Essays on Asset Pricing with Financial Frictions

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Essays on Asset Pricing with Financial Frictions

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A thesis presented for the degree of
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The PhD School in Economics and Management is an active national and international research environment at CBS for research degree students who deal with economics and management at business, industry and country level in a theoretical and empirical manner.

Preface

This thesis represents the product of my PhD studies at the Department of Finance and the Center for Financial Frictions (FRIC) at Copenhagen Business School (CBS). In the process of writing this thesis, I have been fortunate to benefit from the advice, feedback, and support from many more people than I can possibly mention here. This long list of people, however, includes some who deserve special recognition.

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Thomas Kjær Poulsen
Copenhagen, April 2019

Summaries in English

Essay 1: Does Debt Explain the Investment Premium?

The first essay presents new empirical findings which are inconsistent with prominent theories on the investment premium. The investment premium is the positive stock return differential between firms with low and high asset growth. Asset growth is the annual percentage change in total assets and is typically interpreted as the firm's investments. The investment premium is an integral part of recent factor models which are fundamental tools for both finance academics and practitioners.

In the essay I present three new empirical findings. First, I show that firms with low asset growth on average have higher financial leverage. To the extent that firms with higher leverage have higher returns, cross-sectional differences in leverage account for part of the investment premium. Second, I document that there is no investment premium among zero-leverage firms. Third, I find that the investment premium increases with firms' refinancing intensities which are the ratio of short-term debt to total debt. These findings reflect firms' financing decisions and are inconsistent with prominent theories using firms' investment decisions to explain the investment premium.

In the literature there are two prominent theories on why the investment premium exists. On the one hand, rational theories suggest that the investment premium reflects firms' investment decisions (e.g. Cochrane (1991, 1996), Li et al. (2009), Liu et al. (2009), Berk et al. (1999), and Fama and French (2015)). On the other hand, behavioral theories argue that the investment premium reflects mispricing as investors do not properly incorporate information on firms' investment decisions into asset prices (e.g. Titman et al. (2004) and Cooper et al. (2008)). These theories share two important features. First, they predict that the investment premium should also exist among zero-leverage firms. Second, they cannot explain why the investment premium should depend on refinancing intensities.

To explain my empirical findings I develop a new model in which firms not only make investment decisions as in the existing literature but also make financing decisions. The model shows that the investment premium reflects both leverage and refinancing intensities consistent with my empirical findings. In sum, I find that debt-related risks explain part of the investment premium.

Essay 2: Why Does Debt Dispersion Affect Yield Spreads?

The second essay investigates the well-known negative relationship between corporate bond yield spreads and debt dispersion. Yield spreads measure firms' debt financing costs and debt dispersion is the extent to which firms divide their total debt financing into several debt issues. Understanding the determinants of yield spreads remains an important task not only for finance academics but also for finance practitioners to inform corporate policies. In the essay I examine two possible explanations of the negative relationship between yield spreads and debt dispersion.

First, theories of rollover risk argue that firms with more dispersed debt have lower yield spreads when they spread out the debt maturity dates across time. The reason is that firms mitigate the adverse effects of deteriorating capital market conditions by limiting the amount of debt that matures at a given point in time. By spreading out the repayment of debt over multiple time periods, the firm can reduce its default risk and therefore also the yield spread.

Second, theories of strategic debt service suggest that more dispersed debt increases renegotiation frictions which determine how difficult it is to renegotiate the firm's debt. In these models equity holders can threaten to default strategically with a view to obtain debt concessions. Higher renegotiation frictions reduce equity holders' incentive to default strategically. This strategic default effect reduces the probability of default and therefore also the yield spread.

Empirically, measures of debt maturity dispersion and proxies for renegotiation frictions are often highly correlated. Both rollover risk and strategic debt service models can therefore explain the negative relationship between yield spreads and debt dispersion. To disentangle these two candidate explanations from each other I examine how the relationship depends on the level of financial constraints. In rollover risk models yield spreads should decrease more with debt maturity dispersion for financially constrained firms because they more exposed to capital market conditions. I document empirically that the negative relationship is more pronounced for financially constrained firms consistent with rollover risk theories.

In strategic debt service models the relationship between yield spreads and renegotiation frictions is determined by a trade-off between two opposing effects. On the one hand, higher renegotiation frictions reduce yield spreads through the strategic default effect. On the other hand, higher renegotiation frictions also increase expected liquidation costs in bankruptcy because renegotiations are more likely to fail. This recovery effect decreases recovery rates and increases yield spreads. I show theoretically that financial constraints strengthen the recovery effect because equity holders in financially constrained firms default more often. The relationship between yield spreads and renegotiation frictions should therefore be less negative for financially constrained firms. My empirical results contradict this prediction.

Essay 3: What Determines Bid-Ask Spreads in Over-the-Counter Markets?
with Peter Feldhütter

The third essay studies the cross-sectional variation in bid-ask spreads, measured by realized transaction costs, in the U.S. corporate bond market. We use the variation to test over-the-counter (OTC) theories of why the bid-ask spread arises. Bid-ask spreads are often used to measure market liquidity. Market liquidity influences bond prices and therefore directly affects firms' debt financing costs. Our findings shed new light on the ability of OTC theories to explain the cross-sectional variation of bond bid-ask spreads.

Our analysis begins by documenting patterns in the cross-section of bid-ask spreads across bond maturity and rating. When we sort in one dimension alone, we find that average spreads increase with bond maturity and credit risk consistent with findings from the existing literature. When we double-sort on maturity and rating, however, a surprising pattern emerges. Spreads for investment grade bonds increase strongly in maturity, while spreads for speculative grade bonds show no clear relation. For short-maturity bonds, spreads increase in credit risk while for long-maturity bonds, spreads for bonds rated AA+ or AAA are substantially higher than other investment grade bonds. We compare these documented patterns in bid-ask spreads to the variation in proxies motivated by theories of the bid-ask spread in OTC markets.

We consider four theories based on inventory, dealer network, search-and-bargaining frictions, and asymmetric information and examine the extent to which the variation in proxies explains the variation in bid-ask spreads. We find that dealer inventory is the most important determinant of the variation in bid-ask spreads. In inventory models dealers provide immediacy to investors and charge a bid-ask spread to compensate for the risk that the bond price may decline while it is in the dealer's inventory. We also find that models based on dealer networks explain part of the variation in bid-ask spreads especially for speculative grade bonds. In these models, the dealers' position in the network of other dealers as well as the number of dealers involved in intermediating a trade determines the bid-ask spread.

We also find that search-and-bargaining frictions and asymmetric information models have limited explanatory power for bid-ask spreads. In search-and-bargaining models the bid-ask spread depends on the easy of finding counterparties to trade with and the strength of their bargaining power over the transaction price. In asymmetric information models some investors have private information about the value of the security and the dealer charges a bid-ask spread to compensate for losses incurred when trading with informed counterparties.

Taken together, we document new facts about the cross-sectional variation in bid-ask spreads and provide new evidence on the ability of OTC theories to explain the variation.

Summaries in Danish

Essay 1: Does Debt Explain the Investment Premium?

Det første essay præsenterer nye empiriske resultater, som er inkonsistente med prominente teorier om investeringspræmien. Investeringspræmien er det positive aktieafkastdifferentiale imellem virksomheder med lav og høj aktivvækst. Aktivvækst er den årlige procentvise ændring i totale aktiver og bliver typisk fortolket som virksomhedens investeringer. Investeringspræmien udgør et centralt element i de seneste faktormodeller, som er fundamentale værktøjer for både forskere og praktikere.

Artiklen præsenterer tre nye empiriske resultater. For det første har virksomheder med lav aktivvækst i gennemsnit højere finansiel gearing. En del af investeringspræmien kan derfor forklares ud fra tværsnitsforskelle i gearing, såfremt virksomheder med højere gearing også har højere afkast. For det andet eksisterer der ikke nogen investeringspræmie blandt virksomheder uden gæld. For det tredje vokser investeringspræmien med virksomheders gældsandele af kortfristet gæld. Disse tre resultater afspejler virksomheders finansieringsbeslutninger og er inkonsistente med prominente teorier, som forklarer investeringspræmien ud fra virksomheders investeringsbeslutninger.

I litteraturen er der to prominente teorier, som kan forklare hvorfor investeringspræmien eksisterer. På den ene side argumenterer rationelle teorier for, at investeringspræmien afspejler virksomheders investeringsbeslutninger. På den anden side argumenterer adfærdsøkonomiske teorier for, at investeringspræmien skyldes investorers manglende evne til at inkorporere information korrekt i priserne på finansielle aktiver. Disse to teorier har to vigtige egenskaber tilfælles. For det første beror de begge to på, at der eksisterer en investeringspræmie for virksomheder uden gæld. For det andet kan de ikke forklare, hvorfor investeringspræmien vokser med virksomheders gældsandele af kortfristet gæld. Mine empiriske resultater er derfor inkonsistente med disse to teorier og bidrager med et nyt perspektiv på den økonomiske fortolkning af investeringspræmien.

Til at forklare mine empiriske resultater udvikler jeg en ny model, hvori virksomheder træffer både investerings- og finansieringsbeslutninger. Modellen viser, at investeringspræmien afspejler både finansiel gearing og gældsandelen af kortfristet gæld i lighed med de empiriske resultater. Konklusionen er dermed, at gældsrelaterede risici forklarer en betydelig andel af investeringspræmien.

Essay 2: Why Does Debt Dispersion Affect Yield Spreads?

Det andet essay analyserer den velkendte negative relation imellem virksomhedsobligationers kreditspænd og spredning af gæld. Kreditspænd måler virksomheders gældsfinansieringsomkostninger og spredning af gæld angiver i hvor høj grad virksomheder deler deres totale gældsfinansiering op i mindre gældsserier. Det er vigtigt for både forskere og praktikere at forstå determinanterne af kreditspænd, med henblik på at vejlede virksomheder bedst muligt. I artiklen undersøger jeg to potentielle forklaringer på den negative relation imellem kreditspænd og spredning af gæld.

For det første argumenterer teorier om refinansieringsrisiko for, at virksomheder med mere spredt gæld har lavere kreditspænd, hvis de fordeler gældens forfaldstidspunkter over tid. Det skyldes, at virksomheder kan formindske konsekvenserne af forringede kapitalmarkeder ved at begrænse mængden af gæld, som forfalder på et givet tidspunkt. Ved at sprede tilbagebetalingen af gæld ud over flere perioder reduceres virksomhedes fallitrisiko og dermed også kreditspændet.

For det andet argumenterer teorier om strategisk gældsservice for, at spredning af gæld øger genforhandlingsfriktioner, som afgør hvor vanskeligt det er at genforhandle virksomhedens gæld. I disse modeller har aktionærerne mulighed for at lade virksomheden gå strategisk fallit med henblik på at opnå gældssanering. Højere friktioner reducerer aktionærenes incitament til at gå strategisk fallit. Denne strategiske falliteffekt reducerer fallitsandsynligheden og dermed også kreditspændet.

Empirisk er der ofte en stærk korrelation imellem mål for spredning af gældens forfaldstidspunker og proxyvariable for genforhandlingsfriktioner. Både teorier om refinansieringsrisiko og strategisk gældsservice kan altså forklare den negative relation imellem kreditspænd og spredning af gæld. For at adskille disse to potentielle forklaringer fra hinanden, undersøger jeg, hvordan relationen afhænger af virksomheders finansielle begrænsninger. Ifølge refinansieringsrisikomodeller bør kreditspændet aftage i større grad med spredning af gæld for finansielt begrænsede virksomheder eftersom de er mere eksponerede over for kapitalmarkederne. Mine empiriske resultater er konsistente med denne prædiktion.

I strategiske gældsservicemodeller er det en afvejning af to modsatrettede effekter, som bestemmer relationen imellem kreditspænd og spredning af gæld. På den ene side øger spredning af gæld genforhandlingsfriktioner og reducerer kreditspænd gennem den strategiske falliteffekt. På den anden side øger genforhandlingsfriktioner også forventede likvidationsomkostninger i fallit eftersom det bliver sværere at genforhandle virksomhedens gæld. Denne recovery-effekt reducerer gældens recovery-rater og øger kreditspændet. Jeg viser teoretisk, at finansielle begrænsninger gør recovery-effekten stærkere, fordi finansielt begrænsede virksomheder går oftere fallit. Relationen imellem kreditspænd og spredning af gæld bør derfor være mindre negativ for finansielt begrænsede virksomheder. Mine empiriske resultater viser det modsatte.

Essay 3: What Determines Bid-Ask Spreads in Over-the-Counter Markets?
med Peter Feldhütter

Det tredje essay undersøger tværsnitsvariationen af bid-ask spreads, som måles ved realiserede transaktionsomkostninger, i det amerikanske erhvervsobligationsmarked. Vi bruger variationen til at teste over-the-counter (OTC) teorier om bid-ask spreads. Bid-ask spreads benyttes ofte til at måle markedslikviditet. Markedslikviditet påvirker obligationspriser og har dermed direkte indflydelse på virksomheders gældsfinansieringsomkostninger. Vores resultater viser, i hvor høj grad OTC-teorier kan forklare tværsnitsvariationen af bid-ask spreads.

Først dokumenterer vi, hvordan bid-ask spreads varierer på tværs af obligationers løbetid og rating. Når vi sorterer på en dimension alene, så stiger gennemsnitlige bid-ask spreads med løbetid og kreditrisiko i lighed med resultater fra den eksisterende litteratur. Ved at dobbeltsortere på løbetid og rating finder vi et overraskende mønster. Bid-ask spreads stiger tydeligt med løbetid for investment-grade-obligationer, mens der ikke er nogen tydelig relation for speculative-grade-obligationer. For korte obligationer stiger bid-ask spreads med kreditrisiko, hvorimod lange obligationer med en rating på AA+ eller AAA har væsentligt højere bid-ask spreads sammenlignet med alle andre investment-grade-obligationer. Vi sammenligner disse mønstre i bid-ask spreads med variationen i proxyvariable, som vi motiverer ud fra OTC-teorier om bid-ask spreads.

Vi betragter fire teorier baseret på forhandlerbeholdning, forhandlernetværk, search-and-bargaining-friktioner og asymmetrisk information og undersøger i hvor høj grad variation i proxyvariable forklarer variation i bid-ask spreads. Vores resultater viser, at forhandlerbeholding er den vigtigste determinant af variation i bid-ask spreads. I forhandlerbeholdningsmodeller kan investorer handle obligationer med forhandlere, som opkræver et bid-ask spread i kompensation for, at obligationsprisen kan ændre sig mens forhandleren har den på lager. Modeller baseret på forhandlernetværk forklarer også en del af variationen i bid-ask spreads, særligt for speculative-grade-obligationer. I disse modeller er det forhandleres position i forhandlernetværket og også antallet af involverede forhandlere i en given handel, som bestemmer bid-ask spread'et.

Vores resultater viser desuden også, at search-and-bargaining-friktioner og asymmetrisk-informations-modeller har begrænset forklaringsgrad for bid-ask spreads. I search-and-bargaing-modeller afhænger bid-ask spreads af hvor let det er finde modparter at hande med, men også af deres indbyrdes forhandlingskraft over transaktionsprisen. I asymmetrisk-informations-modeller har nogle investorer privat information omkring værdien af et værdipapir og forhandleren opkræver et bid-ask spread som kompensation for de tab, som opstår ved at handle med informerede modparter.

Alt i alt bidrager artiklen med nye resultater om tværsnitsvariationen af bid-ask spreads, men også med at undersøge i hvor høj grad OTC-teorier om bid-ask spreads kan forklare variationen.

Contents

Introduction

This thesis consists of three self-contained essays, which study how financial frictions influence the pricing of equities, corporate bonds, and transaction costs. In the first essay I consider asset pricing implications of firms' investment and financing decisions for the cross-section of equity returns. I show that risks related to firms' debt structures explain a substantial fraction of the investment premium i.e. the finding that firms with low asset growth deliver high average stock returns. In the second essay I investigate why debt dispersion — the extent to which firms divide their total debt financing into several debt issues — affect yield spreads on corporate bonds. I document that the negative relationship between yield spreads and debt dispersion is more pronounced for financially constrained firms and show that this finding is consistent with theories of rollover risk. The third essay (co-authored with Peter Feldhütter) presents new facts on the cross-section of bid-ask spreads in the corporate bond market. We find that models based on dealer inventory and dealer networks explain a large fraction of the variation in bid-ask spreads while models based on search-and-bargaining frictions and asymmetric information have limited explanatory power.

Does Debt Explain the Investment Premium?

The first essay studies the pervasive empirical phenomenon in the stock market called the investment premium. The investment premium is the positive stock return differential between firms with low and firms with high asset growth where asset growth is the annual percentage change in total assets. In this essay I present three new empirical findings. First, I find that the investment premium reflects differences in financial leverage. Second, I document that there is no investment premium among zero-leverage firms. And third, I find that the magnitude of the investment premium increases with firms' refinancing intensities which are the ratio of short-term debt to total debt. These three findings are important because they are inconsistent with prominent explanations of the investment premium.

In the literature there are two prominent theories on why the investment premium exists. On the one hand, rational theories argue that the investment premium reflects firms' investment decisions (e.g. the q-theory of investment including Cochrane (1991, 1996), Li et al. (2009), Liu et al. (2009), real option models such as Berk et al. (1999), and the dividend discount model from Fama and French (2015)). On the other hand, behavioral theories argue that the investment premium reflects mispricing as investors do not properly incorporate information on firms' investment decisions into asset prices (e.g. Titman et al. (2004) and Cooper et al. (2008)). Both of these theories share two important features. First, they predict a positive return differential between zero-leverage firms with low and high asset growth. Second, they cannot explain why the return differential increases with firms' refinancing intensities. My empirical results are therefore inconsistent with these theories and offer a novel perspective on the economic interpretation of the investment premium.

To explain my empirical findings I develop a new model in which firms not only make endogenous investment decisions as in the existing literature but they also make endogenous financing decisions. The model shows that the investment premium reflects both leverage and refinancing intensities consistent with my empirical findings. Taken together, the novelty of the first essay rests in showing that debt-related risks explain part of the investment premium.

Why Does Debt Dispersion Affect Yield Spreads?

