > 0$. This cannot be an equilibrium, since the borrower can pledge p_L to an opportunistic lender. With the following contract the opportunistic lender makes zero-profits:

$$
\begin{aligned}
&(D, R, C) = (d, d/p_L, d + \delta)\\
&d = \frac{p_L v}{1 - p_L v}\delta p_L v
\end{aligned}
$$

and the borrower is strictly better off. Hence, the lenders must ask for collateral $C = D + A > D$ in equilibrium.

Case: $u_H < \frac{u_L}{b - u_L}$. In that case both under transparency and opacity the level of collateral is $C = D + A$.

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Chapter 2

Heterogeneous Lenders and Repo Market Pricing

Abstract

Security dealers finance their inventories through repurchase agreements, using inventory securities as collateral. They face a variety of counterparties of varying degrees of sophistication regarding their ability to value the securities. Theoretically, less sophisticated counterparties should fear the winner's curse of receiving worse collateral. In my model, a dealer seeks a more sophisticated lender because the sophisticated lender cherry-picks collateral and finances at lower rates. The less sophisticated lender cannot observe the dealer's behaviour and charges higher interest rates to compensate. I provide empirical evidence in support of my theory, showing that the compensation increases in the number of contacts that dealers have with sophisticated lenders. The increase in uncertainty during the Covid-19 pandemic serves as an exogenous variation in the informational advantage of more sophisticated lenders. My work suggests that opacity exacerbates fragility for well-connected borrowers, as less sophisticated lenders charge higher rates to compensate for the possibility of hidden cherry-picking.

2.1 Introduction

Shadow banks and credit markets are replacing traditional banks in the provision of maturity transformation and funds for the real economy. While traditional banks rely on demand deposits to finance their activity, less regulated financial institutions rely on short-term secured funding, such as repurchase agreements (repo). Money market funds are important shadow banking institutions that provide short term claims for investors backed by government debt, commercial papers and other rather safe assets. Figure 2.1 demonstrates the importance of money market funds in the U.S. economy, showing the magnitude of its maturity transformation relative to traditional bank deposits and its provision of 1 trillion USD of repo funding in 2020.

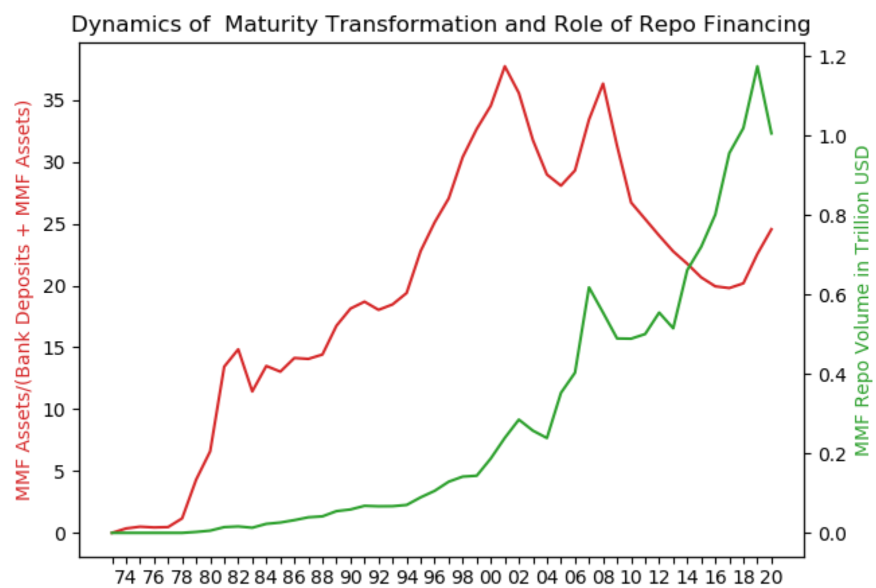

Figure 2.1: Rise of Shadow Banking (left) and Role of Repos (right), data from Federal Flow of Funds

While bank runs are seen as a distant memory of times without credible deposit insurance, the collapse of repo markets in 2007-2008 showed that institutional investors can withdraw funding as abruptly as retail depositors (Gorton and Metrick, 2012). To shed light on the mechanisms behind repo contracting, I develop and test a new theory of repo market pricing. My theory combines two microstructure aspects of repo markets, opacity and heterogeneity of counterparties, to predict the price of repo funding in the cross-section of borrowers. Herein, I argue that heterogeneous counterparties imply a heterogeneity in their ability to screen and evaluate collateral. When financing the same collateral type, more sophisticated counterparties can affect less sophisticated ones by depleting the shared collateral pool of more valuable assets. Since opacity in the repo market masks a borrower's counterparties and trades, less sophisticated counterparties have to form beliefs about the average asset quality that they receive. The lower belief about the collateral quality of better-connected borrowers causes compensation through higher interest rates.

I formalize such a mechanism in a model in which a dealer finances inventory assets using secured debt. The dealer can always contract with an uninformed lender and sometimes with an additional informed lender. The informed lender is the only agent who can evaluate and select the most valuable collateral, allowing the borrower to finance at lower interest rates. The uninformed lender, neither able to evaluate the collateral nor observe the arrival of the informed lender, forms a belief about the collateral value. Under opacity, the dealer wants to secretly finance with the informed lender because the uninformed lender's belief is correct in expectation but overestimates the collateral value conditional on the arrival of the informed lender. The uninformed lender's belief drives the repo interest rate in the model. This belief depends on two main parameters, the dealer's specific probability of meeting an informed lender and the informational advantage of the latter.

I test the model prediction for repo interest rates on data extracted from money market fund filings (N-MFP2). Money market funds play the role of uninformed lenders in my setting, while primary dealers are the borrowers. Primary dealers also act as prime brokers to hedge funds and other investors with more sophisticated investment strategies than that of money market funds. I construct a proxy for the dealer specific probability of meeting an informed lender from data that contains prime brokerage connections (ADV). I assume that a primary dealer with more prime brokerage connections has a higher probability of meeting an informed lender. Since prime brokerage connections are likely endogenous, I use the increase in uncertainty induced by Covid-19 as an exogenous shock in the resulting informational advantage of informed lenders in the time dimension (March to May 2020). In a difference-in-difference analysis, I sort primary dealers into treatment and control groups according to their number of prime brokerage connections. I find that well-connected dealers in the treatment group pay up to ca. 60 basis points more on average on their repo contracts secured with risky corporate bond collateral relative to the control group of less connected dealers. This increase is quantitatively relevant since the average repo spread over the risk-free rate is ca. 30 basis points in my sample.

Primary dealers are the major securities dealers in the U.S. A dealer provides liquidity to different asset markets by quoting bid-ask prices to traders[1]. Their market-making activity requires dealers to hold and finance inventories. To finance inventories, dealers frequently use repurchase agreements to borrow against collateral. Repos are convenient for dealers for two reasons: First, dealers can use their inventory directly as collateral in the repurchase agreement. Secondly, since repos are primarily short-term, dealers can adjust financing to a changing inventory size.

Money market mutual funds are significant sources of cash funding to primary dealers in repo transactions. For example, in December of 2020, they provided more than 642 billion USD of funding to primary dealers (Bak-

[1] Dealers are especially important for asset markets without a central limit order book, such as is the case on most corporate bonds and derivatives markets

lanova, Kuznits and Tatum, 2021). While most repo contracts are secured with safe assets such as Treasuries, money market funds also hold ca. 50 billion dollars of repo contracts with more risky collateral such as corporate bonds, equities and asset-backed securities. This indirect exposure of money market funds to more risky securities is remarkable because regulations restrict them from holding them outright.

Heterogenous lenders: The repo market is simultaneously used by less regulated counterparties, such as hedge funds and other investment companies. These counterparties typically use more sophisticated investment strategies that rely on research on specific assets. Hedge funds not only use repo markets to obtain funding, but they regularly provide cash as well [2]. Gorton, Metrick, and Ross (2020) provide evidence "that the flight of foreign financial institutions, domestic and offshore hedge funds, and other unregulated cash pools predominantly drove the run on repo' in 2008, confirming that hedge funds are important repo lenders.

The simultaneous presence of more and less sophisticated counterparties raises the question of whether dealers behave opportunistically given the notorious opacity in repo markets.

2.1.1 Related literature:

My focus on differences in the cross-section of borrowers is motivated by the observation that some borrowers, e.g. Lehman Brothers, experienced a sudden withdrawal in repo funding in 2008 (Copeland, Martin and Walker (2014)). Similarly, Krishnamurthy, Nagel and Orlov (2014) write that a few borrowers were "disproportionately affected", which they explain with their reliance on particular asset classes. Both studies analyze money market fund repo data but do not study interest rates or only average interest rates for broad asset classes. I study more granular contract level data with infor-

[2]Bank of England published quantitative research, while in the US SIFMA confirms the presence of hedge funds as cash lenders qualitatively.

mation regarding the underlying collateral. The closest study in terms of data is Hu, Pan and Wang (2021), who use the same regulatory money market fund data and explain that, besides collateral and contract terms, fund families determine repo pricing. I add to their analysis using a difference-in-difference analysis that provides quasi-experimental evidence that a borrower's informed lender connections influence prices.

My theoretical hypothesis predicts that better-connected borrowers are more susceptible to price increases and funding withdrawals from uninformed lenders. Spillovers arise between heterogeneous lenders within the network of a borrower because of the latter's inability to commit not to seek out informed lenders first. Therefore, the borrower's network ultimately causes fragility. This is a new mechanism compared to the theoretical literature on the fragility of repo or collateralized borrowing markets. Gorton and Ordoñez (2014) explain the fragility in repo markets with an endogenous information acquisition by lenders that can trigger the partial breakdown of repo markets. In their model of "blissful ignorance", opacity improves welfare when it prevents socially inefficient information acquisition. In my setting, information asymmetry is exogenous, and opacity facilitates its harmful effect. Without opacity, the uninformed lender would correctly update beliefs, suppressing the incentive for the borrower to seek out an informed lender. Martin, Skeie and von Thadden (2014) attribute the fragility in repo markets to coordination failures between investors with different investment horizons. Zhang (2014) has a similar explanation of fragility rooted in roll-over risk in repo markets.

In the literature, the existence of repo markets is explained by transaction costs (Duffie, 1996), collateral re-use (Gottardi, Maurin and Monnet, 2019) or information asymmetry (Duffie and DeMarzo, 1999). I take contract structure as given and study the information asymmetry problem that remains relevant under repo contracts.

My research also relates to the research on the interaction between market and funding liquidity (Brunnermeier and Pedersen, 2009), studying funding frictions in the cross-section of dealers. Macchiavelli and Zhou (2021) study how the price of money market funding for dealers affects secondary market spreads, using the 2016 money market fund reform as an exogenous supply shock. Huh and Infante (2017) study theoretically how repo market frictions affect dealer spreads for corporate bonds. Relative to these papers, I argue that dealers can have funding cost advantages when they are less connected to informed lenders.

In the literature on money market funds behavior, Kacperczyk and Schnabl (2013) study the willingness of money market funds to take risks prior to the financial crisis and related investor runs. Chernenko and Sunderam (2014) study how money market fund relationships shape their lending decisions. I study how money market funds raise interests to compensate for higher collateral value risk.

2.2 The Model

2.2.1 The market-making project

There are three agents, one dealer, one uninformed lender and one informed lender. The dealer has a scaleable market-making project that takes three dates. In $t = 0$ the dealer buys assets for the cash amount, I, to sell them in $t = 2$ *en bloc* at a premium. The dealer can buy more assets, when he raises outside funding from lenders to lever his own capital K. In $t = 1$ the dealer exerts hidden effort to find a buyer. In $t = 2$ the dealer either finds a buyer to exchange assets for cash or keeps the assets otherwise. The contract between the borrower and lender accommodates this technological constraint by stipulating a success repayment denominated in cash and a failure repayment in assets. The repayment in-kind allows a sophisticated lender to profit from collateral selection, as she will receive more valuable assets in the failure state.