While the first essay studies asset pricing in equity markets, the second essay considers asset pricing in corporate bond markets. In particular, I investigate the well-known negative relationship between yield spreads and debt dispersion[1]. Yield spreads measure firms' debt financing costs and debt dispersion is the extent to which firms divide their total debt financing into several debt issues. I document empirically that the negative relationship between yield spreads and debt dispersion is more pronounced for financially constrained firms. This cross-sectional variation is crucial for understanding why debt dispersion affects yield spreads.

In the essay I examine two candidate explanations for the negative relationship between yield spreads and debt dispersion. On the one hand, theories of rollover risk argue that firms with more dispersed debt have lower yield spreads when they spread out debt maturity dates across time (e.g. Choi et al. (2018)). On the other hand, theories of strategic debt service suggest that more dispersed debt increases renegotiation frictions, which determine how difficult it is to renegotiate the firm's debt, and reduce equity holders' incentive to threaten to default strategically (e.g. Davydenko and Strebulaev (2007)). In both models debt dispersion reduces yield spreads but for different reasons.

To disentangle these two candidate explanations from each other I analyze the effects of financial constraints. In rollover risk models yield spreads should decrease more with debt maturity

[1]See e.g. Davydenko and Strebulaev (2007), Dass and Massa (2014), and Nagler (2019).

dispersion for financially constrained firms because they more exposed to capital market conditions. In strategic debt service models I show that the relationship should be less negative for financially constrained firms. I document empirically that the negative relationship is more pronounced for financially constrained firms consistent with theories of rollover risk.

What Determines Bid-Ask Spreads in Over-the-Counter Markets?

Unlike the first two essays that study asset pricing implications for corporate securities, the third essay examines the cost of trading financial securities. More precisely, we study the cross-sectional variation in bid-ask spreads, measured by realized transaction costs, in the U.S. corporate bond market. It is well-documented in the literature that average bid-ask spreads increase in bond maturity and credit risk when considering one dimension alone[2].

Our first contribution is to document two new facts about bid-ask spreads by double-sorting on both bond rating and maturity. First, we find that bid-ask spreads do not increase with maturity for speculative grade bonds. Second, we show that long-maturity bonds rated AAA or AA+ have significantly higher spreads than other investment grade bonds. Our results are robust to excluding the financial crisis, adding time fixed effects, and holds separately for bonds issued by financial and non-financial firms.

Our second contribution is to examine the relative importance of different over-the-counter (OTC) theories ability to explain the variation in bid-ask spreads. We consider four theories based on dealer inventory, dealer networks, search-and-bargaining frictions, and asymmetric information. We find that dealer inventory is the most important determinant of the variation in bid-ask spreads. Dealer network models also explain part of the variation, especially for speculative grade bonds. Lastly, we find that search-and-bargaining frictions and asymmetric information models have limited explanatory power for bid-ask spreads.

[2]See e.g. Edwards et al. (2007), Dick-Nielsen et al. (2012), and Goldstein and Hotchkiss (2018).

Chapter 1

Does Debt Explain the Investment Premium?

Thomas Kjær Poulsen*

Abstract

The investment premium — the finding that firms with low asset growth deliver high average returns — is an integral part of recent factor models. I document empirically that the investment premium (1) reflects financial leverage, (2) does not exist among zero-leverage firms, and (3) increases with firms' refinancing intensities. This new evidence challenges prominent explanations of the investment premium including the q-theory of investment and behavioral finance. To explain the evidence, I develop a model in which firms make both optimal investment and financing decisions. The model shows that the investment premium reflects both leverage and refinancing intensities consistent with my empirical findings.

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1 Introduction

Firms with low asset growth have higher expected stock returns than firms with high asset growth[1]. This return differential is the investment premium from the five-factor Fama and French (2015) model and the q-factor model by Hou et al. (2015). Factor models are fundamental tools for both finance academics and finance professionals. The lack of agreement on the economic interpretation of the factors calls for more empirical evidence to inform asset pricing theories. In this paper, I study the investment factor and document that the investment premium (1) reflects financial leverage, (2) does not exist among zero-leverage firms, and (3) increases with firms' refinancing intensities. This cross-sectional variation reflects firms' financing decisions and is inconsistent with prominent theories using firms' investment decisions to explain the investment premium.

On the one hand, rational theories suggest that the investment premium reflects firms' investment decisions (e.g. the q-theory of investment including Cochrane (1991, 1996), Li et al. (2009), Liu et al. (2009), real option models such as Berk et al. (1999), and the dividend discount model from Fama and French (2015)). On the other hand, behavioral theories argue that the investment premium reflects mispricing as investors do not properly incorporate information on firms' investment decisions into asset prices (e.g. Titman et al. (2004) and Cooper et al. (2008)). Both of these theories share two important features. First, they predict a positive return differential between zero-leverage firms with low and high asset growth. Second, they cannot explain why the return differential increases with firms' refinancing intensities. My empirical results are therefore inconsistent with these theories and offer a novel perspective on the economic interpretation of the investment premium.

I begin my empirical analysis by confirming a strong negative relationship between asset growth and leverage consistent with the findings by Lang et al. (1996). Doshi et al. (2018) argue that leverage explains a substantial fraction of several cross-sectional anomalies. To control for leverage, I use their methodology to unlever stock returns and find that the investment premium decreases from 0.32% per month with levered returns to 0.15% with unlevered returns. If firms' investment decisions fully explain the investment premium and if financing decisions are irrelevant, the investment premium should also exist among zero-leverage firms. I use portfolio sorts to document that the return differential between zero-leverage firms with low and high asset growth is -0.11% per month and statistically insignificant.

Next, I consider levered firms' refinancing intensities and analyze how the return differential between low and high asset-growth firms depends on this financing decision. I measure refinancing

[1]See e.g. Fairfield et al. (2003), Hirshleifer et al. (2004), Titman et al. (2004), Richardson et al. (2005), Anderson and Garvia-Feijóo (2006), Fama and French (2006, 2015), Cooper et al. (2008), Lyandres et al. (2008), Xing (2008), Polk and Sapienza (2009), and Aharoni et al. (2013).

intensity by the ratio of debt maturing within one year to total debt and find that the return differential increases monotonically from 0.12% per month for firms with low refinancing intensities to 0.64% for firms with high refinancing intensities. This increase in the return differential of 0.52% is statistically significant and remains almost the same measured in risk-adjusted returns when I control for exposures to common risk-factors (market, size, value, momentum, profitability, and investments). When I control for leverage, the unlevered return differential between low and high asset-growth firms increases with refinancing intensities by 0.33%. Leverage therefore explains some of the cross-sectional return differential but refinancing intensities remain informative about the investment premium.

My empirical results show that the investment premium reflects both leverage and refinancing intensities. In the time-series, I regress (levered) investment factor returns on two factors constructed based on leverage and refinancing intensities. These two factors explain 36% of the time-series variation in the investment factor. I develop a corporate finance model to study the impact of leverage and refinancing intensities on the investment premium. Specifically, I integrate the growth option from Diamond and He (2014) into the Friewald et al. (2018) model and study implications of firms' investment and financing decisions for expected stock returns. Consistent with my empirical results, the model shows that the investment premium reflects both leverage and refinancing intensities.

The model features a firm with risky debt and a growth option to increase the growth rate of assets-in-place. Equity holders determine the firm's investment and default policies to maximize the value of equity. Debt overhang arises because debt and equity holders share the value from the firm's investments, whereas equity holders pay the entire investment cost. The firm can issue more short-term debt to improve investment incentives and reduce debt overhang at the expense of increasing rollover risk. Rollover risk arises because the firm retires maturing debt at principal value and issues new debt at market value. Equity holders finance the difference between the principal and market value of debt by issuing new equity.

The model shows that investment decisions have implications for expected stock returns. Equity holders capture a lower share of the value from the firm's investments the more risky the firm's debt and vice versa. When the firm has sufficiently risky debt, equity holders' share of the value from the firm's investments is too low to justify paying the investment cost. Since equity holders determine the investment policy, the firm does not invest when it has sufficiently risky debt. In the model, both the riskiness of debt and the expected stock return increase with leverage. Firms therefore invest when they have low leverage and expected stock returns are low, whereas firms do not invest when they have high leverage and expected stock returns are high. The model predicts that firms with low asset growth have higher leverage and higher expected stock returns relative to firms with high asset growth consistent with my empirical findings.

The firm jointly determines optimal leverage and debt maturity by choosing a mix between short-term and long-term bonds. This financing decision reflects a trade-off between investment incentives, rollover risk, and reduced-form debt benefits that reflect tax shields, reduction of agency costs, and/or reduction of information asymmetries. If the firm has no debt benefits, it optimally chooses zero leverage to improve investment incentives. Zero-leverage firms have no debt overhang and always invest because the growth option has positive net present value (NPV). This means that there is no cross-sectional variation in their investment policies and they all have the same leverage ratio of zero. For this reason, their investment decisions remain uninformative about expected stock returns and there is no return differential between zero-leverage firms with low and high asset growth.

If the firm has debt benefits, it chooses an optimal mix of short and long-term debt at inception. The fraction of short-term debt to total debt determines the refinancing intensity and the firm commits to keep the debt principal values constant through time. Over time, leverage changes with fluctuations in the market value of equity, whereas the refinancing intensity remains fixed. While expected stock returns increase with both leverage for a given refinancing intensity and likewise with the refinancing intensity for a given leverage, the model features an important interaction effect. Expected stock returns increase faster with refinancing intensities for firms with high leverage relative to firms with low leverage because short-term debt amplifies rollover risk. Since firms invest when they have low leverage and do not invest when they have high leverage, this interaction effect predicts that the return differential between firms with low and high asset growth increases with refinancing intensities.

1.1 Related Literature

My paper is related to Friewald et al. (2018) who study implications of firms' financing decisions for the cross-section of expected stock returns. They find that leverage and refinancing intensities explain a substantial fraction of the size and value factors. Doshi et al. (2018) also find that the size and value factors reflect leverage. These two papers do not focus on the investment factor. Prominent theories using firms' investment decisions to explain the investment factor do not consider financing decisions. My contribution is to study implications of both investment and financing decisions for expected stock returns.

Rational theories on the investment factor include three main explanations. First, the q-theory of investment predicts that firms invest more when expected stock returns are lower and vice versa. All else equal, firms invest more when discount rates are lower because the NPV of new projects is higher (e.g. Cochrane (1991, 1996), Li et al. (2009), Liu et al. (2009)[2], and Hou et al. (2015)). Second, real option models show that risky growth options have higher expected returns than less risky assets-in-place. When the firm invests, the importance of growth options relative to assets-in-place decreases and the expected stock return decreases as well (e.g. Berk et al. (1999), Carlson et al. (2004), Gomes et al. (2003), and Cooper (2006)). Third, Fama and French (2006, 2015) rewrite the dividend discount model and show that firms with higher expected growth in book equity have lower expected stock returns. They argue that growth in book equity reflects investments.

Behavioral theories on the investment factor include two main explanations. First, Cooper et al. (2008) build on the idea from Lakonishok et al. (1994) that investors extrapolate past performance too far into the future when they value stocks. If firms with high asset growth performed well in the past, investors expect them to continue to do so in the future. Investors overvalue stocks in these firms to the extent that they cannot live up to the high growth expectations going forward. When realized asset growth falls short of expectations, the market corrects the initial overvaluation and these stocks have low returns. Second, Titman et al. (2004) argue that investors fail to recognize that high asset growth may reflect over-investment (see Jensen and Meckling (1976) and Jensen (1986)). Investors therefore tend to overvalue firms with high asset growth. The subsequent low stock returns to high asset-growth firms reflect that the market corrects the initial over-valuation.

My paper also relates to the corporate finance literature on debt overhang and rollover risk which does not consider implications for expected stock returns. Hackbarth and Mauer (2012), Dockner et al. (2012), Sundaresan et al. (2014), Diamond and He (2014), and Chen and Manso (2017) study the debt overhang problem described by Myers (1977) using the conceptual framework from Leland (1994b), Leland (1994a), Leland and Toft (1996), Leland (1998), and Goldstein et al. (2001). The literature on rollover risk include He and Xiong (2012b), He and Milbradt (2014), and Chen et al. (2018) and mainly focuses on credit risk implications of debt rollover and bond market illiquidity.

2 Data and Summary Statistics

I obtain monthly stock returns from the Center for Research in Security Prices (CRSP) and annual firm characteristics from COMPUSTAT. I use the CRSP-COMPUSTAT linking table to merge the two data sets. At the end of June in year t, I calculate accounting based variables using information

[2]In Liu et al. (2009), the firm finances investments using both equity and one-period debt. This model features a leverage effect but the firm cannot choose its debt maturity. Liu et al. (2009) use leverage to improve the quantitative fit of the model and do not analyze the relationship between investments and leverage.

from the fiscal years ending in calendar year $t-1$ and $t-2$. I update all accounting variables annually at the end of June in year t and match them with monthly returns from July of year t to June of $t+1$. This procedure ensures a minimum gap of six months between fiscal year-end and the first following stock return.

A firm must be listed in COMPUSTAT for at least two years before it is included in the sample to mitigate survival bias (see Fama and French (1993)). A firm must also have all data items required to calculate asset growth, leverage, refinancing intensity, and market value. I only consider stock returns on common equity (SHRCD equal to 10 or 11 in CRSP) from stocks listed on NYSE, NASDAQ, or AMEX and I also include delisting returns. I exclude financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999) because they have special capital structures. If an SIC code is not available from COMPUSTAT, I use the SIC code from CRSP. I obtain the Fama-French factors and the risk-free rate from Kenneth French's website. The return tests start in July 1970 and ends in June 2016. These requirements result in 1,669,994 firm-month observations from 14,727 unique firms.

I follow Fama and French (2015) and calculate the firm's asset growth rate (AG) as the change in total assets from the fiscal year ending in $t-2$ to the fiscal year ending in $t-1$ divided by total assets from $t-2$. I measure the refinancing intensity (RI) with the ratio of debt maturing within one year to total debt similar to Barclay and Smith (1995), Guedes and Opler (1996), Stohs and Mauer (1996), Chen et al. (2013), and Friewald et al. (2018). Leverage (LEV) is the ratio of total debt to the sum of total debt and the market value of equity at the end of December in $t-1$ as in Fama and French (1992, 1993). Size (ME) is the market value of equity at the end of June in year t. Appendix A contains a detailed description of all variables. Table 1 presents summary statistics and correlations for firm characteristics as well as monthly excess returns. Before I calculate summary statistics, I winsorize asset growth rates each month at the 1st and 99th percentiles to mitigate the influence of potential data errors and outliers.

[INSERT TABLE 1]

3 Empirical Results

In this section, I investigate the relationship between expected stock returns and firms' investment and financing decisions. My empirical analysis uses portfolio sorts with NYSE breakpoints and value-weighted returns to alleviate the impact of microcaps following Fama and French (1993, 2008, 2015) and Hou et al. (2017)[3]. First, I consider the relationship between the investment

[3] Fama and French (2008) define microcaps as stocks with a market capitalization below the 20^{th} NYSE percentile. They argue that these stocks can be influential in equal-weighted portfolios and Fama and MacBeth (1973) regres-

premium and leverage. Second, I analyze zero-leverage firms because their stock returns by definition cannot reflect any debt related information. Third, I examine the relationship between the investment premium and firms' refinancing intensities. Fourth, I study the time-series variation in the investment premium.

3.1 The Investment Premium and Leverage

I begin by investigating the relationship between the investment premium and leverage. Fama and French (2015) construct the investment factor from an independent portfolio double-sort on size and asset growth. At the end of each June, I therefore independently double-sort stocks into two portfolios based on size and into three portfolios based on asset growth rates using NYSE breakpoints.

[INSERT TABLE 2]

Panel A in Table 2 presents average excess returns on each of the six portfolios. Consistent with Fama and French (2015), I find that average excess returns decrease with asset growth and the effect is more pronounced for small firms. Panel B and C reveal a strong relationship between asset growth and leverage. For both small and big firms, the average leverage ratio decreases monotonically with asset growth. The differences between average leverage ratios in the low and high asset-growth portfolios are highly statistically significant. This negative relationship between asset growth and leverage is consistent with the empirical findings by Lang et al. (1996) and suggests that firms' investment and financing decisions are related.

Doshi et al. (2018) point out the challenges in controlling for leverage in the cross-section of expected stock returns. They advocate to unlever equity returns using leverage ratios instead of including leverage as a control variable in Fama and MacBeth (1973) regressions. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$[4]. Panel D in Table 2 presents average unlevered excess returns for each of the six portfolios constructed based on size and asset growth. With unlevered returns, the return differentials between firms with low and high asset growth are substantially smaller compared to using levered returns. In fact, the average return on the two low minus the average return on the two high asset-growth portfolios is 0.15% per month (t-stat 1.86) with unlevered returns compared

sions. Hou et al. (2017) investigate 447 cross-sectional asset pricing anomalies and find that 286 of these anomalies become statistically insignificant when using NYSE breakpoints and value-weighted portfolios.

[4]Doshi et al. (2018) show that using more sophisticated methods to unlever stock returns such as the Merton (1974) model or the Leland and Toft (1996) model give virtually the same results. For this reason, I use their most simple and model-free approach to unlever stock returns.

to 0.32% (t-stat 3.63) with levered returns. Leverage therefore explains a substantial fraction of the investment premium.

3.2 The Investment Premium and Zero-Leverage Firms

If firms' investment decisions fully explain the investment premium and if financing decisions are irrelevant, the investment premium should also exist among zero-leverage firms. In this section, I therefore analyze the return differential between zero-leverage firms with low and high asset growth. Zero-leverage firms are important for at least two reasons. First, several theories on the investment premium explicitly consider zero-leverage firms and therefore predict a positive return differential between zero-leverage firms with low and high asset growth. Second, zero-leverage firms represent the only firm type in the data without any cross-sectional variation in leverage simply because they have no debt.

At the end of each June, I independently double-sort my sample of zero-leverage firms into two portfolios based on size and into two portfolios based on asset growth rates using NYSE breakpoints. I sort zero-leverage firms based on size to mitigate the influence of the biggest firms in the value-weighted portfolios by allocating these firms to separate portfolios. I need accounting information from the fiscal years ending in year $t-2$ and $t-1$ to calculate asset growth. I follow Strebulaev and Yang (2013) and define firm i as zero-leverage if in both years $t-2$ and $t-1$ the outstanding amounts of both short-term debt (DLC) and long-term debt ($DLTT$) equal zero. My sample of zero-leverage firms features $164,337$ firm-month observations from $3,278$ unique firms. In an average year, zero-leverage firms constitute 9.90% of all firms and account for 4.01% of total market capitalization.

[INSERT TABLE 3]

Panel A in Table 3 shows average excess returns on the low and high asset-growth portfolios for small and big firms. The average excess return of the small and big Low-High AG portfolios is -0.11% per month and statistically insignificant. Even for small firms where the asset-growth effect is more pronounced cf. Table 2, the return differential is 0.12% and statistically insignificant. For big firms, the return differential is -0.34% and statistically insignificant. These results show that there is no investment premium among zero-leverage firms. Panel B reports value-weighted spreads in asset growth of -48.80% for small firms and -35.34% for big firms resulting in an average spread of -42.07%. For comparison, the full sample has an average spread in asset growth of -51.72% cf. Panel B in Table 2. The fact that there is no positive return differential between zero-leverage firms with low and high asset growth is therefore not driven by a lack of a meaningful spread in asset growth.

Panel C shows the average number of stocks in each of the four portfolios. The two portfolios of big firms contain a fairly small number of stocks and in particular during the early part of the sample period. The big portfolio with the lowest number of stocks contains only three stocks in a particular month cf. Panel D. This feature of the data reflects that I use NYSE size breakpoints to construct portfolios and most zero-leverage firms are not listed on NYSE. NYSE firms are typically much larger and few firms listed on NASDAQ or AMEX are large enough to be included in the big portfolios[5]. As a robustness check in Section 3.5, I consider the larger sample of firms with non-positive net debt which has a higher number of stocks in each portfolio. I also find that there is no investment premium among these firms.

Testing theories on the investment premium

The empirical fact that there is no return differential between zero-leverage firms with low and high asset growth is inconsistent with prominent theories on the investment premium. Rational theories such as the dividend discount model and the real option models predict a positive return differential for zero-leverage firms. The q-theory of investment may potentially explain the non-existing return differential but only in the unlikely case that zero-leverage firms have zero adjustment costs of capital. Li and Zhang (2010) and Lam and Wei (2011) use financing constraints to proxy for adjustment costs of capital when they test predictions from q-theory. The empirical evidence from Devos et al. (2012) and Bessler et al. (2013) suggest that zero-leverage firms have severe financial constraints. Geelen (2017) shows theoretically that adverse selection costs preclude zero-leverage firms from issuing debt. These papers therefore suggest that zero-leverage firms are more financially constrained in which case q-theory predicts a positive return differential among these firms.

Behavioral theories such as the over-extrapolation hypothesis from Cooper et al. (2008) does not distinguish between zero-leverage and levered firms. This theory therefore predicts a positive return differential also among zero-leverage firms. According to Jensen (1986) and Titman et al. (2013), zero-leverage firms likely have the highest agency costs because they have no debt forcing management to pay out part of the free cash flow. The over-investment hypothesis therefore predicts a higher positive return differential between zero-leverage firms with low and high asset growth. My empirical findings do not support any of these predictions.

[5]In an average month, the median NYSE-zero-leverage firm is more than four times larger than the median NASDAQ-zero-leverage firm and more than fifteen times larger than the median AMEX-zero-leverage firm. If I instead use NYSE-AMEX-NASDAQ breakpoints to construct portfolios of zero-leverage firms, the portfolio with the lowest average number of stocks contain 53 stocks in an average month and the lowest number of stocks is 12. Using these breakpoints, the value-weighted return differential between zero-leverage firms with low and high asset growth is a statistically insignificant -0.03% per month measured in excess returns.

3.3 The Investment Premium and Refinancing Intensities

In this section, I examine another aspect of firms' financing decisions namely their refinancing intensities. Friewald et al. (2018) show that controlling for refinancing intensities, expected stock returns increase with leverage. Since asset growth is negatively related to leverage in the data, I also analyze if the investment premium reflects refinancing intensities. Importantly, none of the prominent theories on the investment premium feature any testable predictions on firms' refinancing intensities.

At the end of each June, I independently double-sort stocks into five portfolios based on refinancing intensities and into five portfolios based on asset growth rates using NYSE breakpoints[6]. I present average excess returns on the 25 portfolios with value-weighted returns in Table 4. In each asset-growth quintile, I construct a High-Low RI portfolio that buys the High RI portfolio and sells the Low RI portfolio. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. Lastly, I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. This portfolio measures how the return differential between low and high asset-growth firms depends on the refinancing intensity.

[INSERT TABLE 4]

Panel A in Table 4 shows that average excess returns decrease with asset growth in all refinancing quintiles. The Low-High AG column shows that the return differential between firms with low and high asset growth increases monotonically with refinancing intensities from 0.12% to 0.64% per month. The Low-High AG return differential is therefore 0.52% higher for firms with high refinancing intensities compared to firms with low refinancing intensities. This finding means that the magnitude of the investment premium increases with firms' refinancing intensities.

Panel B presents the average leverage ratio for each portfolio. Consistent with my previous findings, leverage decreases with asset growth within each refinancing quintile. The return differential between firms with low and high asset growth therefore partly reflects a leverage effect. To control for leverage, I repeat the independent portfolio double-sort based on refinancing intensities and asset growth using unlevered returns instead of levered returns. Panel C shows that average excess returns continue to decrease with asset growth in most refinancing quintiles. The average excess returns on the Low-High AG portfolios are smaller with unlevered returns but leverage only

[6] I obtain qualitatively and quantitatively similar results when I independently triple-sort stocks into two portfolios based on size, five portfolios based on refinancing intensities, and five portfolios based on asset growth rates. I present the results from the independent portfolio double-sort because they are simpler to describe.

explains part of the return differential. In fact, the unlevered return differential is 0.33% per month higher for firms with high refinancing intensities compared to firms with low refinancing intensities. This finding suggests that refinancing intensities convey information about the investment premium even when controlling for leverage.

[INSERT TABLE 5]

In Table 5, I test if my finding that the return differential between low and high asset-growth firms increases with refinancing intensities can be explained by exposures to common risk-factors. For each refinancing quintile, I calculate alpha estimates from regressing the Low-High AG portfolio excess returns on the market, the three Fama-French factors (market, size, and value), the four factors (market, size, value, and momentum), and the five Fama-French factors (market, size, value, profitability, and investments). Panel A presents alpha estimates for levered returns. The first column shows that CAPM alphas increase from 0.19% to 0.77% per month. Importantly, the High-Low RI portfolio shows that the return differential between low and high asset-growth firms is 0.58% higher in firms with high refinancing intensities relative to firms with low refinancing intensities. Risk-adjusted returns using three, four, and five factors have almost the same magnitude and remain statistically significant.

Panel B shows risk-adjusted return differentials based on unlevered returns. Consistent with my previous findings, the unlevered return differentials remain smaller than levered return differentials. For CAPM alphas, the return differential between firms with low and high asset growth increases from 0.13% per month for firms with low refinancing intensities to 0.53% for firms with high refinancing intensities. The CAPM alpha on the High-Low RI portfolio is 0.41% and remains statistically significant. Risk-adjusted returns using three, four, and five factors have almost the same magnitude. Taken together, the risk-adjusted portfolio returns support my finding that the investment premium increases with firms' refinancing intensities.

Testing theories on the investment premium

Prominent theories on the investment premium cannot explain why the return differential increases with firms' refinancing intensities. Jensen (1986) points out that debt reduces agency costs of free cash flows by committing management to service debt payments. If the investment premium reflects that investors under-react to over-investment, the return differential between low and high asset-growth firms should be larger in firms with higher agency costs. The firm can use its debt maturity to discipline management from engaging in value-decreasing investments. Short-term debt commits the firm to frequently raise new debt in capital markets to roll over maturing debt. Since capital markets reevaluate the firm's prospects as part of the valuation of new debt issuances, firms with short-term debt should have lower agency costs. In turn, the over-investment hypothesis from Titman et al. (2004) predicts a smaller return differential for firms with high refinancing intensities because they have lower agency costs. My results directly contradict this prediction.

The dividend discount model, real option models, the q-theory of investment, and the over-extrapolation hypothesis do not feature any directly testable predictions on refinancing intensities. Li and Zhang (2010) and Lam and Wei (2011) point out that it is challenging to disentangle candidate explanations of the investment premium in the data. For example, q-theory predicts that the return differential should increase with investment frictions because frictions make investment less responsive to changes in the discount rate. Behavioral theories predict a larger return differential in firms with stocks that have high limits-to-arbitrage because rational investors find it more challenging to step in and correct the mispricing. If measures of investment frictions, limits-to-arbitrage, and refinancing intensities are highly correlated then it is challenging to disentangle the predictions from each other. To explore this possibility, I calculate Spearman rank correlations between measures of investment frictions, limits-to-arbitrage, and refinancing intensities.

Li and Zhang (2010) and Lam and Wei (2011) use several proxies to measure investment frictions and limits-to-arbitrage. They hypothesize that firms with high investment frictions have smaller asset size, lower payout rates, and are younger. Firms with high limits-to-arbitrage have high idiosyncratic stock volatility, low stock price, high bid-ask spread, high Amihud (2002) illiquidity measure, and low dollar volume. Appendix A contains a detailed description of all variables. Table 6 presents Spearman rank correlations between these measures and refinancing intensities. Consistent with Li and Zhang (2010) and Lam and Wei (2011), I find high correlations between measures of investment frictions and measures of limits-to-arbitrage. However, Table 6 shows only modest correlations between refinancing intensities and these measures. This finding suggests that refinancing intensities convey information not captured by investment frictions or limits-to-arbitrage.

[INSERT TABLE 6]

It is also not clear from the theoretical literature on debt maturity that we should expect firms with short-term debt to have high investment frictions. For example, Diamond (1991) predicts an inverse U-shape between debt maturity and credit risk when firms trade off lower borrowing costs of short-term debt against higher refinancing risk. Chen et al. (2013) show that firms with higher exposure to systematic risk choose longer debt maturities. Dangl and Zechner (2015) find that short-term debt typically increases firms' debt capacities. To the extent that higher credit risk, higher systematic risk, and lower debt capacity are associated with higher investment frictions, we should not expect firms with short-term debt to have high investment frictions.

For the limits-to-arbitrage measures, it is not clear from the literature how and if they should be related to debt maturity. Chen et al. (2013) and Friewald et al. (2018) show that firms with higher idiosyncratic volatility issue more short-term debt because long-term debt becomes relatively more expensive. Since stocks with high idiosyncratic volatility have high limits-to-arbitrage, it is challenging to disentangle the predictions based on limits-to-arbitrage and refinancing intensities using this measure. Taken together, my results suggest that the higher return differential among firms with high refinancing intensities does not simply reflect higher investment frictions or higher limits-to-arbitrage.

3.4 Time-Series Variation in the Investment Factor

My cross-sectional results show that the investment premium reflects leverage and refinancing intensities. In this section, I study to what extent leverage and refinancing intensities explain the time-series variation in the investment factor.

I follow Fama and French (2015) and construct the investment factor as follows. At the end of each June, I independently double-sort stocks into two portfolios based on size and into three portfolios based on asset growth rates using NYSE breakpoints. This procedure generates a cross-section of $2 \times 3 = 6$ portfolios. The investment factor is the average return on the two low asset-growth portfolios (small and big) minus the average return on the two high asset-growth portfolios using value-weighted portfolios. I use the same procedure to construct two factors based on leverage and refinancing intensities. The leverage factor is the average return on the two high-leverage portfolios (small and big) minus the average return on the two low-leverage portfolios. The refinancing-intensity factor is long stocks with high refinancing intensities and short stocks with low refinancing intensities. I regress the time-series of investment factor returns on the two factors based on leverage and refinancing intensities and present the results in Table 7.

[INSERT TABLE 7]

The first column in Table 7 shows that the investment premium in my sample is 0.32% per month and statistically significant. In column (2), I regress investment factor returns on the leverage factor and find that the intercept decreases to 0.23% and remains statistically significant. The investment factor has positive loading on the leverage factor and the adjusted R^2 of the regression is 34.16%. When I only include the refinancing-intensity factor in the regression then the loading is close to zero and statistically insignificant while the intercept is virtually unchanged.

This finding suggests that refinancing intensities alone has no explanatory power for the time-series variation of the investment factor. When I include both factors in the regression, the loading on each factor is positive and statistically significant. The adjusted R^2 increases to 35.82% and suggests that leverage and refinancing intensities jointly explain a significant fraction of the investment premium.

3.5 Robustness Checks

This section summarizes robustness checks which I include in the Internet Appendix. Table IA.1-IA.4 show that my results are robust to using equal-weighted portfolios. In addition to zero-leverage firms, Strebulaev and Yang (2013) also consider firms with zero long-term debt, almost zero-leverage firms, and firms with non-positive net debt[7]. I also analyze the return differential between firms with low and high asset growth for these firm types. I only report the results for firms with non-positive net debt in the Internet Appendix because it gives the largest sample and the other firm types give similar results (result are available upon request). My sample of firms with non-positive net debt features $518,505$ firm-month observations from $7,741$ unique firms. In an average year, firms with non-positive net debt constitute 30.31% of all firms and account for 23.83% of total market capitalization. Table IA.5 shows that the return differential between low and high asset-growth firms remains close to zero and statistically insignificant.

The number of portfolios to sort stocks into is arguably an arbitrary choice. I therefore also conduct the independent double-sorts based on refinancing intensities and asset growth for a different number of portfolios. I keep the number of portfolios based on asset growth fixed to ensure that each portfolio contains a reasonable number of stocks. The difference between the return differential in firms with low and high refinancing intensities should increase with the number of portfolios because the difference between the average refinancing intensity in the highest and lowest portfolio increases as well. Table IA.6 shows that the return differential increases with the number of portfolios.

In the main analysis, I use independent portfolio double-sorts to analyze the relationship between asset growth and refinancing intensities. The number of stocks in each portfolio can therefore vary considerably. My sample features a large cross-section of stocks and the portfolio with the lowest number of stocks in the 5×5 sorts contains 62 stocks on average and the lowest number of stocks is 29. To mitigate the concern that the portfolios are not well-diversified, I repeat the main analysis using conditional double-sorts. At the end of each June, I first sort stocks into five

[7]Firms with zero long-term debt have $DLTT = 0$, almost zero-leverage firms have $\frac{DLC+DLTT}{AT} \leq 5\%$, and firms with non-positive net debt have $DLTT + DLC - CHE \leq 0$. Capitalized acronyms correspond to annual COMPUSTAT items.

portfolios based on refinancing intensities and then into five portfolios based on asset growth rates. The remainder of the portfolio analysis is identical to the independent double-sorts. I also perform conditional double-sorts by first sorting on asset growth and subsequently sorting on refinancing intensities. The results are qualitatively similar and I present these results in Table IA.7-IA.10.

I also consider different measures of refinancing intensities and asset growth. Almeida et al. (2012) and Gopalan et al. (2014) calculate the refinancing intensity with the ratio of debt maturing within one year to total assets. Lipson et al. (2011) show that the change in total assets, which I use to measure asset growth, largely subsumes other measures of asset growth. Nonetheless, I also consider the investment-to-asset ratio from Lyandres et al. (2008) as a further robustness check of my results[8]. Table IA.11-IA.16 show that my results are qualitatively similar with these measures but quantitatively less pronounced.

Finally, I also repeat the main analysis using Fama and MacBeth (1973) regressions. The dependent variable is either the excess stock return or the unlevered excess stock return in month $t+1$ while the independent variables are characteristics in month t. I present the time-series averages of monthly coefficient estimates from cross-sectional Fama and MacBeth (1973) regressions in Table IA.17-IA.19 in the Internet Appendix. For the cross-sectional regressions, I use either ordinary least squares estimates (equal-weighted) or weighted least squares with the market value of equity as the weighting scheme (value-weighted). The value-weighted Fama and MacBeth (1973) regressions mitigate the influence of small stocks.

Table IA.17 shows that the negative coefficient estimates on asset growth are substantially smaller with unlevered excess returns compared to (levered) excess returns. This result supports my finding that leverage explains a substantial fraction of the investment premium. In addition, Table IA.18 shows that the coefficient estimates on asset growth are statistically insignificant for zero-leverage firms. This result means that there is no investment premium for zero-leverage firms. To analyze how the investment premium depends on firms' refinancing intensities, I regress future returns on asset growth, refinancing intensities, and the interaction between asset growth and refinancing intensities. The coefficient estimates on the interaction term are negative and economically large suggesting that the investment premium is more pronounced for firms with high refinancing intensities but the coefficient estimates are statistically insignificant.

[8] At the end of June in year t, the refinancing intensity is given by $\frac{DD1_{t-1}}{AT_{t-1}}$ and the investment-to-asset ratio is $\frac{\Delta PPEGT_{t-1}+\Delta INVT_{t-1}}{AT_{t-2}}$. Capitalized acronyms correspond to annual COMPUSTAT items.

4 The Model

In this section, I develop a corporate finance model by integrating the investment option from Diamond and He (2014) into the Friewald et al. (2018) model. The purpose of the model is to study the impact of leverage and refinancing intensities on the investment premium. Friewald et al. (2018) study implications of firms' financing decisions for the cross-section of expected stock returns and do not consider investment decisions. Diamond and He (2014) do not analyze implications for expected stock returns. My contribution is to study implications of both investment and financing decisions for expected stock returns within a unified model.

4.1 Firm Fundamental

The firm has assets-in-place that generate cash flows at a rate of $X_t > 0$. The cash flows follow a geometric Brownian motion under the equivalent martingale measure $\mathbb{Q}$:

$$dX_t = \tilde{i}_t X_t dt + \sigma X_t dZ_t \tag{1}$$

where $\tilde{i}_t$ is the risk-neutral growth rate, σ is the volatility, and dZ_t is the increment of a standard Brownian motion $\{Z_t : 0 \leq t < \infty\}$ under $\mathbb{Q}$. One can show that the value of the firm's assets-in-place share their dynamics with X_t because assets-in-place denote a claim to the entire cash flow stream. I refer to the firm's cash flows and assets-in-place interchangeably in the remainder of the paper.