Each asset is indexed with i from the continuum $[0, I]$. The size of the continuum of assets corresponds to the cash value of the asset purchase at date 0, I. The asset holding is a continuum which the dealer can separate and finance separately.

In the success state, i.e. the dealer finds a buyer, each asset i returns $F + V + \tilde{\theta}_i$ in cash, otherwise the asset remains an asset of value $F + \tilde{\theta}_i$ in the failure. Therefore, the continuum of assets of size I takes values:

$$\begin{cases} \int_0^I (F + V + \tilde{\theta}_i) di & \text{in the success state} \\ \int_0^I (F + \tilde{\theta}_i) di & \text{in the failure state} \end{cases}$$

where F is the constant value of an asset. V is the success dependent payoff perfectly correlated across all assets i. $\tilde{\theta}_i$ is an asset-specific private information component that is initially only known by the informed lender. The private information component can be either positive or negative, $+\theta$ or $-\theta$. Therefore, the difference between $+\theta$ and $-\theta$, reflects the informational advantage of the informed lender over the uninformed one. For any initial investment, the private information components are equally distributed and exactly offset each other in the asset continuum.

The probability of the success state depends on the binary effort choice of the borrower, which is hidden and not contractible à la Holmström and Tirole (1997). When the borrower chooses high effort, the probability of success, p_H, is higher than the success probability under low effort, p_L. Since effort is not contractible, the dealer needs to have sufficient exposure to the success state to choose high effort because low effort yields a private benefit of B that scales in the project size and does not depend on the success of the project.

Importantly, the project is only valuable when the dealer chooses high effort. I define the net return on investment (ROI) for high and low effort, u_H and u_L respectively, and I assume formally:

Assumptions 1 (ROI):

$$\mathcal{A}1: \quad u_H \equiv F + p_H V - 1 > 0 > u_L \equiv F + p_L V + B - 1$$

Additionally, I focus on the case where the project is not self-financing, and the dealer, therefore, needs to invest his own capital along with any outside capital. Per unit of investment, the dealer needs to obtain at least $\frac{B}{\Delta p}$ in the success state to choose high effort over low effort, with $\Delta p = p_H - p_L$. Assumption 2 states the necessary parameter condition as:

Assumption 2 (Project is not self-financing):

$$\mathcal{A}2: \quad F + p_H(V - \frac{B}{\Delta p}) - 1 < 0$$

2.2.2 Lenders

There are at most two lenders present. While there is always an uniformed lender present, with probability q an additional informed lender arrives. The lenders differ in their ability to assess the asset-specific private information component $\tilde{\theta}$ at the contracting stage. While the informed lender knows the realization of $\tilde{\theta}_i$ at date $t = 0$, the uninformed lender learns its value only at $t = 2$. At the contracting stage at $t = 0$, the uninformed lender can only verify the face-value of her collateral, i.e. the size of the continuum of assets that she receives. Importantly, the uninformed lender cannot verify whether her collateral corresponds to the total investment I or only to a share of it. Collateral with the same face-value can have different expected values, depending on the associated distributions of $\tilde{\theta}_i$. The informed lender can cherry-pick collateral to skew the ratio of $+\theta$ to $-\theta$ assets in her favour, which in turn negatively affects the share of $+\theta$ assets among the collateral of the uninformed lender.

Both lenders have deep pockets and zero discounting. Both lenders can sell assets for cash at date 2 at zero costs; therefore, conditional on the value, they are indifferent between receiving repayment in cash or in assets $t = 2$. At the contracting stage at $t = 0$, the informed lender knows the true value of the average $\tilde{\theta}$ of his collateral, while the uninformed lender has only an endogenous belief about $\tilde{\theta}$.

2.2.3 Contracting

At $t = 0$ the dealer offers take-it-or-leave-it contracts to each lender consisting of three elements: a loan amount D, a cash repayment R and a collateral amount C. The loan amount and the repayment are denominated in units of cash, while the collateral amount is denominated in the face value of the asset. The face-value of assets corresponds to the size of the continuum of assets. In the following text, (D^u, R^u, C^u) describes the contract offered to the uninformed lender and (D^i, R^i, C^i) to the informed lender. The dealer cannot pledge the same collateral to both lenders, implying that the sum of pledged collateral, $C^u + C^i$, cannot exceed the total investment. When the dealer contracts with both lenders, then he can promise to the informed lender the right to choose first among the continuum of assets. Should the dealer promises more than he can pay in the success state, claims are settled proportional pro-rata to the loan amount.

2.2.4 Information structure and timing

The uninformed lender cannot observe the arrival and the contract that the dealer offers to the informed lender. Both lenders know the amount of capital that the dealer owns.

$t = 0$

- Investment and financing stage.

$t = 1$

- The borrower chooses effort.

$t = 2$

- Uncertainty is resolved and lenders are repaid.

Within the investment and financing stage:

1

- The presence of the informed lender is realized.

2

- Lenders accept contracts.

3

- Dealer invests and provides collateral.

2.3 Characterization

2.3.1 Benchmark: The informed lender never arrives

When the informed lender never arrives, the uninformed lender does not have to fear cherry-picking, and her belief is that the private information component is zero in expectation. Therefore, the problem of the dealer is standard as in the Continuous-Investment size model of financing in Tirole 2006.

Since only a high effort project creates a positive surplus, the contract has to induce high effort. Therefore the contract should satisfy the incentive compatibility constraint of the dealer:

$$
\begin{aligned}
&p_H((F+V)(K+D^u)-R^u)+(1-p_H)F(K+D^u-C^u) \geq \\
&p_L((F+V)(K+D^u)-R^u)+(1-p_L)F(K+D^u-C^u)+B(K+D^u)
\end{aligned}
$$

Additionally, the uninformed lender must make at least zero profits to accept any contract:

$$p_H R^u + (1 - p_H) C^U F - D^u \geq 0$$

The dealer wants to minimize the repayment to the lender and offers a zero-profit contract. Since the dealer is the sole claimant to the project surplus, he offers the following contract that maximizes the size of the investment and his profits:

$$D^u = \frac{1 + u_H - \frac{p_H B}{\Delta p}}{\frac{p_H B}{\Delta p} - u_H} K$$
$$R^u = \frac{F + V - \frac{B}{\Delta p}}{\frac{p_H B}{\Delta p} - u_H} K$$
$$C^u = \frac{1}{\frac{p_H B}{\Delta p} - u_H} K$$

The contract offers the maximum amount of collateral in case the project fails and the highest repayment that still induces high effort. The profit of the dealer is:

$$U^d = p_H((F + V)(K + D^u) - R^u) + (1 - p_H) F (K + D^u - C^u)$$
$$= \frac{1}{\frac{p_H B}{\Delta p} - u_H} K u_H$$

The capital multiplier arises from the moral hazard problem and limits the amount of investment.

2.3.2 The informed lender arrives sometimes

When the probability of the arrival of the informed lender is positive, $q > 0$, then the uninformed lender must consider cherry-picking. I will focus on the parameter range of the model in which the dealer offers the same contract to the uninformed lender regardless of the presence of the informed lender.

In this pooling equilibrium, the uninformed lender's belief is that the dealer always offers the same contract and exerts high effort. I verify that the belief is true, showing that the dealer has no incentive to deviate.

A necessary condition for such an equilibrium is that the good part of the project is self-financing, i.e. the assets with a $+\theta$ private information component satisfy the following condition:

$$u_H + (1 - p_H)\theta - \frac{p_H B}{\Delta p} > 0$$

When the private information component is large enough, the dealer can offer a contract to the informed lender that incentivizes high effort and does not require the dealer to put up his own capital.

The uninformed lender will only accept a contract that provides at least zero profits, given that there can be cherry-picking when the informed lender arrives:

$$(1 - q)[p_H R^u + (1 - p_H)C^U F] + q[p_H R^u + (1 - p_H)C^u(F - \theta)] \geq D^u$$

Similarly, the informed lender accepts only a contract that provides at least zero profits. Contrary to the uninformed lender, the informed lender benefits from asset selection, yielding the following participation constraint for the informed lender:

$$p_H R^i + (1 - p_H)C^i(F + \tilde{\theta}^i) \geq D^I$$

The collateral value of the informed lender, $\tilde{\theta}^i$, depends on the amount of debt and collateral that the dealer contracts with the informed lender relative to the informed lender. Since half of the total project contains good assets, the informed lender cannot pick only good assets when $C^i > (D^u + D^i + K)/2$. Presuming from now on that the dealer offers $C^u = D^u + K$ to the uninformed lender and $C^i = D^i$ to the informed lender, the collateral value writes $\tilde{\theta}^i = \theta(D^u + K)/D^i$. The informed lender's participation constraint follows:

$$p_H R^i + (1 - p_H) D^i [F + \theta \frac{(D^u + K)}{D^i}] \geq D^i$$

The dealer's incentive compatibility constraint must be satisfied in two cases. In the absence of the informed lender, the contract offered to the uninformed lender alone has to induce effort. With the informed lender, the contracts have to motivate high effort jointly:

$$\begin{aligned} & p_H[(F+V)(D^u + D^i + K) - R^u - R^i] \geq \\ & p_L[(F+V)(D^u + D^i + K) - R^u - R^i] + B(D^u + D^i + K) \end{aligned}$$

The following set of contracts satisfies all constraints.

$$\hat{D^u} = \frac{1 + u_H - \frac{p_H B}{\Delta p} - q(1-p_H)\theta}{\frac{p_H B}{\Delta p} + q(1-p_H)\theta - u_H} K$$

$$\hat{R^u} = \frac{F + V - \frac{B}{\Delta p}}{\frac{p_H B}{\Delta p} + q(1-p_H)\theta - u_H} K$$

$$\hat{C^u} = \frac{1}{\frac{p_H B}{\Delta p} + q(1-p_H)\theta - u_H} K$$

The informed lender receives the following contract.

$$\hat{D^i} = \frac{(1-p_H)\theta(\hat{D^u} + K)}{\frac{p_H B}{\Delta p} - u_H}$$

$$\hat{R^i} = F + V - \frac{B}{\Delta p}(\hat{D^i})$$

$$\hat{C^i} = \frac{(1-p_H)\theta(\hat{D^u} + K)}{\frac{p_H B}{\Delta p} - u_H}$$

Proposition 6 *When $\underline{\theta} \leq \theta \leq \overline{\theta}$ and $F \geq \underline{F}$, then offering $(\hat{D^u}, \hat{R^u}, \hat{C^u})$ and $(\hat{D^i}, \hat{R^i}, \hat{C^i})$ is a Perfect Bayesian Equilibrium.*

The dealer exerts high effort regardless of the arrival of the informed lender. When the informed lender is absent, the total size of the project is $I = \hat{D}^u + K$*. Otherwise, the total size of the project is* $I = \hat{D}^u + \hat{D}^i + K$*.*

Proofs are in the appendix.

The contracts yield zero profit to the lenders, therefore, they will accept them. Additionally, the strategy of the dealer does not reveal the arrival of the informed lender. However, there are two relevant deviations for the dealer: he can either offer a low-effort contract to the informed lender or offer less collateral to the uninformed lender in the absence of the informed lender.

The first deviation becomes relevant when the private information component is larger than $\overline{\theta}$, such that the dealer wants to increase the probability of the failure state to expropriate the uninformed lender more often. Even though the low effort project does not generate any surplus, the value of cherry-picking can make it a viable strategy for the dealer.

The second type of deviation can occur because the dealer is informed vis-à-vis the uniformed lender regarding the presence of the informed lender. The consequence is that the dealer might want to offer a different contract to the uninformed lender, depending on the presence of the informed lender. Since the uninformed lender must discount the collateral value due to the expectation of cherry-picking, the dealer pledges the collateral in the absence of the informed lender below its fair value. When the fixed value component of the collateral is sufficiently large, i.e. $F \geq \underline{F}$, then the dealer incurs the discount because the benefit from the productive use of the collateral dominates it.

Corollary 1 to the above proposition describes the breakdown of uninformed secured lending:

Corollary 1 *When $F < \overline{F}$, then the dealer offers always an unsecured contract, $C^u = 0$, to the uninformed lender.*

To derive the hypothesis for the empirical analysis, I define the interest rate that an uninformed lender requires as r^u. The following equation maps the interest rate to the contract variables in the model:

$$
\begin{aligned}
(1 + r^u)D^u &= R^u \\
\iff r^u &= \frac{R^u}{D^u} - 1
\end{aligned}
$$

Proposition 7 *When $q > 0$, $\underline{\theta} \leq \theta \leq \overline{\theta}$ and $F \geq \underline{F}$, then the interest rate paid to the uninformed lender increases when the arrival of the informed lender is more likely,*

$$\frac{\partial r^u}{\partial q} > 0.$$

This increase is larger when the asset private information component θ is larger,

$$\frac{\partial^2 r^u}{\partial q \partial \theta} > 0$$

Proposition 7 is the basis for my empirical analysis.

The equilibrium in proposition 6 yields the same expected profit for the dealer as in the benchmark case. This is only true as long as $\theta \leq \overline{\theta}$ and $F \leq \overline{F}$. Otherwise, the expected profit is smaller.

2.4 Empirical analysis

2.4.1 Data

The primary data source is N-MFP2 filings published by the U.S. Securities and Exchange Commission. In these filings, money market mutual funds disclose their end-of-the-month holdings to the SEC, which publishes them through their EDGAR data platform. Money market funds report all assets, including repurchase agreements and the underlying collateral. For my analysis, I collect N-MFP2 filings from the complete universe of money market funds that report to the SEC between August 2019 and June 2020. I parse the filings automatically, and I record all repurchase agreements that are secured with corporate bonds. In addition to the collateral information, the repurchase agreement data contains information about the counterparty, interest rate, maturity and principal amount. I match individual corporate bonds with data from Eikon Refintiv to obtain credit ratings. Since each repo contract, i is typically secured by multiple corporate bond issues k, I assign a credit rating score to a repo contract by calculating a volume-weighted average credit rating score of the underlying corporate bond collateral:

$$Rating_i = \Sigma_k \frac{CorporateBondRating_{ik} * Volume_{ik}}{\Sigma_k Volume_{ik}}$$

I use the list of primary dealers from the Federal Reserve Bank of New York (as of November 2020) to identify the set of dealers. A second regulatory data source is ADV filings. When managing more than 100 million USD of assets, investment advisers need to register with the SEC and disclose their prime brokerage providers in ADV filings. This allows me to calculate for each dealer how many registered investment adviser-client contacts they have. Figure 2.2 shows the variation in the number of contacts between different dealers.

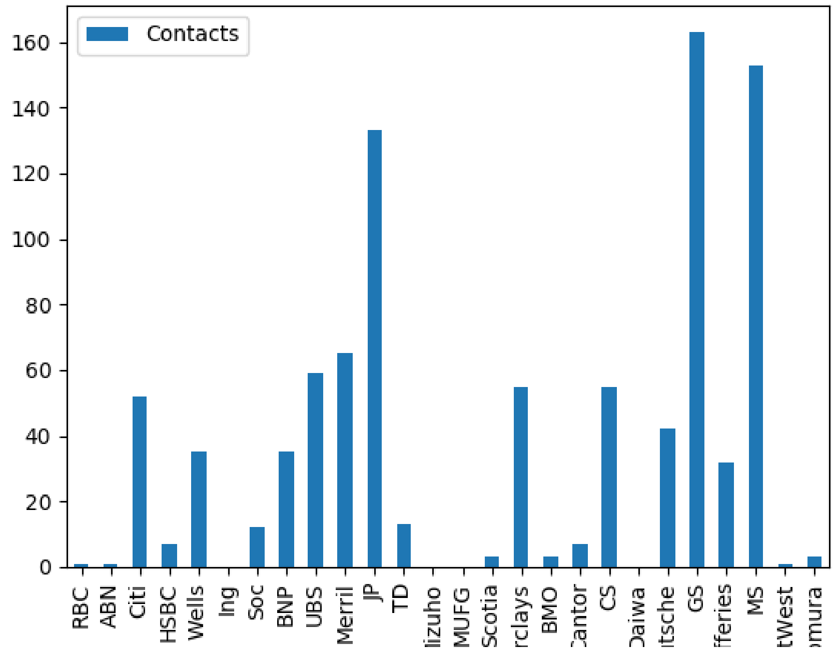

Figure 2.2: Number of Contacts per Dealer

	(Summary stastics)				
	count	mean	sd	min	max
Spread	726	.2825413	.2275508	.01	1.94
Rating	726	10.90892	3.127603	1	18
Principal	726	46.54849	60.62528	.599815	500
N	726				

Table 2.1: Repo contracts

I match the counterparties in the repo contract data with my dealer data to obtain all repo contracts in which the cash borrower is a dealer. My final data set contains 726 observations, where each data point is a contract i, dealer j, date t observation from my eleven-month period. The average repo contract has a spread of 28 basis points above the risk-free rate, at a rating close to BBB+ and a principal amount of 50 million USD[3]. 16 different dealers are active during my sample. Figure 2.3 shows that some dealers rely more on financing their corporate bond holdings through repo contracts.

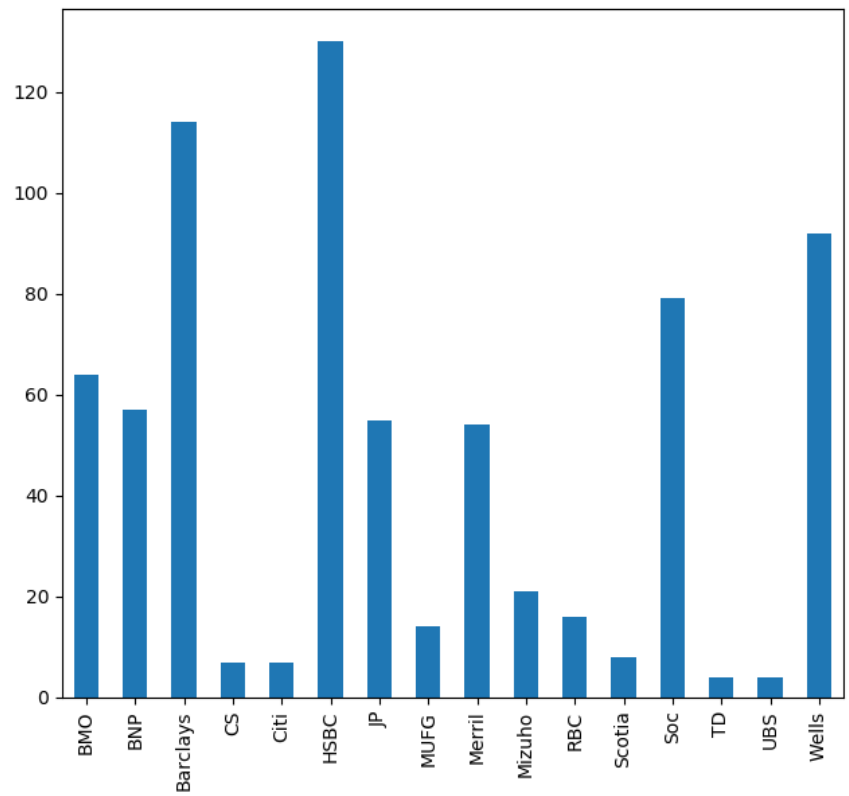

Figure 2.3: Repo Contracts per Dealer in sample

2.4.2 Empirical strategy

My hypothesis is that dealers, ceteris paribus pay higher interest rates to uninformed when they have a higher chance of meeting informed lenders. I

[3] I codify a D grade as 1 and AAA as 18 for S&P ratings.

argue that the number of prime brokerage contacts of a dealer is a proxy for the chance of meeting informed lenders. My argument is that a dealer who interacts more with sophisticated clients through his prime brokerage business will more easily obtain funding from sophisticated lenders in time of need. Unfortunately, my contact measure is likely a choice of dealers and not randomly distributed. Therefore I cannot interpret variation across dealers as a quasi-experimental treatment.

During my study period, there is, however, plausible exogenous variation across time in the amount of uncertainty regarding the fundamental value of securities. In the spring of 2020, the Covid-19 pandemic affected financial markets globally, likely raising uncertainty about the ability of debtors to repay their obligations. The sharp increases in the CBOE volatility index, as well as in the yields for corporate bonds, support the idea that uncertainty increased among investors. Therefore, differences in beliefs about asset values between more and less sophisticated investors should also increase.

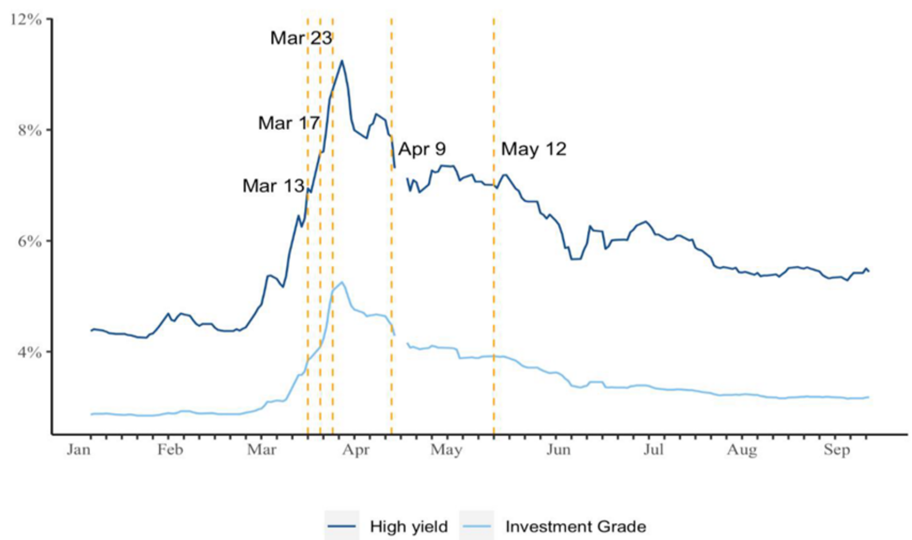

Figure 2.4: Corporate bond yields during Covid-19, from Liang (2020)

The increase in uncertainty should lead in the context of risky and illiquid corporate bonds to an increase in the informational advantage of sophisticated investors, i.e. an increase in θ in the theoretical framework. The hypothesis that follows from the model is:

Hypothesis 1 *An increase in the informational advantage of sophisticated investors should lead to higher increases in the repo contract interest rates for dealers with many prime brokerage contacts.*

I designate the period between March 2020 and May 2020 as the treatment period in which the informational advantage of sophisticated investors is elevated. During the treatment period, I observe a decrease in contracts, as shown in Figure 2.5.

It is plausible that the cherry-picking of collateral by sophisticated lenders is particularly relevant for high-yield corporate bond collateral. Since these assets trade rarely, the latest public transaction price is a poor predictor of the fundamental value, as a stale price will not reflect all current information. While money market funds have limited resources to evaluate securities, hedge funds with dedicated asset research will have a greater informational advantage, i.e. a high θ. For corporate bonds that are less risky, the informational advantage should be small since revealing transaction prices are available and news has a lower impact on the fundamental value.