At each instant in time, the equity holders endogenously determine the growth rate $\tilde{i}_t$ of assets-in-place. The growth rate can take two values $\tilde{i}_t = \{0, i\}$ with $i > 0$. When $\tilde{i}_t = 0$ the firm does not invest and when $\tilde{i}_t = i$ the firm invests. The firm pays an instantaneous investment cost $\lambda i X_t dt$ when it invests. Diamond and He (2014) show that equity holders use a threshold investment strategy i.e. they invest when the current cash flow X_t exceeds an endogenous investment boundary X_i. If the firm always invests, the expected present value of the cash flow stream is:

$$\mathbb{E}_t^{\mathbb{Q}} \left[\int_t^{\infty} e^{-r(s-t)} \left(X_s - \lambda i X_s \right) \mathrm{d}s \right] = \frac{1 - \lambda i}{r - i} X_t$$

If the firm never invests, the expected present value of the cash flow stream is $\frac{X_t}{r}$. I follow Diamond and He (2014) and assume $\lambda r < 1$ to ensure that the growth option has positive net present value. When $\lambda r < 1$, a zero-leverage firm will always choose to invest because the market value of the firm with investments $\frac{1-\lambda i}{r-i} X_t$ is strictly greater than the market value of the firm without investments $\frac{X_t}{r}$. A levered firm with risky debt, however, will not always invest because of debt overhang.

4.2 Debt and Equity

The firm chooses a mix between short-term zero-coupon bonds (S) and long-term zero coupon bonds (L) at time $t = 0$ similar to Friewald et al. (2018). Each bond type $j = \{S, L\}$ has an aggregate principal value P^j and the total principal value corresponds to $P = P^S + P^L$. Each bond matures at a random point in time and the maturity event follows a Poisson occurrence with intensity ϕ^j. Each bond therefore has an expected maturity of $1/\phi^j$ years as in Cheng and Milbradt (2012), He and Xiong (2012a), and Chen et al. (2018). I assume that $\phi^S > \phi^L$ to ensure that S has a shorter expected maturity than L.

I follow Friewald et al. (2018) and assume that the firm obtains a flow of debt benefits $k\phi^j P^j$ with scaling factor $k > 0$ when it issues debt[9]. Short-term debt offers more debt benefits relative to long-term debt since $\phi^S > \phi^L$ to reflect lower fixed issuance costs, better market liquidity, and the potential to reduce agency costs and/or information asymmetries (see for example Flannery (1986), Diamond (1991), Datta et al. (2005), Brockman et al. (2010), He and Milbradt (2014), Chen et al. (2013), and Custódio et al. (2013)). Intuitively, this relative advantage of short-term debt reflects the additional benefits over and above the fact that short-term debt improves investment incentives. The firm commits to keep the aggregate principal values constant through time. This stationary debt structure implies that at each instant in time, the firm retires an expected principal amount of $\phi^S P^S + \phi^L P^L$ and issues new bonds to keep the principal values constant[10]. The newly-issued zero-coupon bonds sell at market value and have the same principal value and seniority as the retired bonds they replace.

When the market value of debt differs from the principal value, the firm incurs expected rollover losses of $\sum_j \phi^j [D^j(X_t) - P^j]$ where $D^j(X_t)$ denotes the market value of bond j[11]. Maturing debt holders receive the full principal value while equity holders finance rollover losses by issuing new equity. Debt rollover therefore features a conflict of interests between equity and debt holders. When cash flows decrease, equity holders service debt payments as long as the option value of keeping the firm alive remains positive. For some positive starting value of the cash flow process, X_0, the firm defaults when X_t reaches a lower endogenous default boundary X_B. The absolute priority rule applies and the firm loses its growth option in bankruptcy. Debt holders recover the

[9]This assumption ensures that the firm has an incentive to issue debt. The Diamond and He (2014) model features no debt benefits and instead allows the firm to choose its optimal debt maturity for a fixed (sub-optimal) amount of debt. The implications of the firm's investment and financing decisions for expected stock returns, however, remain qualitatively the same in the Diamond and He (2014) model and in the model I present.

[10]Leland (1994a), Leland and Toft (1996), and Leland (1998) likewise assume stationary debt structures.

[11]The firm always incur rollover losses with zero-coupon bonds. If the firm instead issues fixed-rate coupon bonds at par values at time $t = 0$ then the firm may face both rollover gains and losses at time $t > 0$. This feature, however, does not qualitatively affect the results and I therefore consider zero-coupon bonds to keep the model as simple as possible.

value of assets-in-place without investments proportionally to their share of the total principal i.e. proportional to P^j/P. These assumptions translate into the following value-matching conditions at X_B:

$$E(X_B) = 0, \qquad D^j(X_B) = \frac{X_B}{r}\theta^j \tag{2}$$

where $E(X_t)$ is the market value of equity, r is the risk-free rate, and θ^j is the fraction of debt j to total debt i.e. $\theta^j = P^j/P$.

The firm's investment policy introduces an additional conflict of interest between equity and debt holders. When the firm invests, the higher asset growth tends to push the firm away from the default boundary over time. Debt holders benefit from the firm's investments because debt becomes safer and hence more valuable. Equity holders pay the entire investment cost but only capture part of the value from the firm's investments. The equity holders therefore have low incentives to invest when a large share of the value from the firm's investments accrues to debt holders. Debt overhang implies a non-investment region when $X_B < X_t < X_i$ where the firm does not invest despite the fact that investment at each instant in time maximizes firm value. This non-investment region reflects that equity holders maximize the value of equity and not the value of the firm. I provide the technical details for the valuation of debt and equity in closed-form in Appendix B.

4.3 Default and Investment Boundaries

Equity holders determine the endogenous default and investment boundaries to maximize the value of equity following the inaugural debt issue. The two boundaries satisfy the following smooth pasting conditions:

$$\left.\frac{\partial E(X)}{\partial X}\right|_{X=X_B} = 0, \qquad \left.\frac{\partial E(X)}{\partial X}\right|_{X=X_i} = \lambda \tag{3}$$

These smooth pasting conditions give rise to a system of non-linear equations, which I solve numerically for the default and investment boundaries. The boundaries characterize the optimal default and investment policies for a given choice of principal values $P^j = \{P^S, P^L\}$.

4.4 Optimal Leverage and Refinancing Intensity

At time $t = 0$, the firm chooses the principal amounts of short and long-term debt to maximize the value of the firm. The optimal principal amounts P^{j*} solve the maximization problem:

$$\{P^{S*}, P^{L*}\} = \underset{P^S, P^L}{\arg\max} \big(E(X_0) + D(X_0)\big) \tag{4}$$

subject to the constraints from equation (3) and the requirements that $D^j(X_B) < P^j/(1 + r/\phi^j)$ for $j = \{S, L\}$. This requirement ensures that there is an interior optimum refinancing intensity. Intuitively, the requirement states that the firm cannot issue risk-free debt which would eliminate the debt overhang problem. The optimal principal amounts are not available in closed-form and must be determined numerically. By choosing the principal amounts of short and long-term debt, the firm jointly chooses optimal leverage and refinancing intensity.

Consistent with the measures of leverage and refinancing intensities from the empirical analysis above, I define the firm's leverage ratio $L(X_t)$ as:

$$L(X_t) = \frac{P}{P + E(X_t)} \tag{5}$$

and I measure the firm's refinancing intensity by the ratio of short-term debt principal to total debt principal:

$$\theta^S = \frac{P^S}{P^S + P^L} \tag{6}$$

4.5 Expected Stock Return

I derive the value of debt and equity from the $\mathbb{Q}$–dynamics of the cash flow process X_t in Appendix B. The calculation of the expected stock return requires the $\mathbb{P}$–dynamics of X_t. For simplicity, I assume a constant risk premium ξ and remain silent on the structure of the pricing kernel that determines the value of the underlying cash flow process in equation (1). The expected stock return is therefore given by:

$$\mathbb{E}_t^{\mathbb{P}}[R_t] = r + \beta_t \xi \tag{7}$$

where the conditional equity beta is:

$$\beta_t = \frac{d\log E(X_t)}{dX_t}$$

5 Model Predictions

In this section, I parameterize the model and explain the trade-off between investment incentives, debt benefits, and rollover risk that determines optimal leverage and refinancing intensity. Next, I consider implications of investment and financing decisions for the cross-section of expected stock returns.

5.1 Optimal Leverage and Refinancing Intensity

I use the parameter values from Diamond and He (2014) and Friewald et al. (2018) and set $X_0 = 1$, $r = 10\%$, $\sigma = 15\%$, $i = 7\%$, and $k = 1\%$. At time $t = 0$, the firm determines the optimal mix between a short-term zero-coupon bond with one-year expected maturity ($\phi^S = 1$) and a long-term zero-coupon bond with ten-year expected maturity ($\phi^L = 0.1$) to maximize firm value. For a given level of the investment cost λ, I consider the firm's optimal choices of leverage and refinancing intensity.

[INSERT FIGURE 1]

Panel A in Figure 1 shows optimal leverage as a function of the investment cost λ[12]. This relationship reflects the firm's trade-off between investment incentives and debt benefits. On the one hand, the value of debt benefits increases as the firm issues more debt. On the other hand, the value of the growth option decreases with the amount of debt because debt distorts investment incentives. As λ increases, it becomes more expensive to invest and the value of the growth option decreases. In turn, the firm has greater incentive to exploit debt benefits compared to improving investment incentives. The optimal leverage therefore increases with λ.

Panel B in Figure 1 displays the optimal principal values of short-term debt P^S and long-term debt P^L as a function of λ. Consistent with the findings on optimal leverage in Panel A, the total amount of debt $P = P^S + P^L$ increases with λ. The figure also shows that the amount of long-term debt increases with λ whereas the amount of short-term debt decreases. This finding has implications for the firm's refinancing intensity.

Panel C in Figure 1 displays the optimal refinancing intensity θ^S as a function of λ. This relationship reflects the firm's trade-off between rollover risk and investment incentives. On the one hand, the firm improves investment incentives by using more short-term debt relative to long-term debt. This feature comes from the fact that the value of short-term debt is less sensitive to the firm's assets-in-place compared to long-term debt. Short-term debt holders therefore share less of the benefits from the firm's investments with equity holders when assets-in-place increase. On the other hand, the firm's rollover risk increases with the amount of short-term debt relative to long-term debt. Short-term debt holders share fewer losses with equity holders when assets-in-place decrease and the firm therefore defaults earlier. Since the value of the growth option decreases

[12] Friewald et al. (2018) emphasize that it is challenging to match the level of several measures from their model (most importantly leverage ratios) with corresponding measures in the real world. I face the same challenge because I extend their model by incorporating the investment option from Diamond and He (2014). Similar to Friewald et al. (2018), the purpose of my theoretical analysis is to study the structural relationships between key variables in a stylized model and to consider implications for expected stock returns. I refer to Strebulaev and Whited (2012) for a more elaborate discussion on the general challenges corporate finance models have in terms of matching real-world quantities.

with λ, the firm has greater incentive to reduce rollover risk compared to improving investment incentives the higher the value of λ. For this reason, the optimal refinancing intensity decreases with λ.

Panel D in Figure 1 depicts the investment and default boundaries as functions of λ. The investment boundary X_i lies above the default boundary X_B when $\lambda > 0$. As λ increases, it becomes more expensive to invest and the firm endogenously chooses higher leverage and lower refinancing intensity. This financing choice impairs investment incentives and X_i increases. Since the value of the growth option decreases with λ, equity holders become less willing to keep the firm alive when assets-in-place deteriorate and this tends to increase X_B. The fact that the firm endogenously chooses higher leverage also tends to increase X_B. The lower refinancing intensity, however, reduces rollover risk and tends to decrease X_B. Nonetheless, the two former effects dominate the latter and X_B increases with λ. In the limiting case where $\lambda \to 0$ then $X_i \to X_B$ because the firm always invests when the investment cost approaches zero. In this case, the model reduces to Friewald et al. (2018) as a special case.

5.2 Expected Stock Returns

The previous section considered the firm's optimal financing decisions at time $t = 0$. At time $t > 0$ most firms deviate from their optimal capital structures (see e.g. Leary and Roberts (2005) and Strebulaev (2007)). In this section, I therefore consider implications of firms' investment and financing decisions for the cross-section of expected stock returns at time $t > 0$. First, I explore the relationship between investments and expected stock returns which gives rise to a return differential consistent with the investment premium. Second, I investigate the return differential among zero-leverage firms. Third, I analyze how the return differential depends on firms' refinancing intensities.

Investments and Expected Stock Returns

I set the asset risk-premium to $\xi = 1\%$ and analyze the relationship between the firm's investment policy and expected stock returns at time $t > 0$. The model has a constant risk-free rate and I refer to the expected excess stock return as the expected stock return below. Consider a single firm with $\lambda = 9.5$ which chooses its optimal leverage and refinancing intensity at time $t = 0$. The firm's refinancing intensity remains fixed over time but leverage does not. At time $t > 0$, the firm's current leverage deviates from its optimal leverage whenever $X_t \neq X_0$. The firm invests when $X_t \geq X_i = 0.67$ and defaults when $X_t = X_B = 0.61$. Debt overhang makes equity holders unwilling to invest when $X_B < X_t < X_i$ even though the growth option has positive NPV.

[INSERT FIGURE 2]

Panel A in Figure 2 shows the expected stock return as a function of the firm's assets-in-place X_t. Consider two identical firms, A and B, with the same value of X_t. Suppose Firm A experiences a negative shock to assets and Firm B experiences a positive shock. Since the principal amount of debt P remains fixed over time, Firm A's current leverage increases whereas Firm B's current leverage decreases. Panel B in Figure 2 shows that the expected stock return increases with current leverage because the conditional equity beta increases. After the shock to assets-in-place, Firm A has a higher expected stock return, whereas Firm B has a lower expected stock return. If we construct a portfolio that is long Firm A with low asset growth and short Firm B with high asset growth, the return differential is positive and consistent with the investment premium.

This mechanism, however, does not imply an investment premium in the cross-section. To see why, consider two firms C and D with different X_t and all other parameters identical. Suppose Firm C has a high X_t and Firm D has a low X_t. Now, Firm C experiences a negative shock to assets and Firm D experiences a positive shock. Firm C moves to a higher expected stock return but it remains a low level. Similarly, Firm D moves to a lower expected stock return but it remains at a high level. In this case, if we construct a portfolio that is long Firm C and short Firm D, the return differential is negative and inconsistent with the investment premium.

In contrast, debt overhang gives rise to an optimal investment policy with implications for the cross-section of stock returns. Equity holders have low incentives to invest when a large share of the value from the firm's investments accrues to debt holders. As the firm's assets-in-place decrease and debt becomes more risky, the sensitivities of the debt claims to assets-in-place increase. Debt holders therefore capture an increasing share of the value from the firm's investments, the lower the assets-in-place. This feature entails that equity holders do not invest when the firm's assets-in-place become sufficiently low because their share of the value from the firm's investments is too low to justify paying the investment cost.

The solid lines in Figure 2 denote the non-investment region where the asset growth rate is $\tilde{i}_t = 0\%$ and the dotted lines denote the investment region where $\tilde{i}_t = 7\%$. Firms with high asset growth are in the investment region where leverage and the expected stock return is low, whereas firms with low asset growth are in the non-investment region where leverage and the expected stock return is high[13]. If we construct a portfolio that is long firms with low asset growth and short firms with high asset growth, the return differential is positive and consistent with the investment

[13] Since asset volatility is constant in the model, leverage measures credit risk. Empirically, firms have different asset volatilities and leverage may therefore be an insufficient measure of credit risk. For this reason, I also estimate one-year default probabilities using the Merton (1974) model as in Vassalou and Xing (2004) which takes into account both leverage and asset volatilities. In the 2×3 independent double-sorts on size and asset growth from Table 2, the average one-year default probabilities are is 2.25%, 0.91%, and 0.81% for the low, medium, and high asset-growth portfolios, respectively. The difference of 1.44 percentage points between the low and high asset-growth portfolio is highly statistically significant (t-stat 26.87). This finding that firms with low asset growth have higher credit risk than firms with high asset growth is also consistent with the model.

premium. This predictions rests on a negative relationship between asset growth and leverage consistent with my empirical findings and Lang et al. (1996).

The Investment Premium and Zero-Leverage Firms

The previous section shows that debt overhang removes the incentive to invest for high leverage firms with risky debt. If firms do not suffer from debt overhang, they should always invest because the growth option has positive NPV. In the model, firms cannot issue risk-free debt and thereby eliminate the debt overhang problem. There are two situations, however, where firms do not suffer from debt overhang.

First, the incentives of debt and equity holders remain aligned when the investment cost $\lambda = 0$ and the firm therefore always invest. Second, when there are no debt benefits $k = 0$ the firm has no incentive to issue debt because doing so would impair investment incentives and reduce firm value. This financing decision has implications for expected stock returns. Zero-leverage firms have no debt overhang and they should always invest. All zero-leverage firms therefore choose the same optimal investment policy and there is no cross-sectional relationship between asset growth and expected stock returns. The reason is that zero-leverage firms have the same $\beta_t = 1$ and the same expected growth rate $\tilde{i}_t = i$[14]. The model therefore predicts that there is no return differential between zero-leverage firms with low and high asset growth consistent with my empirical results.

The Investment Premium and Refinancing Intensities

In this section, I focus on another dimension of firms' financing decisions and the implications for expected stock returns. I consider a cross-section of firms with different levels of investment costs λ and therefore also with different refinancing intensities. At time $t = 0$, all firms choose their optimal leverage and refinancing intensities. I then turn to analyze the relationship between investments and expected stock returns at time $t > 0$ for different levels of refinancing intensities.

Since firms invest when they have safer debt and do not invest when they have riskier debt, a firm in the investment region has lower current leverage than a firm in the non-investment region for a given refinancing intensity. I therefore compare firms at time $t > 0$ in the investment region with a fixed leverage ratio to firms in the non-investment region with a higher fixed leverage ratio[15].

[14] Note that there will be cross-sectional differences in realized asset growth rates among zero-leverage firms. It is only in expectation that the asset growth rate is the same for all zero-leverage firms.

[15] I have to consider extreme leverage ratios because the non-investment region is small for low values of λ cf. the shaded area in Panel D from Figure 1. Since the firm's leverage ratio equals one at the default boundary X_B, the leverage ratio is also high at the investment boundary X_i when X_B and X_i remain close to each other. When I compare firms with different λ but with the same current leverage, I therefore have to choose leverage ratios such that all firms remain in either the investment or the non-investment region respectively. If I change the investment cost to $\lambda(X_t; \rho) = \rho + \lambda i X_t$ where $\rho > 0$ is a fixed flow cost of investment similar to the extension in Diamond and He (2014) then the non-investment region becomes larger and I can compare firms with less extreme leverage ratios.