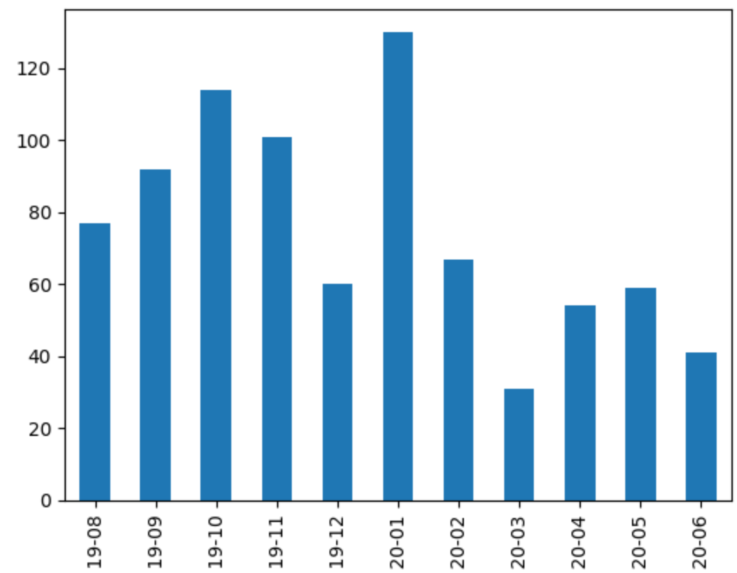

Figure 2.5: Number of Repo Contracts per month

Difference-in-Difference

As a first test of the hypothesis, I employ a difference-in-difference analysis. I separate dealers into two groups according to their number of prime brokerage contacts. When a dealer has more than 25 contacts, I assign him to the treatment group of dealers with strong relationships with informed lenders. For each month, I calculate the average interest rate per group. I take the difference between the average interest rates to obtain the average spread that the group with strong relationships has to pay above the interest rate of the control group. I plot the inter-group spread for all repo contracts in my sample in Figure 2.6. While there is an increase in the spread to 17.5 basis points at the beginning of my treatment period in March 2020, in the other months of the treatment period, there is no visible effect. This changes when I restrict the sample to repo contracts with risky collateral.

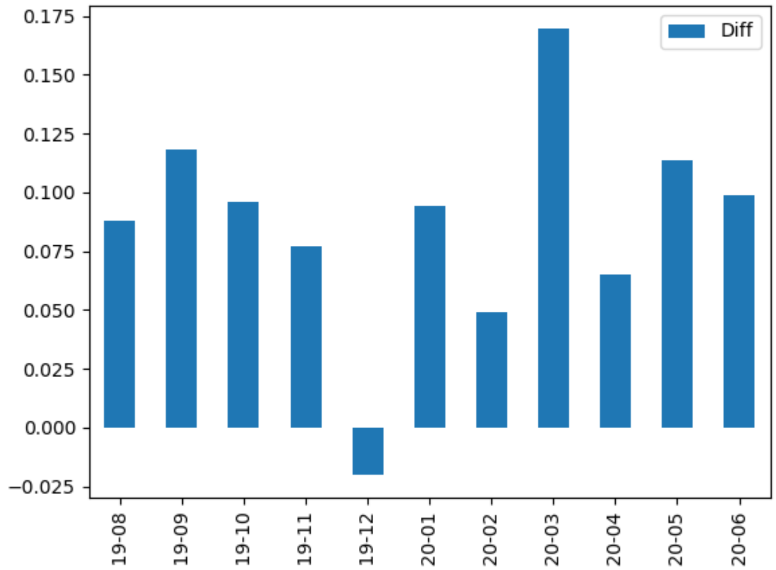

Figure 2.6: Average inter-group spread in the full sample

In Figure 2.7, I plot the same spread, but I only regard repo contracts that have a volume-weighted rating below the BBB grade. In that case, there is a substantial increase in the spread during the treatment period. The inter-group spread increases to more than 40 basis points in March and May and reaches even 60 basis points in April. This increase is substantial as the average risk-free spread is around 30 basis points in the full sample.

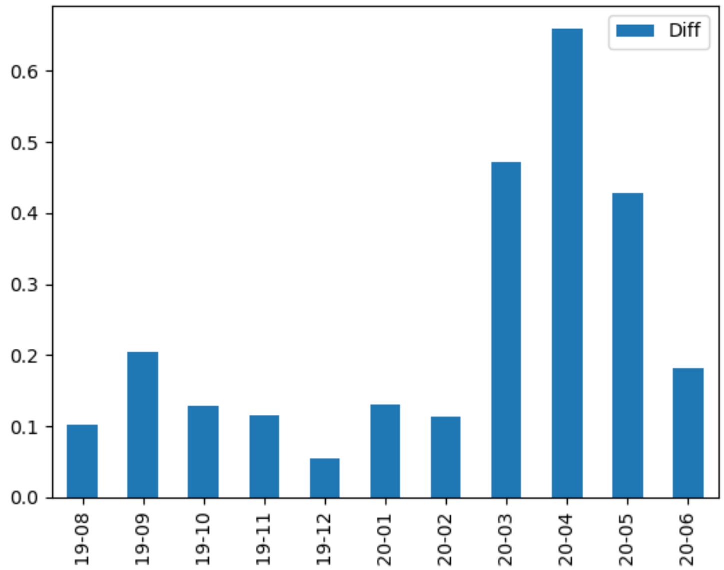

Figure 2.7: Average inter-group spread in risky sample

2.4.3 Regression

While the difference-in-difference analysis requires a cut-off level to sort into control and treatment groups, it is not clear how to select this cut-off. Therefore, in this section, I proceed with a pooled OLS regression analysis, using a continuous Contacts variable instead of a dummy variable based on a cut-off value. Herein, I regress the risk-free spread on the contacts variable and an interaction of the contacts variable with a treatment period dummy. I control for the rating of the repo contract.

$$Spread_{ijt} = \beta_0 + \beta_1 Contacts_j + \beta_2 Contacts_j * Covid_t + \beta_3 Rating_i + \epsilon_{ijt}$$

The regression results show that contacts are positively correlated with repo contract spreads, suggesting that 100 contacts increase the repo con-

Table 2.2: Repo Spreads in %

	(1) Full Sample	(2) Risky Sample	(3) Safe Sample
Rating	-0.0176***	-0.0328***	-0.00520
	(0.00261)	(0.00684)	(0.00543)
Contacts	0.000980***	0.000971*	0.000990***
	(0.000233)	(0.000386)	(0.000277)
Contacts*Covid	0.000532	0.00852***	-0.00130*
	(0.000526)	(0.00125)	(0.000545)
Constant	0.438***	0.524***	0.290***
	(0.0310)	(0.0546)	(0.0692)
Observations	726	224	502
R^2	0.088	0.262	0.032

Standard errors in parentheses

The dependent variable is the annualized spread above the risk-free rate in p.p..

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

tract spread by 10 basis points. For repo contracts with risky collateral, the additional impact of 100 contacts during the treatment period is 85 basis points, raising the total impact to close to 1 percentage point. This increase is statistically significant and economically meaningful since the average repo spread in the sample is less than 30 basis points.

2.4.4 Robustness

Increase in default risk

One concern is that dealers with many contacts had a higher default risk during the treatment period, causing the increase in the observed repo contract spreads. I address this concern by collecting data on unsecured financing interest rates for dealers. Unsecured financing interest rates should reflect changes in the default risk since they are not secured by collateral in the default state. In particular, I use the yields on commercial papers issued by dealers that are held by money market funds and reported in the N-MFP2 filings [4]. For each dealer j, month t, I calculate the average commercial paper yield and match it with my initial data set. Since I do not observe commercial paper returns for all dealers j, month t, my sample decreases to 577 observations. I run the following regression in which the commercial paper return should control for changes in a dealer's default risk.

$$
\begin{aligned}
Spread_{ijt} = \beta_0 + \beta_1 Contacts_j + \beta_2 Contacts_j * Covid_t + \beta_3 Rating_i \\
+ \beta_4 CommercialPaperReturn_j + \epsilon_{ijt}
\end{aligned}
$$

The results in Table 2.3 lend support to my claim that the increase in spreads is not due to an increase in the default risk, as the estimate for the interaction coefficient remains significant and roughly unchanged.

[4] In Item C.17, money market funds must report the "yield of the security as of the reporting date". Hence it should reflect an increase in the default risk.

Table 2.3: Repo Spreads in %

	(1) Full Sample	(2) Risky Sample	(3) Safe Sample
AvgRating	-0.0194***	-0.0332***	-0.0013
	(0.0029)	(0.0074)	(0.0064)
Contacts	0.0008**	0.0010*	0.0006
	(0.0003)	(0.0004)	(0.0003)
ContactsCovid	0.0007	0.0086***	-0.0010
	(0.0007)	(0.0015)	(0.0007)
CommPaperReturn	0.0281	0.0140	0.0117
	(0.0404)	(0.0670)	(0.0474)
Constant	0.4402***	0.5111***	0.2337**
	(0.0368)	(0.0601)	(0.0832)
Observations	577	197	380
R^2	0.095	0.278	0.014

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Risky collateral definition

I study the robustness of my definition of risky collateral. In the initial analysis, I classify repo contracts as risky when they are rated below credit rating grade BBB (=10). I repeat the analysis for two cases. In the first case, I classify a repo contract as risky if it has a rating below A (=12), and in the second case, it must have a rating below BB+ (=8).

In the first case, the sample of risky repo contracts increases and the coefficient of the interaction variable decreases. This is expected since more safe collateral that is less prone to cherry-picking is contained in the risky sample.

Table 2.4: Repo Spreads in %

	(1) Full Sample	(2) Risky Sample	(3) Safe Sample
Rating	-0.0176***	-0.0256***	0.00636
	(0.00261)	(0.00418)	(0.00881)
HFContacts	0.000980***	0.000808**	0.00128***
	(0.000233)	(0.000294)	(0.000373)
HFContactsCovid	0.000532	0.00251***	-0.00172*
	(0.000526)	(0.000751)	(0.000697)
Constant	0.438***	0.505***	0.118
	(0.0310)	(0.0415)	(0.120)
Observations	726	445	281
R^2	0.088	0.115	0.052

Standard errors in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

When the definition of risky repo contracts is more restrictive, i.e. the average rating has to be below rating grade BB+, then the sample decreases and the coefficient of the interaction variable increases.

Table 2.5: Repo Spreads in %

	(1) Full Sample	(2) Risky Sample	(3) Safe Sample
Rating	-0.0176***	-0.0264*	-0.00530
	(0.00261)	(0.0111)	(0.00432)
HFContacts	0.000980***	0.000889	0.000943***
	(0.000233)	(0.000530)	(0.000247)
HFContactsCovid	0.000532	0.0105***	-0.00103
	(0.000526)	(0.00150)	(0.000528)
Constant	0.438***	0.494***	0.292***
	(0.0310)	(0.0746)	(0.0537)
Observations	726	139	587
R^2	0.088	0.322	0.030

Standard errors in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

2.5 Conclusion and policy implications

In this paper, I suggest and test a new mechanism that affects repo interest rates. In an opaque repo market, an uninformed lender's fear of adverse selection makes interest rates sensitive to borrower characteristics and market-wide uncertainty. Using a difference-in-difference analysis, I provide support for such a mechanism. The effects that I find are economically significant. In line with my theory, a borrower's contacts explain a substantial amount of variation in interest rates for risky corporate bond collateral, but not for repo contracts with safe corporate bond collateral.

My analysis highlights that opacity can cause fragility in secured borrowing environments when the used collateral is prone to information asymmetries. In the limit, adverse selection might even lead to a market breakdown of secured uninformed lending when rates become prohibitively high [5]. An obligation to disclose a list of counterparties at the contracting stage could remedy potential negative effects, as it would dissuade the dealer from financing with the informed lender. The implication is that imposing greater transparency can have benefits. My prediction is that efforts to increase transparency, such as the European Regulation on Securities Financing Transactions, could decrease the dispersion in observed spreads between borrowers. I expect that the dispersion would be reduced the most for risky collateral classes, such as risky corporate bonds and equities.

2.6 Appendix

Proof of Proposition 6

The set of contracts is only an equilibrium, if the borrower does not want to deviate. I show that the two relevant deviations do not apply under the parameter conditions stated in Proposition 6.

The dealer does not want to offer a low-effort contract to the informed lender.

When the informed lender arrives, the expected profit of the dealer with contracts from Proposition 1 is:

$$\hat{U}_q^d = p_H((F+V)(\hat{D}^u + \hat{D}^i + K) - \hat{R}^u - \hat{R}^i) - K$$

Alternatively, the dealer could offer a low effort contract to the informed lender. The low effort contract will have $D^i = \hat{D}^u + K$ and $C^i = \hat{D}^u + K$ and

[5]Stated in Corollary 1

$R^i = \frac{\hat{D^u}+K)(1-(1-p_L)(F+\theta)}{p_L}$. Such a contract mirrors the investment financed by the uninformed lender, allowing to expropriate the maximum value from her. Let U^d_q be the expected profit of the dealer form such a deviation. Then it follows:

$$\hat{U}^d_q - U^d_q = (u_H + (1-p_H)\theta)\frac{(1-p_H)\theta}{\frac{p_H B}{\Delta p} - u_H}(\hat{D}^u + K) - (u_L + (1-p_L))(\hat{D}^u + K) > 0$$

$$\iff \theta < \overline{\theta}$$

The above difference is positive as long as θ does not exceed $\overline{\theta}$ which is the positive root to the quadratic equation in θ

$$\theta^2 + \theta\frac{(1-p_H)u_H - (1-p_L)(p_H B/\Delta p - u_H)}{(1-p_H)^2} - \frac{u_L(p_H B/\Delta p - u_H)}{(1-p_H)^2} = 0$$

The dealer does not want to change his offer to the uninformed lender in the absence of the informed lender.

The dealer might want to decrease the amount of collateral pledged to the uninformed lender by $\epsilon > 0$, i.e. $C^u = \hat{C^u} - \epsilon$. I will characterize the condition under which the dealer chooses $\epsilon = 0$.

Reducing the collateral by ϵ decreases the maximum repayment to the uninformed lender due to the IC condition:

$$R^u(\epsilon) = (F + V - \frac{B}{\Delta p})(D + K) - \epsilon F$$

The participation constraint of the uninformed lender yields the maximum debt equal to:

$$D^u(\epsilon) = \frac{1 + u_H - \frac{p_H B}{\Delta p} - q(1-p_H)\theta}{-u_H + \frac{p_H B}{\Delta p} + q(1-p_H)\theta} K - \epsilon \frac{F - q(1-p_H)\theta}{-u_H + \frac{p_H B}{\Delta p} + q(1-p_H)\theta}$$

The dealer's profit in the absence of the informed lender when offering $(D^u(\epsilon), R^u(\epsilon), C^u(\epsilon))$ is:

$$U^d_{1-q}(\epsilon) = p_H((F+V)(D^u(\epsilon)+K) - R^u(\epsilon)) + (1-p_H) - K$$

It follows that:

$$\begin{aligned} & U^d_{1-q}(0) - U^d_{1-q}(\epsilon) \geq 0 \\ \iff & F \geq \frac{\frac{p_H B}{\Delta p} q(1-p_H)\theta}{u_H - q(1-p_H)\theta} \equiv \underline{F} \end{aligned}$$

Proof of Corollary 1

Let $U^d_{1-q}(\epsilon)$ describe the expected utility of the dealer in the absence of the informed lender with an uninformed lender contract parameterized with ϵ. Here $\epsilon = 0$ refers to the case $C^u = K + D^u$ and $\epsilon = K + D^i$ to the case $C^u = 0$. Since F is smaller than $\underline{F}$ the dealer gains more from offering a contract without collateral to the uninformed lender than with collateral when the informed lender is absent, i.e. $U^d_{1-q}(\epsilon = K + D^i) > U^d_{1-q}$. A contract with collateral, therefore, reveals the arrival of the informed lender, making it uninteresting to finance with the uninformed lender. Once the informed lender arrives, he does all the secured financing. Therefore, the dealer always offers the following contract to the uninformed lender,

$$(D^u, R^u, C^u) = (\frac{p_H(V - \frac{B}{\Delta p}}{1 - (p_H(V - \frac{B}{\Delta p})} K, \frac{V - \frac{B}{\Delta p}}{1 - (}$$

K, 0),

and to informed lender:

$$(D^i, R^i, C^i) = (\frac{F + p_H(v - B/\Delta p)}{p_H B/\Delta p - u_H} \frac{(1-p_H)F}{1-(p_H(V - \frac{B}{\Delta p})} K,$$
$$\frac{F + v - B/\Delta p}{p_H B/\Delta p - u_H} \frac{(1-p_H)F}{1-(p_H(V - \frac{B}{\Delta p})} K, D^u + D^i + K)$$

With these two sets of contracts, the borrower always finances unsecured with the uninformed lender and exerts high effort.

Proof of Proposition 7

$$r^u = \frac{R^u}{D^u} - 1 = \frac{F + V - B/\Delta p}{1 + u_H - p_H B/\Delta p - q(1-p_H)\theta} K - 1$$
$$\frac{\partial r^u}{\partial q} = (1-p_H)\theta \frac{F + V - B/\Delta p}{(1 + u_H - p_H B/\Delta p - q(1-p_H)\theta)^2} K > 0$$
$$\frac{\partial^2 r^u}{\partial q \partial \theta} = (1-p_H) \frac{F + V - B/\Delta p}{(1 + u_H - p_H B/\Delta p - q(1-p_H)\theta)^2} K$$
$$+ 2q(1-p_H)^2\theta \frac{F + V - B/\Delta p}{(1 + u_H - p_H B/\Delta p - q(1-p_H)\theta)^3} K > 0$$

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Chapter 3

Dynamic Liquidity Provision for Corporate Bonds under Capital Constraints

Abstract

After the financial crisis, corporate bond practitioners lamented a poor state of market liquidity for large corporate bond trades, while academic research painted an inconclusive picture of liquidity conditions. Motivated by this tension, I find theoretically that scarce capital, together with market incompleteness, can delay trades. The market incompleteness stems from restrictive investment mandates that prohibit agents from trading derivative contracts, in particular forward contracts. Due to the absence of forward contracts, the agents must trade bundles of state-contingent claims. When the buyer's capital is scarce, the buyer wants to minimize capital used on the purchase of claims without gains from trade. Waiting unbundles claims, allowing for more productive use of capital. Therefore, I argue that scarce capital after the financial crisis may explain a deterioration in the time dimension of liquidity that may cause differences in opinion. My model relates the trade timing to the scarcity of capital, the bargaining power distribution and the dynamics of gains from trade. It also explains that investment funds with restrictive mandates, who are therefore limited to spot trades, are more affected by scarce capital.

3.1 Introduction and Motivation

Between 2009 and 2018, firms issued more than one trillion $ of US debt securities per year, which represents four times the annual average of equity sales[1]. Due to the integral role of corporate bonds in firms' capital structure, academic researchers and regulators pay attention to bond investor complaints about the poor state of market liquidity after the financial crisis. Conventional wisdom prescribes that poor market liquidity harms the real economy through increased transaction costs and financing rates.

The body of recent empirical academic work delivers a nuanced assessment of the state of market liquidity. On the one hand, Adrian, Fleming, Shachar, and Vogt (2017) reject the bond investors' complaints, documenting a return of their price impact measure after the crisis to pre-crisis levels. Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018) corroborate this view, showing a temporary increase in transaction costs during the crisis and a subsequent return to pre-crisis levels. However, they point out that broker-dealers use less capital for trade intermediation after the crisis, especially during surges in intermediation demand. Furthermore, Trebbi and Xiao (2017) fail to find empirical evidence for a structural break in the evolution of different liquidity measures over time.

On the other hand, Dick-Nielsen and Rossi (2018) and Bao, O'Hara and Zhou (2018) show that around stress events, such as index exclusions or rating downgrades, measures of illiquidity increase significantly after the financial crisis, suggesting that liquidity evaporates when needed most. Anderson and Stulz (2017) conclude that price-based liquidity measures appear in line with pre-crisis levels, but the turnover of corporate bonds fell significantly with more frequent trades of smaller size. In the same vein of a purported change in the trading behaviour, Choi and Huh (2018) argue that bond investors other than broker-dealers are increasingly providing liquidity, given

[1] According to data from the Securities Industry and Financial Markets Association.

more frequent observations of trades between a broker-dealer and an investor that are followed by almost instantaneous trades of the same size in the opposite direction. Presumably, broker-dealers use prearranged roundtrip trades to evade inventory risk. The authors insist that studies on liquidity costs will suffer from measurement error if they do not control for the share of prearranged trades.

In light of the conflicting empirical evidence on the price dimension of liquidity and the pessimistic practitioners' view, I study the impact of capital constraints in the time dimension of liquidity theoretically. Herein, I focus on the interaction of specific microstructure elements of secondary markets for corporate bonds. I study a bilateral trade environment, in which the buyer has capital constraints, the seller incurs holding costs depending on the asset's fundamental value, and agents can only carry out spot trades.

Given the empirical evidence of Choi and Huh (2018) and accounts by corporate bond practitioners [2], I interpret liquidity provision in risky corporate bonds as a bilateral bargaining game. Since regulations after the 2007-2008 financial crisis caused broker-dealers to commit less capital to market-making, bond investors adapted to fill out the vacant roles of liquidity suppliers. In this new market microstructure, a liquidity demanding investor contacts a broker-dealer who then searches for a counterparty instead of trading immediately. Once the broker-dealer finds a counterparty, the transaction price is determined in bilateral bargaining between the liquidity demanding party and the liquidity supplying one. The respective bargaining positions depend on the arrival of news about the asset value, and trade is delayed until the parties reach an agreement on the quantity and on the price.

The expected holding costs of the seller motivate trade. The seller incurs holding cost instantaneously when there is a sufficient decrease in the fundamental value. To prevent the holding cost, the seller must transfer the asset to the buyer before the shock realizes. I show that in such an environment, a

[2] See Tchir "A day in the life of a high-yield bond", Forbes 5th March 2016

delay in trade can increase welfare. Essentially the restriction to spot trades constitutes a market incompleteness since agents can only trade a bundle of claims. When capital is scarce, early trade might waste capital on claims in states with no gains from trade, while later trade allows for more productive use of scarce capital. My model explains how holding costs, capital constraints and bargaining power distributions affect the trade timing.

Another important assumption relates to the instantaneous holding costs after a negative fundamental value shock. I argue that such costs reflect well four different scenarios in the corporate bond context: (i) institutional investors with a risky (low value) bond position that contradicts their investment mandate and triggers a remuneration penalty, (ii) insurance companies and banks who face regulatory costs for holding risky bonds, (iii) investors who specialize in financing bonds with repo contracts that require safe assets as collateral and that have no immediate access to alternative cheap funding and (iv) open-ended corporate bond mutual funds that face redemption runs after negative asset shocks. Empirical evidence reported in Feldhuetter and Poulsen (2018) that bid-ask spreads for corporate bonds are inversely related to ratings supports the argument that gains from trade are inversely related to the asset's fundamental value.

Furthermore, I argue that the limitation to spot trades is a plausible description of quantitatively relevant constraints since many funds have restrictive investment mandates. The Bank for International Settlement reports supporting findings from their international fund survey in 2003, stating that "restrictions as to the use of leverage and derivatives being a common feature" of investment mandates. Koski and Pontiff (1999) corroborate that a majority of US equity mutual funds do not use derivatives. I see the exclusion of derivatives as an exclusion of contingent trades that, in practice, limit the available contracts to spot trades.

Historically, the infrastructure for corporate bond trading developed into over-the-counter (OTC) markets with broker-dealer companies at their centre

[3]. To make a market, broker-dealers quote bid-ask prices and build bond inventories to balance out demand and supply from investors, providing liquidity. Market-making carries the risk of changes in the value of the inventory, hence requiring capital. Since most major broker-dealers are subsidiaries of investment banks, they have benefited from easier access to funding in the past. Today, different regulatory measures imposed on bank-holding companies might have diminished the funding benefit from the parent-subsidiary union, thus causing the alleged deterioration of liquidity. Duffie (2012) contends that the ban on proprietary trading for bank-holding companies under the Volcker rule harms market liquidity since regulators cannot distinguish between market-making and proprietary trading. Additionally, various changes in the Basel III regulatory catalogue could make capital for market-making prohibitively expensive [4]. Since many regulations changed simultaneously, it is difficult to disentangle effects empirically.