Panel A in Figure 3 shows that expected stock returns increase with refinancing intensities θ^S for both high and low asset-growth firms. This finding reflects that equity holders require a higher expected stock return for firms with higher rollover risk.

[INSERT FIGURE 3]

Panel A also shows that expected stock returns for low asset-growth firms increase faster with θ^S compared to high asset-growth firms. To see this relationship more clearly, Panel B plots the stock return differential of low asset-growth firms relative to high asset-growth firms as a function of θ^S. The stock return differential increases monotonically with firms' refinancing intensities and reflects an interaction effect between refinancing intensities and leverage. Expected stock returns increase faster with refinancing intensities for firms with high leverage relative to firms with low leverage because short-term debt amplifies rollover risk. Since firms invest when they have low leverage and do not invest when they have high leverage, this interaction effect predicts that the return differential between low and high asset-growth firms increases with firms' refinancing intensities. My empirical results support this prediction.

6 Conclusion

In this paper, I document that the investment premium (1) reflects financial leverage, (2) does not exist among zero-leverage firms, and (3) increases with firms' refinancing intensities. This new evidence challenges prominent explanations of the investment premium. On the one hand, rational theories such as the q-theory of investment, real option models, and the dividend discount model suggest that the investment premium reflects firms' investment decisions. On the other hand, behavioral theories argue that the investment premium reflects mispricing as investors do not properly incorporate information on firms' investment decisions into asset prices. Both of these theories predict a positive return differential between zero-leverage firms with low and high asset growth. They also cannot explain why the return differential increases with firms' refinancing intensities. My empirical results are therefore inconsistent with these theories.

My empirical results show that leverage and refinancing intensities explain a significant fraction of the investment premium. These findings suggest that the investment premium reflects firms' financing decisions. I therefore develop a corporate finance model in which firms make both optimal investment and financing decisions. Specifically, I integrate the investment option from Diamond and He (2014) into the Friewald et al. (2018) model. The model shows that the investment premium reflects both leverage and refinancing intensities consistent with my empirical findings.

The predictions from the model remain qualitatively the same and I therefore focus on the simplest case with $\rho = 0$.

Taken together, my results offer a novel perspective on the economic interpretation of the investment premium and shed new light on the asset pricing implications of firms' investment and financing decisions. I focus on the effects of leverage and refinancing intensities but the investment premium may also be related to other financing decisions such as the choice of debt covenants. For example, Billet et al. (2007) study the impact of growth options on the joint choices of leverage, debt maturity, and covenant protection while Helwege et al. (2017) analyze the relationship between covenants and expected stock returns. The impact of debt covenants on the investment premium remains an interesting avenue for future research.

Appendices

A Definition of Variables

This section contains the detailed variable descriptions. The capitalized acronyms correspond to annual COMPUSTAT data items and subscripts refer to the calendar time.

Main Variables

AG_t Asset growth at the end of June in year t is:

$$AG_t = \frac{AT_{t-1} - AT_{t-2}}{AT_{t-2}}$$

where AT_{t-1} denotes "Assets - Total" at the end of the fiscal year ending in $t-1$.

RI_t Refinancing intensity at the end of June in year t is:

$$RI_t = \frac{DD1_{t-1}}{DLC_{t-1} + DLTT_{t-1}}$$

where $DD1_{t-1}$ is "Long-Term Debt Due in One Year", DLC_{t-1} is "Debt in Current Liabilities - Total", and $DLTT_{t-1}$ is "Long-Term Debt - Total" at the end of the fiscal year ending in $t-1$.

ME_t Size is measured by the market value of equity at the end of June in year t:

$$ME_t = abs(PRC_t) * SHROUT_t$$

where PRC_t is the stock price at the end of June in year t and $SHROUT_t$ is the number of shares outstanding from CRSP.

LEV_t Leverage at the end of June in year t is:

$$LEV_t = \frac{DLC_{t-1} + DLTT_{t-1}}{DLC_{t-1} + DLTT_{t-1} + ME_{t-1}}$$

where DLC_{t-1} is "Debt in Current Liabilities - Total", $DLTT_{t-1}$ is "Long-Term Debt - Total", and ME_{t-1} is the market value of equity at the end of December in year $t-1$ from CRSP.

Measures of Investment Frictions

AT_t	Total assets at the end of June in year t is given by AT_{t-1} i.e. "Assets - Total" from the fiscal year ending in year $t-1$.
AGE_t	Age is the number of years a firm has appeared in COMPUSTAT at the end of the previous fiscal year.
PAY_t	Payout at the end of June in year t is the tercile ranking of the payout ratio: $$Payout\ Ratio_t = \frac{PRSTKC_{t-1} + DVP_{t-1} + DVC_{t-1}}{OIBDP_{t-1}}$$ where $PRSTKC_{t-1}$ is "Purchase of Common and Preferred Stock", DVP_{t-1} is "Dividends - Preferred/Preference", DVC_{t-1} is "Dividends Common/Ordinary", and $OIBDP_{t-1}$ is "Operating Income Before Depreciation" at the end of the fiscal year ending in $t-1$. For firms with non-positive $OIBDP_{t-1}$, I include those with positive distributions in the high payout tercile and those with zero distributions in the low payout tercile.

Measures of Limits-to-Arbitrage

$IVOL_t$	Idiosyncratic stock volatility is estimated from daily stock returns over the last year ending in June in year t. I run time-series regressions of each stock's daily realized returns on market returns obtained from Kenneth French's website and use the standard deviation of the residuals to measure idiosyncratic volatility. I require at least 200 observations in the estimation window.
PRC_t	Price is the stock price at the end of June in year t from CRSP.
BA_t	Bid-ask spread is the time-series average of daily stock bid-ask spreads over the last year ending in June in year t. I calculate daily bid-ask spreads as : $$Bid\text{-}Ask\ Spread_t = \frac{ASK_t - BID_t}{\frac{1}{2}(ASK_t + BID_t)}$$ where ASK_t is the end-of-day ask price and BID_t is the end-of-day bid price from CRSP.
AM_t	Amihud (2002) illiquidity measure is the time-series average of absolute daily returns divided by daily dollar trading volume over the past year ending in June in year t from CRSP.

Measures of Limits-to-Arbitrage (continued)

$DVOL_t$	Dollar volume is the time-series average of daily trading volumes calculated as stock price times trading volume over the past year ending in June in year t from CRSP.

B Valuations of Debt and Equity

In this appendix, I derive the value of debt and equity. For simplicity, I omit time subscripts such that $X = X_t$ throughout the derivations.

Debt Value

The market value of debt, $D^j(X)$, for $j = \{S, L\}$ is the solution to the ordinary differential equation (ODE):

$$rD^j = \frac{1}{2}\sigma^2 X^2 D^j_{XX} + \tilde{i} X D^j_X + \phi^j[P^j - D^j] \tag{B.1}$$

where I write $D^j = D^j(X)$ and use subscripts to denote partial derivatives. The equation states that the required return on the left-hand side must equal the expected return on the right-hand side. The first two terms is the expected change in the value of debt when X fluctuates where $\tilde{i}$ is the asset growth rate determined by equity holders which depends on X. The third term is the change in debt value from retiring maturing debt at principal value and issuing new debt at market value.

Diamond and He (2014) show that equity holders follow a threshold investment strategy: the firm invests when $X \geq X_i$ and it does not invest when $X_B < X < X_i$. The general solution to equation (B.1) is therefore given by:

$$D^j(X) = \begin{cases} d^j_1 X^{-\gamma^j_1} + p^j, & X \geq X_i \\ d^j_2 X^{-\gamma^j_2} + d^j_3 X^{\delta^j_2} + p^j, & X_B < X < X_i \end{cases} \tag{B.2}$$

where $p^j = \frac{P^j}{1+r/\phi^j}$ is the default-free debt value and the exponents are given by:

$$\begin{aligned} \gamma^j_1 &= \frac{(i - \frac{1}{2}\sigma^2) + \sqrt{(i - \frac{1}{2}\sigma^2)^2 + 2\sigma^2(r + \phi^j)}}{\sigma^2} > 0 \\ \gamma^j_2 &= \frac{-\frac{1}{2}\sigma^2 + \sqrt{\frac{1}{4}\sigma^4 + 2\sigma^2(r + \phi^j)}}{\sigma^2} > 0 \\ \delta^j_2 &= \frac{\frac{1}{2}\sigma^2 + \sqrt{\frac{1}{4}\sigma^4 + 2\sigma^2(r + \phi^j)}}{\sigma^2} > 1 \end{aligned} \tag{B.3}$$

The value-matching condition at X_B together with the continuity and differentiability conditions at X_i determine the three coefficients d_1^j, d_2^j and d_3^j:

$$\begin{aligned} D^j(X_B) &= \frac{X_B}{r}\theta^j \\ \lim_{X\uparrow X_i} D^j(X) &= \lim_{X\downarrow X_i} D^j(X) \\ \lim_{X\uparrow X_i} D_X^j(X) &= \lim_{X\downarrow X_i} D_X^j(X) \end{aligned} \tag{B.4}$$

which are then given by:

$$\begin{aligned} d_1^j &= d_2^j X_i^{\gamma_1^j-\gamma_2^j} + d_3^j X_i^{\gamma_1^j+\delta_2^j} \\ d_2^j &= d_3^j \frac{\gamma_1^j+\delta_2^j}{\gamma_2^j-\gamma_1^j} X_i^{\gamma_2^j+\delta_2^j} \\ d_3^j &= \frac{\theta^j X_B/r - p^j}{\frac{\gamma_1^j+\delta_2^j}{\gamma_2^j-\gamma_1^j} X_i^{\gamma_2^j+\delta_2^j} X_B^{-\gamma_2^j} + X_B^{\delta_2^j}} \end{aligned} \tag{B.5}$$

Equity Value

The market value of equity, $E(X)$, satisfies the equation:

$$rE = \max_{\tilde{i}\in\{0,i\}} \frac{1}{2}\sigma^2 X^2 E_{XX} + \tilde{i}XE_X + X - \lambda\tilde{i}X + k\sum_j \phi^j P^j - \sum_j \phi^j[P^j - D^j] \tag{B.6}$$

where I have omitted the optimal default policy. The equation states that the required return on the left-hand side must equal the expected return on the right-hand side given equity holders' optimal investment strategy. The first two terms is the expected change in the value of equity when X fluctuates. The third and fourth terms are the cash flows to equity holders per unit time from the firm's cash flow minus the investment cost. The fifth term is the debt benefits and the sixth term is debt rollover costs.

It is challenging to solve equation (B.6) directly, because it depends on the debt values $D^j(X)$. Instead, I value the equity claim as the residual between the levered firm value and debt value. The general solution to the unlevered firm value, $V(X)$, is given by:

$$V(X) = \begin{cases} v_1 X^{-\gamma_3} + \dfrac{X(1-\lambda i)}{r-i}, & X \geq X_i \\ v_2 X^{-\gamma_4} + v_3 X^{\delta_4} + \dfrac{X}{r}, & X_B < X < X_i \end{cases} \tag{B.7}$$

where the expected present value of the earnings stream is $\frac{X(1-\lambda i)}{r-i}$ when the firm always invests and $\frac{X}{r}$ when the firm never invests. The exponents are given by:

$$\begin{aligned}
\gamma_3 &= \frac{(i-\frac{1}{2}\sigma^2)+\sqrt{(i-\frac{1}{2}\sigma^2)^2+2\sigma^2 r}}{\sigma^2} > 0 \\
\gamma_4 &= \frac{-\frac{1}{2}\sigma^2+\sqrt{\frac{1}{4}\sigma^4+2\sigma^2 r}}{\sigma^2} > 0 \\
\delta_4 &= \frac{\frac{1}{2}\sigma^2+\sqrt{\frac{1}{4}\sigma^4+2\sigma^2 r}}{\sigma^2} > 1
\end{aligned} \tag{B.8}$$

The value-matching condition at X_B together with the continuity and differentiability conditions at X_i determine the coefficients v_1, v_2 and v_3:

$$\begin{aligned}
V(X_B) &= \frac{X_B}{r} \\
\lim_{X\uparrow X_i} V(X) &= \lim_{X\downarrow X_i} V(X) \\
\lim_{X\uparrow X_i} V_X(X) &= \lim_{X\downarrow X_i} V_X(X)
\end{aligned} \tag{B.9}$$

which are then given by:

$$\begin{aligned}
v_1 &= -\frac{i(1-\lambda r)}{r(r-i)} X_i^{1+\gamma_3} - v_3 X_B^{\gamma_4+\delta_4} X_i^{\gamma_3-\gamma_4} + v_3 X_i^{\gamma_3+\delta_4} \\
v_2 &= -v_3 X_B^{\gamma_4+\delta_4} \\
v_3 &= \frac{(1+\gamma_3)\frac{i(1-\lambda r)}{r(r-i)} X_i^{\gamma_4+1}}{(\gamma_3+\delta_4)X_i^{\delta_4+\gamma_4} - (\gamma_3-\gamma_4)X_B^{\gamma_4+\delta_4}}
\end{aligned} \tag{B.10}$$

The general solution to the value of debt benefits, $B(X)$, is given by:

$$B(X) = \begin{cases} b_1 X^{-\gamma_3} + k\sum_j \frac{\phi^j P^j}{r}, & X \geq X_i \\ b_2 X^{-\gamma_4} + b_3 X^{\delta_4} + k\sum_j \frac{\phi^j P^j}{r}, & X_B < X < X_i \end{cases} \tag{B.11}$$

where $k\sum_j \frac{\phi^j P^j}{r}$ is the expected present value of receiving the debt benefits in perpetuity. The value-matching condition at X_B together with the continuity and differentiability conditions at X_i

determine the coefficients b_1, b_2 and b_3:

$$
\begin{aligned}
B(X_B) &= 0 \\
\lim_{X \uparrow X_i} B(X) &= \lim_{X \downarrow X_i} B(X) \\
\lim_{X \uparrow X_i} B_X(X) &= \lim_{X \downarrow X_i} B_X(X)
\end{aligned}
\tag{B.12}
$$

which are then given by:

$$
\begin{aligned}
b_1 &= -b_3 X_B^{\gamma_4+\delta_4} X_i^{\gamma_3-\gamma_4} - k \sum_j \frac{\phi^j P^j}{r} X_B^{\gamma_4} X_i^{\gamma_3-\gamma_4} + b_3 X_i^{\gamma_3+\delta_4} \\
b_2 &= -b_3 X_B^{\gamma_4+\delta_4} - k \sum_j \frac{\phi^j P^j}{r} X_B^{\gamma_4} \\
b_3 &= \frac{(\gamma_3-\gamma_4) k \sum_j \frac{\phi^j P^j}{r} X_B^{\gamma_4}}{(\gamma_3+\delta_4) X_i^{\delta_4+\gamma_4} - (\gamma_3-\gamma_4) X_B^{\gamma_4+\delta_4}}
\end{aligned}
\tag{B.13}
$$

Given the unlevered firm value from equation (B.7), the value of debt benefits from equation (B.11), and the debt values from equation (B.2), the equity value is the residual:

$$
E(X) = V(X) + B(X) - \sum_j D^j(X) \tag{B.14}
$$

Table 1: Summary Statistics and Correlations

This table shows summary statistics and correlations for the variables I use in the main empirical analysis. Panel A reports time-series averages of the cross-sectional mean, standard deviation, 25%–quantile, median, and 75%–quantile of monthly excess returns, annual asset growth rates (AG), refinancing intensities (RI), and leverage (LEV) in percent. I calculate AG as the change in total assets from the fiscal year ending in $t-2$ to the fiscal year ending in $t-1$ divided by total assets from $t-2$. RI is the ratio of debt maturing within one year to total debt in $t-1$. LEV is the ratio of total debt to the sum of total debt and the market value of equity at the end of December in $t-1$. ME is the market value of equity in millions of USD measured at the end of June in year t. Before I calculate summary statistics, I winsorize asset growth rates each month at the 1st and 99th percentiles. Panel B presents time-series averages of the monthly cross-sectional Spearman rank correlations. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999).