My paper relates to the literature that studies asset prices in search and bargaining models of OTC markets. The seminal paper of Duffie, Gârleanu, and Pedersen (2005) started this literature, showing how search-and-matching frictions relate to bid-ask spreads. Other contributions in this literature relaxed the restrictions made in the seminal paper: Lagos and Rocheteau (2009) relax the assumption of limited asset positions, while Vayanos and Weill (2008) focus on a model with heterogeneous assets. In these models, bargaining leads to immediate trade upon a match since agents do not face capital constraints. In my model, the limited capital combined with inversely related gains from trade and fundamental value leads to bargaining delay. One exception is Tsoy (2021), who has endogenous bargaining delays that arise due to the private information of the agents on their respective as-

[3] Biais and Green (2019) overview the 20th-century history of corporate bond trading infrastructure.

[4] The 2004 BIS report, "Market-making and proprietary trading: industry trends, drivers and policy implications", identifies the leverage ratio, liquidity coverage ratio and net stable funding ratio as potential obstacles to market-making due to higher capital costs.

set valuations. My work centres on an imperfect information setting in which agents have symmetric information, and trade delays occur in expectation of a partial resolution of symmetric uncertainty.

The classic paper on strategic bargaining is Rubinstein (1982), that models alternating offers in a perfect information environment that causes immediate trade. Gul and Sonnenschein (1988) and Abreu and Gul (2000) show how trading delays arise, either to screen private information or to mimic types. My analysis focuses on a time-varying stochastic process in the private value component that gives rise to an option value of waiting under capital constraints. Furthermore, for non-degenerate bargaining weights, I do not model the bargaining process explicitly but employ the Nash bargaining solution at each date of the resolution of uncertainty.

3.2 Analysis

I present the model with an exogenous amount of capital for the buyer. First, I explain my main mechanism in the case in which all bargaining power is with the buyer. Then I use the Nash bargaining solution to obtain allocations in an environment with arbitrary distributions of bargaining power. To show the robustness of my analysis and its main mechanism, I present endogenous capital constraints in a later section.

3.2.1 Baseline model

Two agents, one buyer, B, and one seller, S, live through three dates, $t \in \{0, 1, 2\}$. They are risk-neutral and want to consume cash at date 2, i.e. $U^S(x) = U^B(x) = x$. Both agents have symmetric information and beliefs regarding any random variable. There are two goods, cash and the divisible asset A owned by the seller. The common value of this asset is a random variable, $\tilde{A}$, its cash return at date 2. $\tilde{A}$ consists of a sure component D and

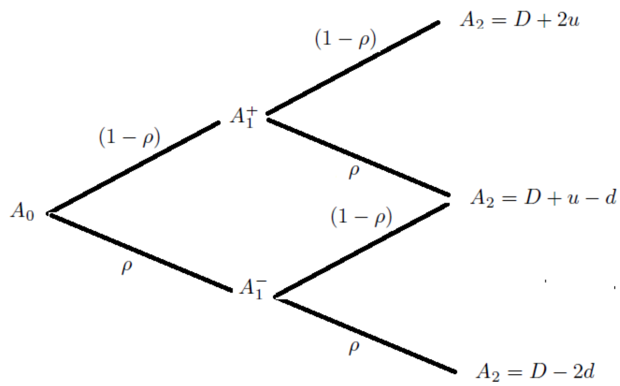

Figure 3.1: Evolution of A

two random shocks, $\tilde{\epsilon_1}$ and $\tilde{\epsilon_2}$. The first shock is realized between $t = 0$ and $t = 1$ and the second shock between $t = 1$ and $t = 2$. The shocks are binary and i.i.d. according to:

$$\tilde{\epsilon_t} = \begin{cases} u > 0 & \text{w.p. } (1-\rho), \\ -d < 0 & \text{w.p. } \rho \end{cases}$$

The time-varying fundamental value of the asset is the expectation of the common value $\tilde{A}$ given the resolved uncertainty until t.Therefore, at date 0 the fundamental value of the asset is $A_0 = E_0[\tilde{A}]$, while at date 1 the fundamental value after a positive shock is $A_1^+ = E[\tilde{A}|\epsilon_1 = u]$ and $A_1^- = E[\tilde{A}|\epsilon_1 = u]$ after a negative one.

In contrast to the buyer, the seller may incur a holding cost l. The holding cost introduces a private value component that differentiates and creates gains from trade between the agents. The holding costs are an instantaneous non-monetary charge on the seller. They occur instantaneously between any two dates in which the fundamental value of the asset is below a fundamental threshold A^L. Importantly, the seller incurs the holding cost simultaneous to the relevant shock realization and before the next date (and trade opportunity). The seller incurs l proportional to the share of asset A in owned. Selling a share or the whole asset at a prior date prevents holding costs, hence there is a trading motive rooted in precaution.

The holding costs in the model should reflect various monetary or non-monetary costs of investors to hold risky or low rated assets. I assume that A^L is within the interval $(A_1^-, min(A_0, A_2^{+-}))$, such that the seller incurs the holding cost when ϵ_1 is negative and when ϵ_2 is negative conditional on negative realization of $\tilde{\epsilon_1}$. Consequently, the seller's valuation for the asset is equal to its fundamental value net of expected holding costs:

$$V_0^S = A_0 - \rho(l + \rho l)$$

$$V_1^S = \begin{cases} A_1^+ & if \epsilon_1 = u \\ A_1^- - \rho l & if \epsilon_1 = d \end{cases}$$

The buyer only cares about the fundamental value of the asset as he does not incur holding costs, therefore $V_t^B = A_t$. The buyer has cash K and cannot raise outside funding, which limits the cash available for any transfer between the buyer and the seller. The difference in valuations at t creates gains from trade g_t that fluctuate over time as they equal the seller's holding costs.

$$g_t = V_t^B - V_t^S$$

Buyer and seller meet at $t = 0$ and $t = 1$ to trade. Buyer and seller can only agree on spot trades and are not able to trade future claims[5].

In the baseline model, the borrower has full bargaining power and makes take-it-or-leave offers at both trading dates. At date t, the buyer offers to buy a share of the asset, q_t, at the asset valuation $\mathcal{P}_t$. I proceed by giving a benchmark planner solution. Then I will show which trades arise when

[5] The real-world inspiration for this assumption are constraints of some investment funds to hold derivatives.

the buyer has full bargaining power and how the trade timing depends on parameter assumptions.

3.2.2 Characterization

First best

I will characterize a first-best solution that is a state-contingent trade schedule at $t = 0$ and $t = 1$ chosen by a social planner. The planner maximizes the sum of the expected welfare of the buyer and the seller. The planner's allocation must only satisfy the *ex-ante* expected utility reservation value of the seller and the buyer, i.e. $U^B = K$ and $U^S = V_0^S$. This allows the planner to implement more allocations than can arise in the bargaining game between buyer and seller. When buyer and seller bargain, each trade at any date t must satisfy the respective *interim* reservation value, i.e. the reservation value given the resolved uncertainty.

Any cash transfer between buyer and seller is welfare neutral therefore maximizing total welfare amounts to maximizing the amount of prevented holding costs in expectation. The planner can choose three transfer pairs, (q_0, T_0), (q_1^+, T_1^+) and (q_1^-, T_1^-), where q describes the asset share transferred to the buyer and T the cash received by the seller. This leads to the following welfare function:

$$\begin{aligned} &\max W = \rho((q_0)l + \rho(q_0 + q_1^-)l) \quad \text{s.t.} \\ &U^B \geq K, \\ &U^S \geq V_0^S \end{aligned}$$

When K is small, the planner's solution is as follows: Since the planner only cares about maximizing the asset transfer at date 0 and at date 1 after a negative shock, it is the reservation value of the seller that is the binding constraint. To ease satisfying the constraint, the planner allocates the whole asset to the seller asset after a positive shock at date 1. For a similar reason, the seller will receive the full capital from the buyer, i.e. $T_0 = K$. To minimize the expected holding cost, the planner will transfer the full asset to the buyer at date 0 and return only as much as necessary at date 1 after a negative shock to satisfy the seller's reservation value. This leads to the following trade schedule:

Lemma 3 *When $K \leq V_0^S - (1-\rho)V_1^{S+}$, then the social planner chooses the following trade schedule:*
$(q_0, T_0) = (1, K)$, $(q_1^+, T_1^+) = (-1, 0)$, $(q_1^-, T_1^-) = (-\frac{V_0^S - K - (1-\rho)V_1^{S+}}{\rho V_1^{S-}}, 0)$.
Total welfare is $\rho l + \frac{\rho K}{V_1^{S-}} l$.
When $K \leq V_0^S - (1-\rho)V_1^{S+}$ then there is no need to return the asset after a negative shock, i.e. $q_1^- = 0$ and welfare is maximal at $(\rho + \rho^2)l$.

All proofs are in the appendix.

In the planner solution, there is always a trade at $t = 0$, and there is a potential asset return at date 1. Such a state-contingent allocation cannot be implemented without derivative contracts. Next, I will show that the allocation that arises from bargaining may differ over two dimensions, the timing and the trade volume.

The buyer has full bargaining power

When the buyer has full bargaining power, i.e. has the right to make take-it-or-leave-it offers, the asset valuation equals the reservation value of the seller, $\mathcal{P}_t =_t^S$, for all trades.

Furthermore, after a positive shock, $\epsilon_1 = u$, there are no gains from trade, hence I assume that there is no further trade between buyer and seller. At date 0 the buyer faces the following problem:

$$\begin{aligned} maxE[U(x)] \qquad &= q_0(A_0 - V_0^S) + E[q_1(A_1 - V_1^S)] + K \\ &= q_0(A_0 - V_0^S) + \rho q_1^-(A_1^- - V_1^{S-}) + K \end{aligned}$$

s.t.

$$q_0 + q_1^- \leq 1$$

$$q_0 \leq \frac{V_0^S}{K}$$

$$q_1^- \leq \frac{K - q_0 V_0^S}{V_1^{S-}}$$

When the buyer is so cash-rich that his capital exceeds the reservation value of the seller, then budget constraints do not matter. The buyer is the sole claimant to the gains from trade and has sufficient cash to realize them fully. This follows directly from the problem when substituting $q_1^- = 1 - q_0$ and taking the derivative with respect to q_0:

$$\begin{aligned} &(A_0 - V_0^S) - \rho(A_1^- - V_1^{S-}) \\ &= g_0 - \rho g_1^- > 0 \end{aligned}$$

Since gains from trade are decreasing in expectation, the buyer trades $q_0 = 1$ and realizes full gains from trade.

When the buyer owns less capital, in particular so little capital that the feasibility constraint never binds, i.e. $K < V_1^{S-}$, then substituting the budget constraint yields the following derivative:

$$\begin{aligned} &(A_0 - V_0^S) - \rho(A_1^- - V_1^{S-})\frac{A_0}{V_1^{S-}} \\ &= g_0 - \rho g_1^- \frac{V_0^S}{V_1^{S-}} \end{aligned}$$

The sign of the derivative can be either positive or negative, implying that it is either better to trade only at date 0 or to wait and to trade only after a negative shock after date 1.

For the buyer to be indifferent between buying at $t = 0$ and waiting the model parameters have to satisfy the following condition:

$$\frac{g_0}{V_0^S} = E_0[\frac{g_1}{V_1^S}] \iff$$
$$\frac{(\rho+\rho^2)l}{A_0-(\rho+\rho^2)l} = \rho\frac{\rho l}{A_1^- - \rho l}$$

This equation yields a lower bound on the holding costs, $\bar{l}$, such that waiting weakly dominates:

$$l \geq \frac{(1+\rho)A_1^- - \rho A_0}{(1-\rho)(\rho+\rho^2)} \equiv \bar{l}$$

Or equivalently written in the fundamental value components as:

$$l \geq \frac{1}{\rho-\rho^3}(D + 2u(1-\rho) - 2\rho d + (\rho^2-1)(u+d)) \equiv \bar{l}$$

Figure 3.2 depicts the lower bound on the holding costs as a function of the probability of a negative fundamental value shock, ρ, for different symmetric fundamental value shocks.