Panel A: Summary Statistics

	Mean	SD	Q25	Median	Q75
Excess return (RET)	0.94	16.27	-7.04	-0.26	7.05
Asset growth rate (AG)	18.54	47.70	-1.99	7.70	22.00
Refinancing intensity (RI)	13.27	19.18	1.56	5.73	16.13
Leverage (LEV)	25.45	23.10	5.59	19.75	40.07
Size (ME)	1,753	8,492	44	177	723

Panel B: Spearman Rank Correlations

	RET	AG	RI	LEV	ME
Excess return (RET)	1.00				
Asset growth rate (AG)	0.00	1.00			
Refinancing intensity (RI)	-0.01	-0.06	1.00		
Leverage (LEV)	0.00	-0.14	-0.17	1.00	
Size (ME)	0.05	0.21	-0.22	-0.08	1.00

Table 2: Portfolios Independently Sorted by Size and Asset Growth

At the end of each June, I independently double-sort stocks into two portfolios based on size (ME) and into three portfolios based on asset growth rates (AG) using NYSE breakpoints. This procedure generates a cross-section of $2 \times 3 = 6$ portfolios. For both small and big firms, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B and C show value-weighted average asset growth rates and leverage ratios in percent. Panel D presents monthly value-weighted means of unlevered excess returns in percentage points. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1-L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	2	High AG	Low-High AG	t-stat
			Panel A: Excess Returns		
Small	0.94	0.97	0.53	0.41	(4.87)
Big	0.78	0.63	0.54	0.24	(1.79)
Average	0.86	0.80	0.54	0.32	(3.63)
			Panel B: Asset Growth		
Small	-8.63	7.48	53.11	-61.74	(-59.23)
Big	-4.08	7.54	37.62	-41.71	(-53.82)
Average	-6.35	7.51	45.37	-51.72	(-59.68)
			Panel C: Leverage		
Small	30.22	23.88	20.01	10.21	(53.92)
Big	25.80	19.44	15.41	10.38	(42.10)
Average	28.01	21.66	17.71	10.29	(54.85)
			Panel D: Unlevered Excess Returns		
Small	0.62	0.73	0.42	0.21	(2.76)
Big	0.55	0.50	0.45	0.10	(0.82)
Average	0.59	0.62	0.43	0.15	(1.86)

Table 3: Portfolios of Zero-Leverage Firms Independently Sorted by Size and Asset Growth

At the end of each June, I independently double-sort zero-leverage firms into two portfolios based on size (ME) and into two portfolios based on asset growth rates (AG) using NYSE breakpoints. This procedure generates a cross-section of $2 \times 2 = 4$ portfolios. For both small and big firms, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B shows value-weighted asset growth rates in percent. Panel C presents the average number of stocks in each portfolio and Panel D shows the minimum number of stocks in each portfolio. I define firm i as zero-leverage if in both years $t-2$ and $t-1$ the outstanding amounts of both short-term debt (DLC) and long-term debt ($DLTT$) equal zero. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	High AG	Low-High AG	t-stat
		Panel A: Excess Returns		
Small	0.80	0.67	0.12	(0.84)
Big	0.44	0.77	-0.34	(-1.42)
Average	0.62	0.72	-0.11	(-0.72)
		Panel B: Asset Growth		
Small	-3.69	45.11	-48.80	(-46.29)
Big	2.10	37.44	-35.34	(-37.64)
Average	-0.80	41.27	-42.07	(-45.87)
		Panel C: Average Number of Stocks		
Small	141	100		
Big	18	40		
		Panel D: Minimum Number of Stocks		
Small	27	15		
Big	3	6		

Table 4: Portfolios Independently Sorted by Refinancing Intensitites and Asset Growth

At the end of each June, I independently double-sort stocks into five portfolios based on refinancing intensities (RI) and into five portfolios based on asset growth rates (AG) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. In each asset-growth quintile, I construct a High-Low RI portfolio that buys the High RI portfolio and sells the Low RI portfolio. I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B shows value-weighted average leverage ratios in percent. Panel C presents monthly value-weighted means of unlevered excess returns in percentage points. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	2	3	4	High AG	Low-High AG	t-stat
				Panel A: Excess Returns			
Low RI	0.70	0.81	0.76	0.79	0.57	0.12	(0.62)
2	0.90	0.81	0.65	0.70	0.47	0.43	(2.27)
3	0.76	0.80	0.75	0.50	0.31	0.45	(2.52)
4	0.87	0.68	0.56	0.72	0.36	0.51	(3.16)
High RI	1.11	0.77	0.77	0.66	0.46	0.64	(3.46)
High-Low RI	0.41	-0.04	0.01	-0.12	-0.11	0.52	(2.60)
t-stat	(2.62)	(-0.28)	(0.08)	(-0.81)	(-0.70)		
				Panel B: Leverage			
Low RI	26.97	20.60	18.38	15.49	14.84	12.13	(37.04)
2	31.52	25.87	20.86	18.31	18.43	13.09	(30.61)
3	30.06	25.10	21.18	17.81	22.40	7.66	(16.50)
4	33.95	25.69	21.88	18.88	20.82	13.13	(27.02)
High RI	28.97	21.57	19.70	15.13	11.85	17.11	(41.05)
High-Low RI	2.00	0.97	1.32	-0.36	-2.98	4.98	(12.27)
t-stat	(4.67)	(2.63)	(2.28)	(-0.93)	(-12.76)		
				Panel C: Unlevered Excess Returns			
Low RI	0.46	0.62	0.62	0.66	0.47	-0.01	(-0.08)
2	0.58	0.59	0.50	0.56	0.38	0.19	(1.21)
3	0.51	0.57	0.57	0.42	0.18	0.32	(2.13)
4	0.56	0.49	0.41	0.60	0.26	0.30	(2.24)
High RI	0.72	0.59	0.58	0.56	0.40	0.32	(1.87)
High-Low RI	0.26	-0.03	-0.04	-0.10	-0.07	0.33	(1.93)
t-stat	(2.05)	(-0.22)	(-0.30)	(-0.75)	(-0.51)		

Table 5: Long-Short Portfolios Independently Sorted by Refinancing Intensitites and Asset Growth

At the end of each June, I independently double-sort stocks into five portfolios based on refinancing intensities (RI) and into five portfolios based on asset growth rates (AG) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. For each of these five long-short portfolios, I calculate monthly value-weighted means in percentage points of alpha estimates from regressing excess returns on the market (MKT), the three Fama-French factors (MKT, SMB, HML), the four factors including momentum (MKT, SMB, HML, UMD), and the five Fama-French factors (MKT, SMB, HML, RMW, CMA). I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents the results for risk-adjusted levered returns and Panel B shows the results for risk-adjusted unlevered returns. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, *** when $p < 0.01$, and t-statistics are in parenthesis.

	CAPM α	3-factor α	4-factor α	5-factor α
	Panel A: Risk-Adjusted Returns			
Low RI	0.19	-0.14	-0.24	-0.47***
	(0.96)	(-0.81)	(-1.33)	(-2.91)
2	0.52***	0.19	0.14	-0.16
	(2.75)	(1.12)	(0.79)	(-1.05)
3	0.51***	0.33*	0.28	0.19
	(2.91)	(1.91)	(1.60)	(1.15)
4	0.59***	0.38**	0.46***	0.21
	(3.70)	(2.55)	(3.05)	(1.43)
High RI	0.77***	0.42***	0.37**	0.05
	(4.21)	(2.63)	(2.31)	(0.33)
High-Low RI	0.58***	0.56***	0.61***	0.52**
	(2.88)	(2.77)	(2.97)	(2.49)
	Panel B: Risk-Adjusted Unlevered Returns			
Low RI	0.13	-0.15	-0.24	-0.43***
	(0.77)	(-0.97)	(-1.55)	(-3.15)
2	0.35**	0.11	0.06	-0.17
	(2.27)	(0.75)	(0.44)	(-1.29)
3	0.44***	0.31**	0.24	0.20
	(2.97)	(2.12)	(1.61)	(1.42)
4	0.44***	0.29**	0.34***	0.17
	(3.50)	(2.44)	(2.82)	(1.43)
High RI	0.53***	0.25*	0.21	-0.06
	(3.47)	(1.85)	(1.57)	(-0.48)
High-Low RI	0.41**	0.39**	0.45***	0.38**
	(2.39)	(2.30)	(2.59)	(2.14)

Table 6: Correlations between Refinancing Intensitites, Investment Frictions, and Limits-to-Arbitrage

This table reports time-series averages of Spearman rank correlations at each June between refinancing intensities, measures of investment frictions, and measures of limits-to-arbitrage. Refinancing intensity (RI) is the ratio of debt maturing within one year to total debt. Measures of investment frictions include total assets (AT), age (AGE), and payout tercile (PAY). Measures of limits-to-arbitrage include idiosyncratic volatility ($IVOL$), stock price (PRC), bid-ask spread (BA), Amihud (2002) illiquidity measure (AM), and dollar volume ($DVOL$). I explain the detailed construction of each variable in Appendix A. Before I calculate correlations, I winsorize AT, $IVOL$, BA, and AM each June at the 1st and 99th percentiles. The sample period is from June 1970 to June 2015 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). Correlations involving bid-ask spreads cover the sample period from June 1983 to June 2016 because bid and ask quotes are not available in CRSP before November 1982.

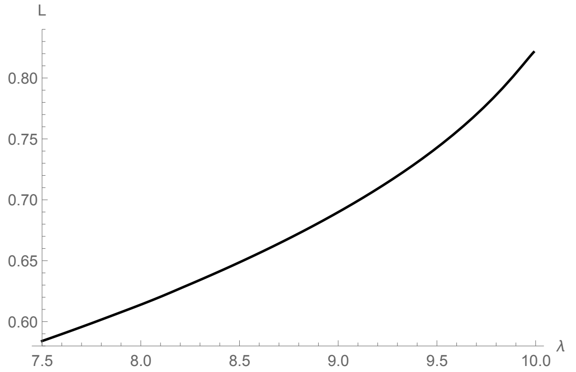
	RI	AT	AGE	PAY	$IVOL$	PRC	BA	AM	$DVOL$
Refinancing intensity (RI)	1.00								
Total assets (AT)	-0.27	1.00							
Age (AGE)	-0.13	0.46	1.00						
Payout tercile (PAY)	-0.08	0.17	0.21	1.00					
Idiosyncratic vol. ($IVOL$)	0.18	-0.62	-0.42	-0.25	1.00				
Stock price (PRC)	-0.18	0.69	0.37	0.18	-0.74	1.00			
Bid-ask spread (BA)	0.15	-0.71	-0.17	-0.14	0.69	-0.77	1.00		
Amihud measure (AM)	0.20	-0.82	-0.33	-0.16	0.64	-0.78	0.93	1.00	
Dollar volume ($DVOL$)	-0.19	0.79	0.27	0.12	-0.51	0.74	-0.89	-0.96	1.00

Table 7: Time-Series Variation in Investment Factor Returns

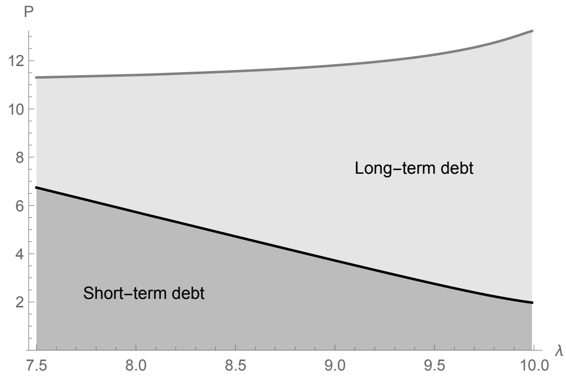
This table presents regression results with investment factor returns as the dependent variable. The independent variables are leverage and/or refinancing-intensity factor returns. I construct the factors as follows. At the end of each June, I independently double-sort stocks into two portfolios based on size (ME) and into three portfolios based on either asset growth rates (AG), leverage (LEV), or refinancing intensities (RI). The investment factor is the average return on the two low AG portfolios (small and big) minus the average return on the two high AG portfolios. I use the same procedure to construct the leverage and refinancing intensity factors. The leverage factor is long high LEV stocks and short low LEV stocks, whereas the refinancing-intensity factor is long high RI stocks and short low RI stocks. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, *** when $p < 0.01$, and t-statistics are in parenthesis.

	(1)	(2)	(3)	(4)
Intercept	0.32***	0.23***	0.32***	0.23***
	(3.63)	(3.17)	(3.63)	(3.16)
Leverage factor		0.42***		0.44***
		(16.94)		(17.59)
Refinancing-intensity factor			-0.01	0.23***
			(-0.13)	(3.90)
Adj. R^2	0.00	34.16	-0.18	35.82
N	552	552	552	552

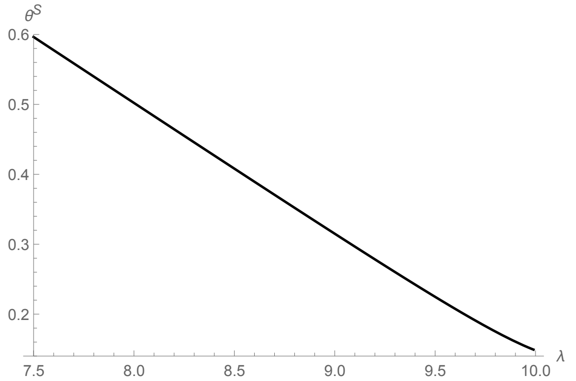
Figure 1: Optimal Leverage and Refinancing Intensity



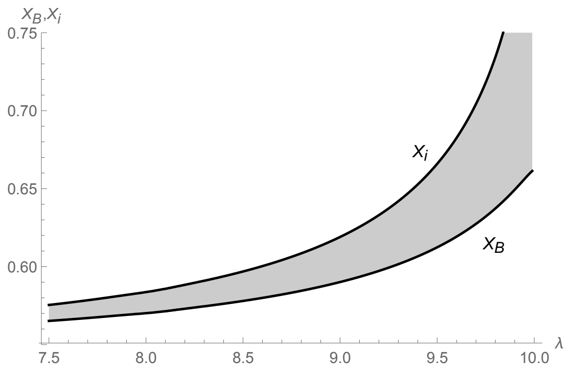
(A) Optimal leverage



(B) Optimal principal values



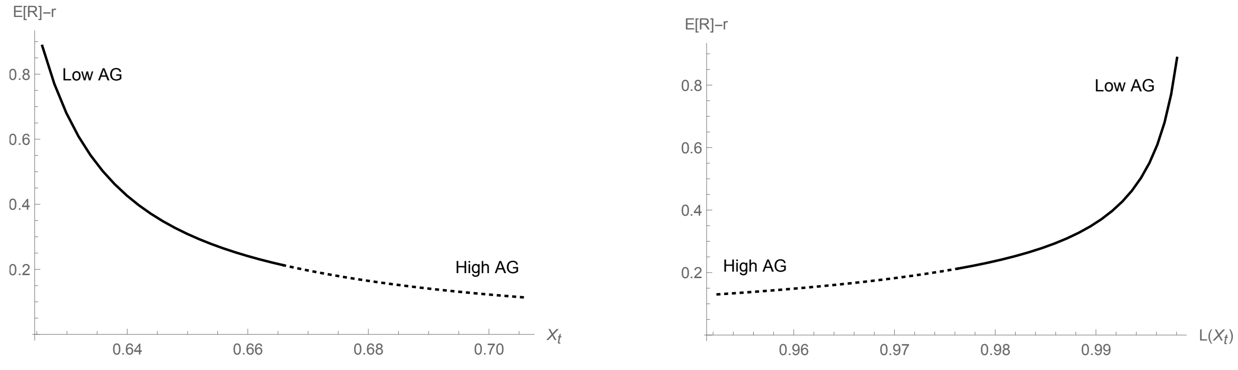
(C) Optimal refinancing intensity



(D) Investment and default boundaries

This figure shows the firm's optimal leverage and refinancing intensity at time $t = 0$ for different levels of investment costs λ. Panel A reports the optimal leverage and Panel B the optimal debt principal values. Panel C displays the optimal refinancing intensity and Panel D shows that the investment boundary lies above the default boundary. I set the remaining parameter values to $X_0 = 1$, $r = 10\%$, $i = 7\%$, $\sigma = 15\%$, $k = 1\%$, $\phi^S = 1$, and $\phi^L = 0.1$.

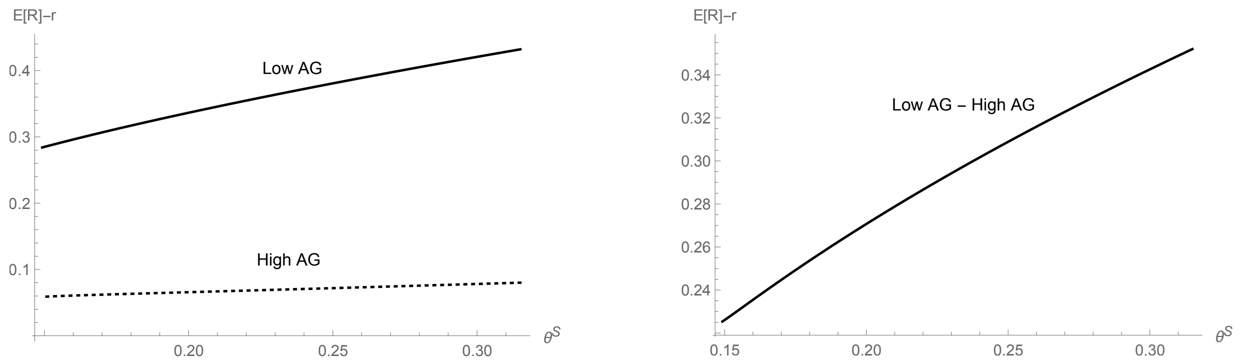
Figure 2: Expected Excess Stock Returns



(A) Expected return and assets-in-place **(B)** Expected return and leverage

This figure shows the expected excess stock return at time $t > 0$ as a function of either assets-in-place (Panel A) or current leverage (Panel B) for a firm with $\lambda = 9.5$. The firm chooses its optimal leverage and refinancing intensity at time $t = 0$. The dotted line denotes the investment region where $\tilde{i}_t = 7\%$ and the solid line denotes the non-investment region where $\tilde{i}_t = 0\%$. I set the remaining parameter values to $X_0 = 1$, $r = 10\%$, $\sigma = 15\%$, $k = 1\%$, $\phi^S = 1$, $\phi^L = 0.1$, and $\xi = 1\%$.

Figure 3: The Investment Premium and Refinancing Intensities



(A) Stock returns and refinancing intensities **(B)** Stock return differential

This figure illustrates the relationship between expected excess stock returns and refinancing intensities at time $t > 0$. Firms differ in the level of investment costs λ and choose their optimal refinancing intensity at time $t = 0$ by solving the optimization problem in equation (4). Panel A shows expected excess stock returns for low and high asset-growth firms with fixed leverage at time $t > 0$. I calibrate X_t such that all low asset-growth firms have a leverage ratio of 0.99 and all high asset-growth firms have a leverage ratio of 0.90 (see the discussion on these values in footnote 15.). Panel B shows the stock return differential of low asset-growth firms relative to high asset-growth firms as a function of the refinancing intensity. I set the remaining parameter values to $X_0 = 1$, $r = 10\%$, $i = 7\%$, $\sigma = 15\%$, $k = 1\%$, $\phi^S = 1$, $\phi^L = 0.1$, and $\xi = 1\%$.

Internet Appendix for:

Does Debt Explain the Investment Premium?

Abstract

This Internet Appendix contains the robustness checks mentioned in the paper. First, I present the results from the paper with equal-weighted returns (IA.1-IA.4). Second, I show the results for firms with non-positive net debt (IA.5). Third, I repeat the independent portfolio double-sort based on refinancing intensities and asset growth with a different number of portfolios (IA.6). Fourth, I present the results with sequential portfolio double-sorts using either refinancing intensities or asset growth as the first sorting variable (I.7-I.10). Fifth, I show the results using the investment-to-assets ratio from Lyandres et al. (2008) to measure asset growth (IA.11-IA.14). Sixth, I show the results using short-term debt to total assets to measure refinancing intensities (IA.15-IA.16). Seventh, I present the results from Fama and MacBeth (1973) regressions (IA.17-IA.19).

Table IA.1: Portfolios Independently Sorted by Size and Asset Growth: Equal-Weighted Returns

At the end of each June, I independently double-sort stocks into two portfolios based on size (ME) and into three portfolios based on asset growth rates (AG) using NYSE breakpoints. This procedure generates a cross-section of $2 \times 3 = 6$ portfolios. For both small and big firms, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B and C show value-weighted average asset growth rates and leverage ratios in percent. Panel D presents monthly value-weighted means of unlevered excess returns in percentage points. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1-L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	2	High AG	Low-High AG	t-stat
		Panel A: Excess Returns			
Small	1.35	1.09	0.55	0.80	(8.61)
Big	0.90	0.85	0.59	0.31	(2.90)
Average	1.13	0.97	0.57	0.56	(6.70)
		Panel B: Asset Growth			
Small	-11.65	7.29	57.29	-68.94	(-61.53)
Big	-5.30	7.50	44.73	-50.03	(-46.21)
Average	-8.48	7.40	51.01	-59.48	(-55.29)
		Panel C: Leverage			
Small	30.87	26.09	22.56	8.31	(43.54)
Big	28.97	21.99	17.38	11.60	(67.82)
Average	29.92	24.04	19.97	9.95	(58.84)
		Panel D: Unlevered Excess Returns			
Small	0.81	0.77	0.37	0.44	(5.97)
Big	0.59	0.64	0.47	0.12	(1.27)
Average	0.70	0.70	0.42	0.28	(3.87)

Table IA.2: Portfolios of Zero-Leverage Firms Independently Sorted by Size and Asset Growth: Equal-Weighted Returns

At the end of each June, I independently double-sort zero-leverage firms into two portfolios based on size (ME) and into two portfolios based on asset growth rates (AG) using NYSE breakpoints. This procedure generates a cross-section of $2 \times 2 = 4$ portfolios. For both small and big firms, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. Panel A presents monthly equal-weighted means of excess returns in percentage points. Panel B shows equal-weighted asset growth rates in percent. Panel C presents the average number of stocks in each portfolio and Panel D shows the minimum number of stocks in each portfolio. I define firm i as zero-leverage if in both years $t-2$ and $t-1$ the outstanding amounts of both short-term debt (DLC) and long-term debt ($DLTT$) equal zero. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	High AG	Low-High AG	t-stat
Panel A: Excess Returns				
Small	1.24	0.88	0.35	(2.61)
Big	0.48	0.76	-0.28	(-1.62)
Average	0.86	0.82	0.04	(0.31)
Panel B: Asset Growth				
Small	-6.91	46.77	-53.68	(-54.19)
Big	1.37	37.45	-36.08	(-38.61)
Average	-2.77	42.11	-44.88	(-48.49)
Panel C: Average Number of Stocks				
Small	141	100		
Big	18	40		
Panel D: Minimum Number of Stocks				
Small	27	15		
Big	3	6		

Table IA.3: Portfolios Independently Sorted by Refinancing Intensitites and Asset Growth: Equal-Weighted Returns

At the end of each June, I independently double-sort stocks into five portfolios based on refinancing intensities (RI) and into five portfolios based on asset growth rates (AG) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. In each asset-growth quintile, I construct a High-Low RI portfolio that buys the High RI portfolio and sells the Low RI portfolio. I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents monthly equal-weighted means of excess returns in percentage points. Panel B shows equal-weighted average leverage ratios in percent. Panel C presents monthly equal-weighted means of unlevered excess returns in percentage points. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	2	3	4	High AG	Low-High AG	t-stat
			Panel A: Excess Returns				
Low RI	1.08	1.06	0.90	0.90	0.37	0.71	(4.37)
2	1.17	1.14	0.95	0.77	0.47	0.70	(4.72)
3	1.17	1.12	0.90	0.76	0.35	0.82	(5.93)
4	1.27	1.29	1.02	1.00	0.39	0.88	(6.91)
High RI	1.45	1.16	1.14	1.00	0.39	1.06	(7.82)
High-Low RI	0.38	0.11	0.24	0.10	0.03	0.35	(2.47)
t-stat	(3.09)	(0.96)	(2.34)	(0.99)	(0.25)		
			Panel B: Leverage				
Low RI	31.42	27.87	23.87	22.08	22.46	8.96	(40.39)
2	44.40	37.93	32.45	29.53	30.14	14.26	(69.61)
3	44.38	38.20	32.56	29.80	30.46	13.93	(64.47)
4	40.67	35.74	31.15	27.63	28.63	12.04	(41.49)
High RI	29.16	24.87	21.68	18.49	17.65	11.52	(52.28)
High-Low RI	-2.26	-2.99	-2.20	-3.59	-4.82	2.56	(13.84)
t-stat	(-10.03)	(-16.72)	(-12.72)	(-28.43)	(-25.05)		
			Panel C: Unlevered Excess Returns				
Low RI	0.57	0.73	0.64	0.68	0.22	0.35	(3.03)
2	0.56	0.62	0.60	0.52	0.29	0.28	(2.96)
3	0.52	0.58	0.57	0.49	0.18	0.34	(4.01)
4	0.59	0.76	0.66	0.67	0.17	0.41	(4.83)
High RI	0.85	0.79	0.85	0.79	0.26	0.59	(5.50)
High-Low RI	0.28	0.06	0.22	0.10	0.04	0.24	(2.37)
t-stat	(3.12)	(0.76)	(2.72)	(1.28)	(0.41)		

Table IA.4: Long-Short Portfolios Independently Sorted by Refinancing Intensitites and Asset Growth: Equal-Weighted Returns

At the end of each June, I independently double-sort stocks into five portfolios based on refinancing intensities (RI) and into five portfolios based on asset growth rates (AG) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. For each of these five long-short portfolios, I calculate monthly equal-weighted means in percentage points of alpha estimates from regressing excess returns on the market (MKT), the three Fama-French factors (MKT, SMB, HML), the four factors including momentum (MKT, SMB, HML, UMD), and the five Fama-French factors (MKT, SMB, HML, RMW, CMA). I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents the results for risk-adjusted levered returns and Panel B shows the results for risk-adjusted unlevered returns. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, *** when $p < 0.01$, and t-statistics are in parenthesis.

	CAPM α	3-factor α	4-factor α	5-factor α
	Panel A: Risk-Adjusted Returns			
Low RI	0.80***	0.63***	0.58***	0.61***
	(4.99)	(4.13)	(3.74)	(4.19)
2	0.75***	0.50***	0.45***	0.39***
	(5.00)	(3.68)	(3.27)	(2.83)
3	0.83***	0.66***	0.66***	0.62***
	(5.94)	(4.99)	(4.82)	(4.77)
4	0.91***	0.74***	0.74***	0.70***
	(7.10)	(6.09)	(5.92)	(5.85)
High RI	1.14***	0.95***	0.90***	0.92***
	(8.55)	(7.66)	(7.16)	(7.74)
High-Low RI	0.34**	0.32**	0.32**	0.31**
	(2.39)	(2.19)	(2.17)	(2.09)
	Panel B: Risk-Adjusted Unlevered Returns			
Low RI	0.48***	0.37***	0.32***	0.37***
	(4.40)	(3.54)	(2.98)	(3.76)
2	0.40***	0.29***	0.23***	0.23***
	(4.76)	(3.65)	(2.84)	(2.95)
3	0.45***	0.40***	0.36***	0.40***
	(5.82)	(5.23)	(4.56)	(5.31)
4	0.51***	0.44***	0.40***	0.44***
	(6.45)	(5.70)	(5.09)	(5.86)
High RI	0.74***	0.62***	0.54***	0.58***
	(7.57)	(6.60)	(5.75)	(6.56)
High-Low RI	0.26**	0.24**	0.22**	0.21*
	(2.52)	(2.35)	(2.11)	(1.94)

Table IA.5: Portfolios of Firms with Non-Positive Net Debt Independently Sorted by Size and Asset Growth

At the end of each June, I independently double-sort firms with non-positive net debt into two portfolios based on size (ME) and into two portfolios based on asset growth rates (AG) using NYSE breakpoints. This procedure generates a cross-section of $2 \times 2 = 4$ portfolios. For both small and big firms, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B shows value-weighted asset growth rates in percent. Panel C presents the average number of stocks in each portfolio and Panel D shows the minimum number of stocks in each portfolio. I define firm i as a firm with non-positive net debt if in both years $t-2$ and $t-1$ the sum of short-term debt (DLC) and long-term debt ($DLTT$) minus cash and short-term investments (CHE) is non-positive. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	High AG	Low-High AG	t-stat
Panel A: Excess Returns				
Small	0.82	0.66	0.16	(1.65)
Big	0.59	0.62	-0.03	(-0.18)
Average	0.71	0.64	0.07	(0.64)
Panel B: Asset Growth				
Small	-2.47	48.12	-50.59	(-38.53)
Big	3.54	31.43	-27.88	(-31.56)
Average	0.54	39.78	-39.24	(-37.73)
Panel C: Average Number of Stocks				
Small	430	349		
Big	53	107		
Panel D: Minimum Number of Stocks				
Small	78	55		
Big	17	36		

Table IA.6: Long-Short Portfolios Independently Sorted by Refinancing Intensities and Asset Growth with Different Number of Portfolios

At the end of each June, I independently double-sort stocks into N portfolios based on firms' refinancing intensities (RI) and into five portfolios based on firms' asset growth rates (AG). This procedure generates a cross-section of $N \times 5$ portfolios. In each refinancing quantile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. Next, I calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. For this portfolio, I calculate the monthly value-weighted mean in percentage points of excess returns and alpha estimates from regressing value-weighted excess returns on the market (MKT), the three Fama-French factors (MKT, SMB, HML), the four factors including momentum (MKT, SMB, HML, UMD), and the five Fama-French factors (MKT, SMB, HML, RMW, CMA). I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, *** when $p < 0.01$, and t-statistics are in parenthesis.

	Levered Returns			Unlevered Returns		
	3×5	5×5	7×5	3×5	5×5	7×5
Excess return	0.38**	0.52***	0.78***	0.24	0.33*	0.57***
	(2.12)	(2.60)	(3.65)	(1.56)	(1.93)	(2.99)
CAPM α	0.41**	0.58***	0.79***	0.28*	0.41**	0.64***
	(2.28)	(2.88)	(3.68)	(1.86)	(2.39)	(3.36)
3-factor α	0.42**	0.56***	0.76***	0.29*	0.39**	0.64***
	(2.33)	(2.77)	(3.48)	(1.92)	(2.30)	(3.36)
4-factor α	0.55***	0.61***	0.78***	0.41***	0.45***	0.66***
	(3.05)	(2.97)	(3.49)	(2.68)	(2.59)	(3.37)
5-factor α	0.42**	0.52**	0.68***	0.31**	0.38**	0.60***
	(2.26)	(2.49)	(3.05)	(2.00)	(2.14)	(3.07)

Table IA.7: Portfolios Sequentially Sorted by Refinancing Intensitites and Asset Growth

At the end of each June, I sequentially double-sort stocks first into five portfolios based on refinancing intensities (RI) and then into five portfolios based on asset growth rates (AG) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. In each asset-growth quintile, I construct a High-Low RI portfolio that buys the High RI portfolio and sells the Low RI portfolio. I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B shows value-weighted average leverage ratios in percent. Panel C presents monthly value-weighted means of unlevered excess returns in percentage points. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	2	3	4	High AG	Low-High AG	t-stat
			Panel A: Excess Returns				
Low RI	0.73	0.76	0.76	0.73	0.56	0.17	(0.94)
2	0.88	0.81	0.63	0.71	0.48	0.40	(2.18)
3	0.81	0.82	0.76	0.46	0.32	0.49	(2.72)
4	0.89	0.67	0.58	0.65	0.48	0.41	(2.44)
High RI	1.11	0.81	0.79	0.69	0.44	0.67	(3.53)
High-Low RI	0.38	0.05	0.03	-0.04	-0.12	0.50	(2.45)
t-stat	(2.30)	(0.31)	(0.17)	(-0.24)	(-0.76)		
			Panel B: Leverage				
Low RI	26.35	21.22	17.74	13.84	16.04	10.31	(28.22)
2	31.08	25.20	20.06	18.51	18.67	12.41	(29.50)
3	29.88	25.16	20.37	18.11	22.91	6.97	(15.19)
4	34.23	26.14	21.76	19.34	20.53	13.70	(28.71)
High RI	28.75	23.12	20.57	15.16	12.22	16.53	(38.92)
High-Low RI	2.40	1.90	2.83	1.32	-3.83	6.22	(14.66)
t-stat	(5.87)	(5.77)	(5.54)	(3.49)	(-14.24)		
			Panel C: Unlevered Excess Returns				
Low RI	0.50	0.58	0.62	0.63	0.45	0.05	(0.33)
2	0.56	0.60	0.50	0.57	0.39	0.17	(1.08)
3	0.56	0.58	0.60	0.38	0.19	0.36	(2.37)
4	0.56	0.48	0.44	0.51	0.37	0.20	(1.43)
High RI	0.73	0.60	0.60	0.58	0.37	0.35	(2.07)
High-Low RI	0.23	0.01	-0.02	-0.05	-0.07	0.30	(1.71)
t-stat	(1.68)	(0.09)	(-0.18)	(-0.38)	(-0.49)		

Table IA.8: Long-Short Portfolios Sequentially Sorted by Refinancing Intensitites and Asset Growth

At the end of each June, I sequentially double-sort stocks first into five portfolios based on refinancing intensities (RI) and then into five portfolios based on asset growth rates (AG) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. For each of these five long-short portfolios, I calculate monthly value-weighted means in percentage points of alpha estimates from regressing excess returns on the market (MKT), the three Fama-French factors (MKT, SMB, HML), the four factors including momentum (MKT, SMB, HML, UMD), and the five Fama-French factors (MKT, SMB, HML, RMW, CMA). I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents the results for risk-adjusted levered returns and Panel B shows the results for risk-adjusted unlevered returns. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, *** when $p < 0.01$, and t-statistics are in parenthesis.

	CAPM α	3-factor α	4-factor α	5-factor α
Panel A: Risk-Adjusted Returns				
Low RI	0.24	-0.07	-0.16	-0.29*
	(1.29)	(-0.43)	(-0.93)	(-1.88)
2	0.50***	0.19	0.14	-0.13
	(2.77)	(1.15)	(0.86)	(-0.85)
3	0.55***	0.35**	0.32*	0.22
	(3.05)	(2.04)	(1.79)	(1.29)
4	0.48***	0.23	0.34**	0.06
	(2.88)	(1.52)	(2.27)	(0.39)
High RI	0.77***	0.42**	0.41**	0.10
	(4.13)	(2.56)	(2.46)	(0.63)
High-Low RI	0.54***	0.49**	0.57***	0.39*
	(2.62)	(2.39)	(2.72)	(1.83)

Panel B: Risk-Adjusted Unlevered Returns				
Low RI	0.18	-0.07	-0.15	-0.27*
	(1.12)	(-0.51)	(-1.03)	(-1.95)
2	0.33**	0.09	0.06	-0.15
	(2.22)	(0.65)	(0.45)	(-1.20)
3	0.46***	0.31**	0.26*	0.22
	(3.06)	(2.15)	(1.76)	(1.49)
4	0.34***	0.16	0.24**	0.04
	(2.60)	(1.36)	(1.98)	(0.34)
High RI	0.55***	0.26*	0.26*	0.00
	(3.47)	(1.88)	(1.83)	(-0.04)
High-Low RI	0.37**	0.34*	0.41**	0.26
	(2.13)	(1.91)	(2.30)	(1.43)

Table IA.9: Portfolios Sequentially Sorted by Asset Growth and Refinancing Intensitites

At the end of each June, I sequentially double-sort stocks first into five portfolios based on asset growth rates (AG) and then into five portfolios based on refinancing intensities (RI) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. In each asset-growth quintile, I construct a High-Low RI portfolio that buys the High RI portfolio and sells the Low RI portfolio. I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B shows value-weighted average leverage ratios in percent. Panel C presents monthly value-weighted means of unlevered excess returns in percentage points. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	2	3	4	High AG	Low-High AG	t-stat
			Panel A: Excess Returns				
Low RI	0.70	0.86	0.77	0.82	0.59	0.12	(0.60)
2	0.93	0.77	0.62	0.70	0.43	0.50	(2.69)
3	0.71	0.82	0.72	0.51	0.35	0.35	(2.09)
4	0.92	0.74	0.55	0.69	0.35	0.57	(3.48)
High RI	1.14	0.73	0.75	0.69	0.48	0.66	(3.69)
High-Low RI	0.44	-0.13	-0.02	-0.12	-0.11	0.54	(2.70)
t-stat	(2.70)	(-0.86)	(-0.13)	(-0.83)	(-0.68)		
			Panel B: Leverage				
Low RI	27.10	21.33	18.67	15.67	14.39	12.71	(34.54)
2	31.59	26.07	20.91	17.56	18.12	13.47	(34.02)
3	31.02	25.25	21.39	17.77	22.51	8.51	(17.65)
4	33.61	25.46	21.93	18.62	21.35	12.26	(24.60)
High RI	27.54	22.15	19.44	15.63	12.64	14.90	(34.47)
High-Low RI	0.44	0.82	0.77	-0.04	-1.75	2.19	(4.43)
t-stat	(0.93)	(2.24)	(1.37)	(-0.10)	(-6.71)		
			Panel C: Unlevered Excess Returns				
Low RI	0.46	0.66	0.63	0.69	0.49	-0.03	(-0.16)
2	0.62	0.55	0.49	0.57	0.34	0.28	(1.76)
3	0.48	0.59	0.54	0.43	0.25	0.23	(1.60)
4	0.58	0.53	0.40	0.58	0.23	0.35	(2.65)
High RI	0.77	0.56	0.57	0.57	0.42	0.35	(2.16)
High-Low RI	0.31	-0.10	-0.06	-0.12	-0.07	0.38	(2.17)
t-stat	(2.31)	(-0.84)	(-0.46)	(-0.88)	(-0.49)		

Table IA.10: Long-Short Portfolios Sequentially Sorted by Refinancing Intensitites and Asset Growth

At the end of each June, I sequentially double-sort stocks first into five portfolios based on asset growth rates (AG) and then into five portfolios based on refinancing intensities (RI) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. For each of these five long-short portfolios, I calculate monthly value-weighted means in percentage points of alpha estimates from regressing excess returns on the market (MKT), the three Fama-French factors (MKT, SMB, HML), the four factors including momentum (MKT, SMB, HML, UMD), and the five Fama-French factors (MKT, SMB, HML, RMW, CMA). I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents the results for risk-adjusted levered returns and Panel B shows the results for risk-adjusted unlevered returns. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, *** when $p < 0.01$, and t-statistics are in parenthesis.