In the following proposition, I distinguish three cases. In the first two cases, there is an incentive for delay and scarce capital, resulting in (partly) delayed trade. In the third case, trade happens immediately.

Proposition 8 *When $l > \bar{l}$ and $K < V_1^{S-}$, then the buyer waits and trades $q_1^- = \frac{K}{V_1^{S-}}$ at date 1 at a valuation $\mathcal{P}_1 = V_1^{S-}$. Total welfare equals $\rho\frac{K}{V_1^{S-}}\rho l$.*

When $l > \bar{l}$ and $V_0^S > K > V_1^{S-}$, then the buyer trades at both dates: $q_0 = \frac{K-V_1^{S-}}{V_0^S-V_1^{S-}}$ at $\mathcal{P}_\prime = V_0^S$ and $q_1^- = (1-q_0)$ at $\mathcal{P}_1 = V_1^{S-}$. Total welfare is $\rho l\frac{K-V_1^{S-}}{V_0^S-V_1^{S-}} + \rho^2 l$.

When $l < \bar{l}$ or $K > V_0^S$ then the buyer trades all his capital or buys the

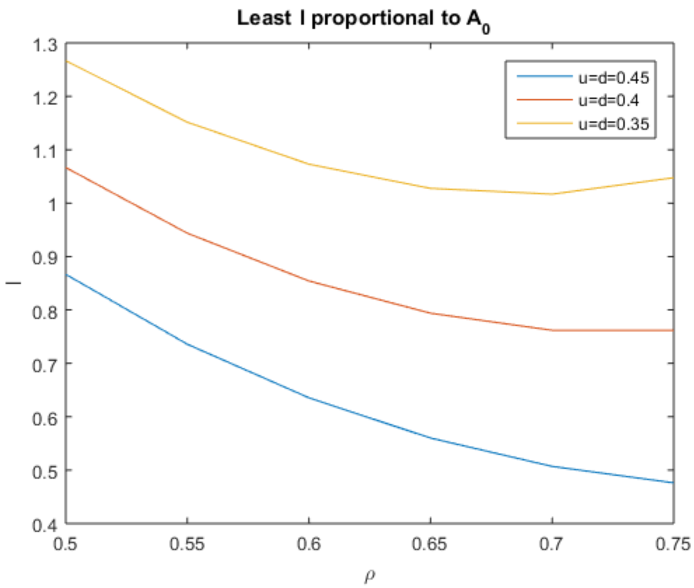

Figure 3.2: Least holding costs that motivate delay

whole asset at date 0 *at an asset valuation of* $\mathcal{P}_0 = V_0^S$. *Total welfare equals* $min(\frac{K}{V_0}, 1)(\rho + \rho^2)l$.

The trading delay is rooted in market incompleteness. The buyer and seller cannot trade contingent claims on all states of the world. Claims are bundled, in particular, when the buyer buys an asset on the first date, then he owns a claim to the asset on the second date in both states of the world, after a positive shock and a negative one. When capital is scarce, it is costly to waste capital on an asset claim after a positive shock, when gains from trade between buyer and seller are zero. This cost lead the buyer to prefer waiting since, after a negative shock and a decreased fundamental value, capital can be used more efficiently. When capital is abundant, then the buyer is indifferent since the marginal value of capital is 1.

The consequence is that if capital is scarce, $K < V_0^S$, then the bargaining between buyer and seller over spot trades yields always a welfare outcome that is strictly dominated by the planner's solution. The trade volume in date

0 is always lower in the bargaining situation, and the first trade might even only happen at date 1. The difference in total welfare between the bargaining outcome and the planner's solution increases when the bargaining power of the buyer decreases.

The seller has full bargaining power

When the seller has full bargaining power, then the agents trade at an asset valuation that equals the fundamental value, $\mathcal{P}_t = A_t$. The seller decides to wait whenever the following condition holds:

$$g_0 - g_1^- \rho \frac{A_0}{A_1^-} < 0$$

The above expression yields the following insight regarding the relative eagerness to wait between the two agents in the polar cases. When the seller has full bargaining power and wants to wait, then the buyer would always wait as well if he had the bargaining power. The reverse case does not hold:

Lemma 4 *When $g_0 - \rho g_1^- \frac{A_0}{A_1^-} < 0$, then the lower bound on the holding costs is negative and the buyer has an incentive to wait for any positive l.*

When $g_0 - \rho g_1^- \frac{V_0^S}{V_1^{S-}} > 0$, then the lower bound on the holding cost is positive, i.e. $\bar{l} > 0$ and the buyer would have an incentive to wait for any $l \geq \bar{l}$.

3.3 Arbitrary bargaining power distribution

In this section, I study allocations when the asset valuation corresponds to the Nash Bargaining solution for an arbitrary bargaining power distribution. The agents bargain in a staggered way. First, they bargain at date 0, knowing that they have the option to bargain again at date 1 after the resolution of some uncertainty. Therefore, I calculate the Nash bargaining solutions backwards. First, I calculate the asset valuation as the Nash Bargaining solutions to bargaining at date 1, when the outside option is not to trade. I use the asset valuation at date 1 to calculate an outside option of later bargaining at date 0. Given the outside option, I calculate the asset valuation at date 0. With the established asset valuations, agents accept to trade at the time when it maximizes the surplus between the two agents, given that the relative surplus distribution only depends on exogenous bargaining weights.

When the agents decide not to trade at date 0, then at date 1 after a negative shock the buyer uses all his capital to purchase a share of the asset equal to $q_1^- = K/\mathcal{P}_1^-$. The Nash bargaining solution maximizes the surplus of the following equation:

$$\max_{\mathcal{P}_1^-}(q_1^-(V_1^{B-} - \mathcal{P}_1^-) - 0)^\theta (q_1^-(\mathcal{P}_1^- - V_1^{S-}) - 0)^{1-\theta} =$$
$$\frac{K}{\mathcal{P}_1^-}(V_1^{B-} - \mathcal{P}_1^-)^\theta (\mathcal{P}_1^- - V_1^{S-})^{1-\theta}$$

The following asset valuation maximizes the surplus product at date 1 after a negative shock:

$$\mathcal{P}_1^- = \frac{V_1^{S-}V_1^{B-}}{\theta V_1^{B-} + (1-\theta)V_1^{S-}}$$

The Nash Bargaining solution nests the cases in which either agent has full bargaining power, i.e. $\mathcal{P}_1^-(\theta = 1) = V_1^{S-}$ and $\mathcal{P}_1^-(\theta = 0) = A_1^-$.

At date 0, the Nash Bargaining solution maximizes the surplus product relative to the outside option of bargaining at a later date. For the outside option, there is only relevant bargaining after a negative fundamental value shock:

$$\max_{\mathcal{P}_0}(q_0(V_0^B - \mathcal{P}_0) - \rho q_1^-(V_1^{B-} - \mathcal{P}_1^-))^\theta (q_0(V_0^B - \mathcal{P}_0) - \rho q_1^-(\mathcal{P}_1^- - V_1^{S-}))^{1-\theta}$$

Trade at date 0 would imply a transfer of $q_0 = K/\mathcal{P}_1$, while in the outside option trade is $q_1^- = K/\mathcal{P}_1^-$. The following asset valuation maximizes the surplus product at date 0:

$$\mathcal{P}_0 = \frac{V_0^S V_0^B \mathcal{P}_1^-}{\theta V_0^B((1-\rho)\mathcal{P}_1^- + \rho V_1^{S-}) + (1-\theta)V_0^S((1-\rho)\mathcal{P}_1^- + \rho V_1^{B-})}$$

Similarly, as at date 1, the Nash Bargaining solution at date 0 nests the cases with one-sided bargaining power, i.e. $\mathcal{P}_0(\theta = 1) = V_0^S$ and $\mathcal{P}_0(\theta = 1) = V_0^S$.

With the established asset valuations, the agents will trade at the time in which the surplus is maximal. A late trade is optimal when:

$$\rho \frac{g_1^-}{\mathcal{P}_1^-} \geq \frac{g_0}{\mathcal{P}_0}$$

Proposition 9 *When* $K < \frac{V_1^{S-}V_1^{B-}}{{}_1^{B-}+(1-\theta)V_1^{S-}}$ *and* $\rho\frac{g_1^-}{\mathcal{P}_1^-} < \frac{g_0}{\mathcal{P}_0}$*, then there is only trade at date* 0*. The asset valuation is* $\mathcal{P}_0 = \frac{V_0^S V_0^B \mathcal{P}_1^-}{\theta V_0^B((1-\rho)\mathcal{P}_1^- + \rho V_1^{S-}) + (1-\theta)V_0^S((1-\rho)\mathcal{P}_1^- + \rho V_1^{B-})}$ *and the transferred share is* $q_0 = K/P_0$.

When $K < \frac{V_1^{S-}V_1^{B-}}{{}_1^{B-}+(1-\theta)V_1^{S-}}$ *and* $\rho\frac{g_1^-}{\mathcal{P}_1^-} \geq \frac{g_0}{\mathcal{P}_0}$*, then there is only trade at date* 1 *after a negative shock. The asset valuation is* $\mathcal{P}_1^- = \frac{V_1^{S-}V_1^{B-}}{{}_1^{B-}+(1-\theta)V_1^{S-}}$ *and the transferred share is* $q_1^- = K/\mathcal{P}_1^-$.

3.3.1 Welfare Impact of Bargaining Power distribution

Lemma 2 shows that changes in the bargaining power distribution may change the trade timing. Formally, the countervailing timing incentives occur whenever $g_0/A_0 - g_1^- \frac{A_0}{A_1^-} < 0$ and $l > \bar{l}$ are satisfied. Interestingly, in this parameter region, buyer and seller can benefit from a mediator who randomly assigns full bargaining power to either agent at both dates. This becomes apparent when plotting total welfare under trade at date 0, $g_0 K/\mathcal{P}_0(\theta)$, and total welfare under trade at date 1, $\rho g_1^- K/\mathcal{P}_1^-(\theta)$. While total welfare under immediate trade is a concave function in θ, it is linear under delayed trade:

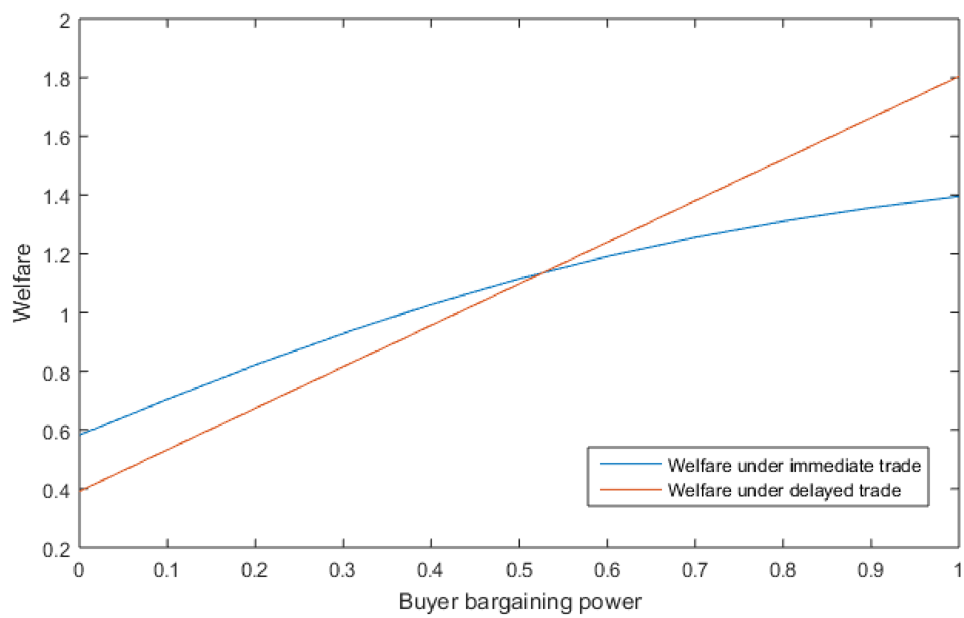

Figure 3.3: For $u = d = 0.45$, $\rho = 0.55$ and $l = 0.8$

Figure 3.3 reveals visually that the convex combination of the welfare outcomes under degenerate bargaining power distributions dominates the welfare that arises otherwise.

3.4 Robustness check: Endogenous capital constraints

So far, the buyer could not raise outside capital and had to operate with K only. Such a constraint describes well investment funds with "long-only" mandates that prevent leverage, but it does not fit typically levered investment funds, such as hedge funds. In this section, I extend the model by an agency friction on the buyer's side that limits outside capital. I model this agency friction as in Bruche and Kuong (2021), where the buyer has to provide effort in order to maximize the value of the trade.

In the new setup, the technological description of the asset is the same, except that the asset does not pay cash at the terminal period. The seller still values the fundamental value of the asset at date 2, while the buyer needs to find a suitable terminal investor in order to receive cash and realize the value of the trade.

Formally, the buyer chooses hidden effort, $e \in \{H, L\}$ at date 2 to find a suitable terminal investor who pays the fundamental value in cash. With high effort, $e = H$, the probability of finding the suitable investor is high, p_H, and low otherwise. The non-monetary cost c for high effort scales in the fundamental value at date 2 and must be borne by the buyer. Failing to find a suitable terminal investor implies that the buyer must monetize the asset at a pawnbroker at a discount on the fundamental value equal to δ.

High effort is necessary for gains from trade between the buyer and the seller, $V_t^B(e = h) - V_t^S > 0 > V_t^B(e = 0) - V_t^S$.

Let R_t denote the maximum pledgeable cash flow from the whole asset that the buyer can promise to lenders subject to his incentive compatibility constraint. Herein, the buyer can make payment promises contingent on the arrival of the suitable terminal investor, $\overline{R}$ and $\underline{R}$. To ease satisfying the incentive compatibility constraint, the repayment in absence of the suitable terminal investor is maximal at $\underline{R}(A_t)q_t = (1 - \delta)A_t q_t$. This implies the incentive compatibility constraint:

$$(p_H(A_2 - \overline{R}(A_2)) - eA_2)q_t \geq (p_L(A_2 - R^+(A_2)))q_t$$

From the incentive compatibility constraint follows that the maximal pledgeable cash flow from the whole asset is:

$$R_t \equiv E_t[R(A)] = A_t - (1 - p_H)\delta A_t - p_H \frac{e}{p_H - p_L} A_t$$

Let d_t be the outside funding granted lenders, then the zero profit condition for lenders requires:

$$d_t = q_t R_t$$

This implies that at date t and asset valuation $\mathcal{P}_t$, the buyer can afford an asset share purchase of:

$$q_t = \frac{K + d_T}{\mathcal{P}_t} = \frac{K}{\mathcal{P}_t - R_t}$$

When $\mathcal{P}_t - R_t$ is positive, then the buyer needs some capital $K > 0$ to purchase the asset. When the buyer has full bargaining power, then the asset valuation is $\mathcal{P}_t = V_t^S$. When the buyer's capital is sufficiently small, $K < V_0^S - R_0$, the buyer cannot purchase the whole asset. Similarly, as in the baseline model, the buyer has an incentive to wait when:

$$\frac{K}{V_0^S - R_0} g_0 - \rho \leq \frac{K}{V_1^{S-} - R_1^-} g_1^-$$

This yields the new lower bound on the holding cost, $\bar{l}_n$, for which the buyer has a waiting incentive:

$$\bar{l}_n \equiv \frac{1}{p - p^3}((1 + \rho)(A_1^- - R_1^-) + \rho(A_0 - R_0)$$

Proposition 3 is the counterpart to proposition 1 in the endogenous capital constraint framework.

Proposition 10 *When $l > \bar{l}_n$ and $K < V_1^{S-} - R_1^-$, then the buyer waits and trades $q_1^- = \frac{K}{V_1^{S-} - R_1^-}$ at date 1 at a valuation $\mathcal{P}_1 = V_1^{S-}$. Total welfare equals $\rho \frac{K}{V_1^{S-} - R_1^-} \rho l$.*

When $l > \bar{l}_n$ and $V_0^S - R_0 > K > V_1^{S-} - R_1^-$, then the buyer trades at both dates: $q_0 = \frac{K - (V_1^{S-} - R_1^-)}{V_0^S - R_0 - (V_1^{S-} - R_1^-}$ at $\mathcal{P}_\prime = V_0^S$ and $q_1^- = (1 - q_0)$ at $\mathcal{P}_1 = V_1^{S-}$. Total welfare is $\rho l \frac{K - (V_1^{S-} - R_1^-)}{V_0^S - R_0 - (V_1^{S-} - R_1^-} + \rho^2 l$.

When $l < \bar{l}_n$ or $K > V_0^S - R_0$ then the buyer trades all his capital or buys the whole asset at date 0 at an asset valuation of $\mathcal{P}_0 = V_0^S$. Total welfare equals $min(\frac{K}{V_0 - R_0}, 1)(\rho + \rho^2)l$.

3.5 Conclusion and implications

I study the relation between capital constraints and the timing of trade in an environment that captures characteristics of corporate bond trades. When capital constraints bind, then the combination of inversely related fundamental value and gains from trade together with the spot trade restriction generates an incentive for waiting. The incentive for waiting can dominate the decrease in gains from trade over time, leading to a trading delay. The buyer has a stronger incentive to wait than the seller, such that the bargaining power distribution may affect the timing of trade.

In this paper, I interpret investment mandate restrictions on derivatives trading as a limitation to spot trades. In bilateral bargaining, a one-sided restriction suffices to cause such a limitation. When liquidity provision comes increasingly from investment funds rather than broker-dealers, it becomes more likely that at least one party is subject to such restrictions.

Another implication relates to the cross-section of investment funds: funds with derivative restrictions will be more affected by scarce capital than funds without such restrictions. My empirical prediction is that for latter funds, liquidity trades should happen more frequently in a situation with scarce capital.

3.6 Appendix

Proof of Proposition 8:

For small and for large amounts of capital, the proof follows from the text. When the buyer has capital $K \in (V_0^S, V_1^{S-})$ and $l > \bar{l}$ then the buyer has an incentive to wait. Not spending any capital at a date 0, however, leads to leftover capital at date 1 after a negative shock, which cannot be in the best interest of the buyer. Therefore, in this parameter region, the buyer purchases at date 0 only as much as necessary to prevent leftover capital at date 1 after a negative shock. i.e.:

$$\frac{K - q_0 V_0^S}{V_1^{S-}} = 1 - q_0$$

Proof of Lemma 3: Since the binding constraint is the reservation value of the seller, the planner's allocations have to satisfy the following constraint:

$$U^S = -q_0 V_0^S + T_0 + (1-\rho)(-q_1^{V_1^{S+}} + T_1^+) + \rho(-q_1^{V_1^{S-}} + T_1^-) + V_0^S \geq V_0^S$$

Plugging in $(q_0, T_0) = (1, K)$, $(q_1^+, T_1^+) = (-1, 0)$ and $T_1^- = 0$ results in a binding constraint:

$$q_1^- = max(\frac{V_0^S - K - (1-\rho)V_1^{S+}}{\rho V_1^{S-}}, 0)$$

Proof of Lemma 4:

Suppose that $g_0 - \rho g_1^- \frac{A_0}{A_1^-} < 0$. Dividing the left hand side by the positive expression $A_0 \rho l(\rho - \rho^3)$ yields exactly $\bar{l}$. Therefore, the least amount of holding cost would be negative and the buyer always wants to wait.

Similarly, when $g_0 - \rho g_1^- \frac{A_0}{A_1^-} > 0$, then $\bar{l}$ is positive after the same operation.

Proof of Proposition 9:

The objective function at date 1 for any amount of capital $K \leq \mathcal{P}_\infty^-$, $q_1^- = K/\mathcal{P}_\infty^-$ Pareto dominates. Furthermore, since there are gains from trade at date 0, leftover capital can never be part of a Pareto-dominant trade schedule. With the outside option of no trade that yields a zero net increase in respective expected utility, the objective function is:

$$\frac{K}{\mathcal{P}_1^-}(V_1^{B-} - \mathcal{P}_1^-)^\theta (\mathcal{P}_1^- - V_1^{S-})^{1-\theta}$$

The derivative with respect to $\mathcal{P}_1^-$ yields:

$$\begin{aligned}&- \frac{K}{(\mathcal{P}_1^-)^2}(V_1^{B-} - \mathcal{P}_1^-)^\theta (\mathcal{P}_1^- - V_1^{S-})^{1-\theta} \\ &+ \frac{K}{\mathcal{P}_1^-}[-\theta(V_1^{B-} - \mathcal{P}_1^-)^{\theta-1}(\mathcal{P}_1^- - V_1^{S-})^{1-\theta} + (1-\theta)(V_1^{B-} - \mathcal{P}_1^-)^\theta(\mathcal{P}_1^- - V_1^{S-})^{-\theta}]\end{aligned}$$

Setting the expression equal to zero, first shows that the asset valuation is independent of the amount of capital that is available at date 1 as long as $K < \mathcal{P}_1^-$. Solving for $\mathcal{P}_1^-$ yields:

$$\mathcal{P}_1^- = \frac{V_1^{S-}V_1^{B-}}{\theta V_1^{B-} + (1-\theta)V_1^{S-}}.$$

At date 0, the outside option of trading at date 1 yields a net increase in expected utility of $q_1^- \rho(A_1^- - \mathcal{P}_1^-)$ for the buyer. There is only a net increase in expected utility after a negative shock. Furthermore, the traded share is maximal at $q_1^- = K/\mathcal{P}_1^-$.

After similar considerations for the seller, this yields the following equation:

$$(\frac{K}{P_0}(V_0^B - \mathcal{P}_0) - \rho\frac{K}{\mathcal{P}_1^-}(V_1^{B-} - \mathcal{P}_1^-))^{\theta}(\frac{K}{P_0}(V_0^B - \mathcal{P}_0) - \rho\frac{K}{\mathcal{P}_1^-}(\mathcal{P}_1^- - V_1^{S-}))^{1-\theta}$$

To ease exposition, define

$$\mathcal{B} = (\frac{K}{P_0}(V_0^B - \mathcal{P}_0) - \rho\frac{K}{\mathcal{P}_1^-}(V_1^{B-} - \mathcal{P}_1^-))^{\theta},$$
$$\mathcal{S} = (\frac{K}{P_0}(V_0^B - \mathcal{P}_0) - \rho\frac{K}{\mathcal{P}_1^-}(\mathcal{P}_1^- - V_1^{S-}))^{1-\theta}$$

The derivative with respect to $\mathcal{P}_0$ yields:

$$\theta\mathcal{B}^{\frac{\theta-1}{\theta}}(1-\theta)\frac{-V_0^B}{(\mathcal{P}_0)^2}\mathcal{S} + (1-\theta)\mathcal{B}\mathcal{S}^{\frac{\theta}{\theta-1}}\frac{V_0^S}{(\mathcal{P}_0)^2}$$

Setting the derivative equal to zero and solving for $\mathcal{P}\prime$ finally yields:

$$\mathcal{P}_0 = \frac{V_0^S V_0^B \mathcal{P}_1^-}{\theta V_0^B((1-\rho)\mathcal{P}_1^- + \rho V_1^{S-}) + (1-\theta)V_0^S((1-\rho)\mathcal{P}_1^- + \rho V_1^{B-})}$$

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