	CAPM α	3-factor α	4-factor α	5-factor α
	Panel A: Risk-Adjusted Returns			
Low RI	0.20	-0.14	-0.25	-0.46***
	(1.02)	(-0.82)	(-1.41)	(-2.90)
2	0.56***	0.28	0.21	-0.07
	(3.00)	(1.60)	(1.16)	(-0.46)
3	0.43**	0.24	0.21	0.10
	(2.53)	(1.46)	(1.27)	(0.61)
4	0.67***	0.44***	0.50***	0.28*
	(4.11)	(2.87)	(3.23)	(1.85)
High RI	0.76***	0.44***	0.39**	0.11
	(4.30)	(2.78)	(2.46)	(0.80)
High-Low RI	0.56***	0.58***	0.65***	0.57***
	(2.77)	(2.82)	(3.07)	(2.69)
	Panel B: Risk-Adjusted Unlevered Returns			
Low RI	0.12	-0.16	-0.25*	-0.44***
	(0.74)	(-1.05)	(-1.65)	(-3.20)
2	0.42***	0.21	0.14	-0.05
	(2.76)	(1.47)	(0.98)	(-0.35)
3	0.35**	0.21	0.17	0.10
	(2.52)	(1.62)	(1.23)	(0.78)
4	0.50***	0.33***	0.38***	0.22*
	(4.02)	(2.90)	(3.25)	(1.95)
High RI	0.54***	0.27**	0.23*	0.01
	(3.58)	(2.00)	(1.68)	(0.10)
High-Low RI	0.42**	0.43**	0.48***	0.46**
	(2.37)	(2.40)	(2.66)	(2.48)

Table IA.11: Portfolios Independently Sorted by Size and Investment-to-Assets

At the end of each June, I independently double-sort stocks into two portfolios based on size (ME) and into three portfolios based on investment-to-assets (IA) using NYSE breakpoints. This procedure generates a cross-section of $2 \times 3 = 6$ portfolios. For both small and big firms, I construct a Low-High IA portfolio that buys the Low IA portfolio and sells the High IA portfolio. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B and C show value-weighted average investment-to-assets ratios and leverage ratios in percent. Panel D presents monthly value-weighted means of unlevered excess returns in percentage points. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low IA	2	High IA	Low-High IA	t-stat
Panel A: Excess Returns					
Small	0.92	0.92	0.57	0.35	(4.59)
Big	0.71	0.60	0.55	0.15	(1.40)
Average	0.82	0.76	0.56	0.25	(3.39)
Panel B: Investment-to-Assets					
Small	-4.61	5.96	39.65	-44.26	(-12.19)
Big	-1.86	6.08	22.91	-24.77	(-76.78)
Average	-3.24	6.02	31.28	-34.52	(-18.52)
Panel C: Leverage					
Small	27.59	22.81	22.68	4.91	(26.55)
Big	24.46	18.48	16.62	7.84	(33.34)
Average	26.02	20.65	19.65	6.37	(36.90)
Panel C: Unlevered Excess Returns					
Small	0.64	0.68	0.43	0.21	(3.11)
Big	0.52	0.47	0.45	0.07	(0.68)
Average	0.58	0.58	0.44	0.14	(2.03)

Table IA.12: Portfolios of Zero-Leverage Firms Independently Sorted by Size and Investment-to-Assets

At the end of each June, I independently double-sort zero-leverage firms into two portfolios based on size (ME) and into two portfolios based on investment-to-assets (IA) using NYSE breakpoints. This procedure generates a cross-section of $2 \times 2 = 4$ portfolios. For both small and big firms, I construct a Low-High IA portfolio that buys the Low IA portfolio and sells the High IA portfolio. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B shows value-weighted asset growth rates in percent. Panel C presents the average number of stocks in each portfolio and Panel D shows the minimum number of stocks in each portfolio. I define firm i as zero-leverage if in both years $t-2$ and $t-1$ the outstanding amounts of both short-term debt (DLC) and long-term debt ($DLTT$) equal zero. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low IA	High IA	Low-High IA	t-stat
Panel A: Excess Returns				
Small	0.75	0.68	0.06	(0.46)
Big	0.41	0.76	-0.35	(-1.42)
Average	0.58	0.72	-0.14	(-0.96)
Panel B: Asset Growth				
Small	11.36	35.32	-23.96	(-29.99)
Big	16.61	38.10	-21.49	(-21.98)
Average	13.98	36.71	-22.73	(-29.16)
Panel C: Average Number of Stocks				
Small	154	86		
Big	26	32		
Panel D: Minimum Number of Stocks				
Small	27	18		
Big	1	5		

Table IA.13: Portfolios Independently Sorted by Refinancing Intensitites and Investment-to-Assets

At the end of each June, I independently double-sort stocks into five portfolios based on refinancing intensities (RI) and into five portfolios based on investment-to-assets (IA) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High IA portfolio that buys the Low IA portfolio and sells the High IA portfolio. In each investment-to-assets quintile, I construct a High-Low RI portfolio that buys the High RI portfolio and sells the Low RI portfolio. I also calculate the return differential of buying the Low-High IA portfolio for firms with high refinancing intensities and selling the Low-High IA portfolio for firms with low refinancing intensities. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B shows value-weighted average leverage ratios in percent. Panel C presents monthly value-weighted means of unlevered excess returns in percentage points. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low IA	2	3	4	High IA	Low-High IA	t-stat
			Panel A: Excess Returns				
Low RI	0.77	0.57	0.77	0.71	0.64	0.13	(0.68)
2	0.80	0.77	0.59	0.69	0.43	0.37	(2.03)
3	0.63	0.69	0.77	0.65	0.33	0.30	(1.81)
4	0.76	0.70	0.57	0.55	0.39	0.37	(2.22)
High RI	1.04	0.74	0.56	0.66	0.43	0.61	(3.28)
High-Low RI	0.27	0.16	-0.21	-0.05	-0.21	0.48	(2.18)
t-stat	(1.65)	(1.09)	(-1.31)	(-0.35)	(-1.17)		
			Panel B: Leverage				
Low RI	25.28	17.18	17.15	16.19	18.60	6.67	(14.32)
2	27.85	24.22	20.34	19.22	19.08	8.77	(21.98)
3	28.64	23.75	21.81	19.61	22.30	6.34	(16.00)
4	29.86	27.15	21.92	18.98	21.13	8.73	(19.67)
High RI	25.74	24.39	17.10	13.42	12.96	12.78	(34.01)
High-Low RI	0.46	7.21	-0.06	-2.78	-5.64	6.10	(11.19)
t-stat	(1.03)	(15.50)	(-0.12)	(-7.02)	(-22.39)		
			Panel C: Unlevered Excess Returns				
Low RI	0.55	0.48	0.64	0.54	0.51	0.05	(0.29)
2	0.49	0.57	0.45	0.56	0.36	0.13	(0.82)
3	0.41	0.51	0.57	0.50	0.22	0.19	(1.35)
4	0.57	0.50	0.42	0.43	0.26	0.30	(2.21)
High RI	0.71	0.54	0.45	0.56	0.35	0.36	(2.15)
High-Low RI	0.15	0.06	-0.19	0.02	-0.16	0.31	(1.64)
t-stat	(1.14)	(0.50)	(-1.31)	(0.13)	(-0.98)		

Table IA.14: Long-Short Portfolios Independently Sorted by Refinancing Intensitites and Investment-to-Assets

At the end of each June, I independently double-sort stocks into five portfolios based on refinancing intensities (RI) and into five portfolios based on investment-to-assets (IA) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High IA portfolio that buys the Low IA portfolio and sells the High IA portfolio. For each of these five long-short portfolios, I calculate monthly value-weighted means in percentage points of alpha estimates from regressing excess returns on the market (MKT), the three Fama-French factors (MKT, SMB, HML), the four factors including momentum (MKT, SMB, HML, UMD), and the five Fama-French factors (MKT, SMB, HML, RMW, CMA). I also calculate the return differential of buying the Low-High IA portfolio for firms with high refinancing intensities and selling the Low-High IA portfolio for firms with low refinancing intensities. Panel A presents the results for risk-adjusted levered returns and Panel B shows the results for risk-adjusted unlevered returns. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1-L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, *** when $p < 0.01$, and t-statistics are in parenthesis.

	CAPM α	3-factor α	4-factor α	5-factor α
	Panel A: Risk-Adjusted Returns			
Low RI	0.21	0.00	-0.10	-0.23
	(1.06)	(-0.02)	(-0.53)	(-1.22)
2	0.52***	0.31*	0.22	0.03
	(2.92)	(1.82)	(1.27)	(0.18)
3	0.35**	0.19	0.11	-0.04
	(2.08)	(1.15)	(0.68)	(-0.22)
4	0.43**	0.26	0.31*	0.21
	(2.52)	(1.58)	(1.90)	(1.30)
High RI	0.70***	0.45**	0.49***	0.09
	(3.75)	(2.55)	(2.75)	(0.53)
High-Low RI	0.49**	0.45**	0.59***	0.31
	(2.21)	(2.00)	(2.61)	(1.37)
	Panel B: Risk-Adjusted Unlevered Returns			
Low RI	0.16	0.00	-0.07	-0.17
	(0.97)	(-0.02)	(-0.46)	(-1.08)
2	0.31**	0.13	0.08	-0.05
	(2.06)	(0.91)	(0.57)	(-0.33)
3	0.28**	0.15	0.09	-0.02
	(2.02)	(1.14)	(0.68)	(-0.15)
4	0.42***	0.32**	0.36***	0.29**
	(3.15)	(2.48)	(2.71)	(2.25)
High RI	0.52***	0.32**	0.34**	0.01
	(3.27)	(2.15)	(2.21)	(0.04)
High-Low RI	0.36*	0.33*	0.42**	0.17
	(1.91)	(1.71)	(2.13)	(0.88)

Table IA.15: Portfolios Independently Sorted by Refinancing Intensitites and Asset Growth

At the end of each June, I independently double-sort stocks into five portfolios based on refinancing intensities (RI) and into five portfolios based on asset growth rates (AG) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. In each asset-growth quintile, I construct a High-Low RI portfolio that buys the High RI portfolio and sells the Low RI portfolio. I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents monthly value-weighted means of excess returns in percentage points. Panel B shows value-weighted average leverage ratios in percent. Panel C presents monthly value-weighted means of unlevered excess returns in percentage points. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The parentheses contain t-statistics.

	Low AG	2	3	4	High AG	Low-High AG	t-stat
			Panel A: Excess Returns				
Low RI	0.54	0.77	0.80	0.66	0.65	-0.11	(-0.60)
2	0.96	0.81	0.60	0.73	0.54	0.42	(2.14)
3	0.72	0.81	0.65	0.66	0.26	0.46	(2.77)
4	0.76	0.80	0.71	0.60	0.38	0.38	(2.44)
High RI	1.04	0.73	0.73	0.62	0.64	0.40	(2.18)
High-Low RI	0.50	-0.04	-0.08	-0.04	-0.01	0.51	(2.45)
t-stat	(3.01)	(-0.27)	(-0.48)	(-0.26)	(-0.06)		
			Panel B: Leverage				
Low RI	15.53	12.98	11.89	9.42	7.55	7.99	(28.57)
2	25.08	20.62	16.03	12.63	13.68	11.40	(33.72)
3	27.92	25.10	20.41	17.66	17.38	10.54	(28.70)
4	33.66	28.01	24.04	21.09	22.98	10.68	(26.87)
High RI	39.81	32.61	31.52	28.85	27.76	12.05	(24.39)
High-Low RI	24.28	19.63	19.63	19.44	20.22	4.07	(7.16)
t-stat	(54.57)	(44.90)	(47.81)	(55.35)	(57.16)		
			Panel C: Unlevered Excess Returns				
Low RI	0.43	0.64	0.71	0.59	0.61	-0.18	(-1.03)
2	0.70	0.63	0.50	0.63	0.44	0.26	(1.46)
3	0.48	0.58	0.49	0.56	0.20	0.28	(1.94)
4	0.49	0.56	0.52	0.47	0.25	0.25	(1.86)
High RI	0.57	0.46	0.44	0.43	0.50	0.08	(0.52)
High-Low RI	0.14	-0.18	-0.26	-0.16	-0.12	0.26	(1.43)
t-stat	(1.01)	(-1.36)	(-1.97)	(-1.08)	(-0.70)		

Table IA.16: Long-Short Portfolios Independently Sorted by Refinancing Intensitites and Asset Growth

At the end of each June, I independently double-sort stocks into five portfolios based on refinancing intensities (RI) and into five portfolios based on asset growth rates (AG) using NYSE breakpoints. In each refinancing quintile, I construct a Low-High AG portfolio that buys the Low AG portfolio and sells the High AG portfolio. For each of these five long-short portfolios, I calculate monthly value-weighted means in percentage points of alpha estimates from regressing excess returns on the market (MKT), the three Fama-French factors (MKT, SMB, HML), the four factors including momentum (MKT, SMB, HML, UMD), and the five Fama-French factors (MKT, SMB, HML, RMW, CMA). I also calculate the return differential of buying the Low-High AG portfolio for firms with high refinancing intensities and selling the Low-High AG portfolio for firms with low refinancing intensities. Panel A presents the results for risk-adjusted levered returns and Panel B shows the results for risk-adjusted unlevered returns. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, *** when $p < 0.01$, and t-statistics are in parenthesis.

	CAPM α	3-factor α	4-factor α	5-factor α
	Panel A: Risk-Adjusted Returns			
Low RI	-0.01	-0.35**	-0.40**	-0.64***
	(-0.08)	(-2.15)	(-2.35)	(-4.51)
2	0.51***	0.17	0.12	-0.14
	(2.60)	(0.99)	(0.68)	(-0.83)
3	0.53***	0.33**	0.34**	0.22
	(3.19)	(2.08)	(2.14)	(1.40)
4	0.46***	0.25*	0.30**	0.08
	(2.95)	(1.71)	(1.99)	(0.53)
High RI	0.51***	0.22	0.31*	-0.11
	(2.79)	(1.35)	(1.85)	(-0.68)
High-Low RI	0.52**	0.57***	0.70***	0.53**
	(2.47)	(2.78)	(3.35)	(2.54)
	Panel B: Risk-Adjusted Unlevered Returns			
Low RI	-0.04	-0.36**	-0.41***	-0.63***
	(-0.24)	(-2.41)	(-2.62)	(-4.85)
2	0.40**	0.13	0.08	-0.14
	(2.34)	(0.84)	(0.47)	(-0.93)
3	0.40***	0.24*	0.25*	0.17
	(2.88)	(1.83)	(1.90)	(1.30)
4	0.39***	0.25**	0.26**	0.12
	(3.17)	(2.14)	(2.19)	(1.01)
High RI	0.23*	0.03	0.13	-0.21*
	(1.68)	(0.28)	(1.01)	(-1.73)
High-Low RI	0.27	0.40**	0.53***	0.42**
	(1.49)	(2.27)	(2.99)	(2.42)

Table IA.17: FM Regressions: Asset Growth and Leverage

This table presents the results of Fama and MacBeth (1973) regressions of future excess returns on the logarithm of asset growth (AG), beta (β), the logarithm of the market value of equity (ME), the logarithm of the book-to-market ratio (BM), and the logarithm of operating profitability (OP). For the cross-sectional regressions, I use either ordinary least squares estimates (equal-weighted) or weighted least squares with the market value of equity as the weighting scheme (value-weighted). I estimate β as in Fama and French (1992) while BM and OP are calculated as in Fama and French (2015). Panel A presents the results for excess returns and Panel B shows the results for unlevered excess returns. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The t-statistics in parenthesis are adjusted following Newey and West (1987) using six lags. The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, and *** when $p < 0.01$.

	Value-weighted		Equal-weighted	
	(1)	(2)	(3)	(4)
Panel A: Excess Returns				
Log(1+AG)	-0.66**	-0.36**	-1.41***	-1.11***
	(-2.35)	(-2.19)	(-7.71)	(-9.45)
β		-0.08		-0.05
		(-0.25)		(-0.17)
Log(ME)		-0.08**		-0.13***
		(-2.29)		(-4.14)
Log(BM)		0.15		0.20***
		(1.64)		(2.96)
Log(1+OP)		0.87***		0.43**
		(3.39)		(2.58)
Adj. R^2	0.01	0.10	0.00	0.03
N	3025.35	2786.96	3025.35	2786.96

Panel B: Unlevered Excess Returns				
Log(1+AG)	-0.42	-0.21	-0.86***	-0.75***
	(-1.60)	(-1.45)	(-5.95)	(-8.44)
β		-0.09		-0.11
		(-0.32)		(-0.52)
Log(ME)		-0.06**		-0.08***
		(-2.07)		(-3.45)
Log(BM)		0.02		0.04
		(0.26)		(0.67)
Log(1+OP)		0.56**		0.32**
		(2.56)		(2.15)
Adj. R^2	0.02	0.10	0.00	0.03
N	3025.35	2786.96	3025.35	2786.96

Table IA.18: FM Regressions: Asset Growth and Zero-Leverage Firms

This table presents the results of Fama and MacBeth (1973) regressions of future excess returns on the logarithm of asset growth (AG), beta (β), the logarithm of the market value of equity (ME), the logarithm of the book-to-market ratio (BM), and the logarithm of operating profitability (OP) for zero-leverage firms. For the cross-sectional regressions, I use either ordinary least squares estimates (equal-weighted) or weighted least squares with the market value of equity as the weighting scheme (value-weighted). I estimate β as in Fama and French (1992) while BM and OP are calculated as in Fama and French (2015). I define firm i as zero-leverage if in both years $t-2$ and $t-1$ the outstanding amounts of both short-term debt (DLC) and long-term debt ($DLTT$) equal zero. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The t-statistics in parenthesis are adjusted following Newey and West (1987) using six lags. The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, and *** when $p < 0.01$.

	Value-weighted		Equal-weighted	
	(1)	(2)	(3)	(4)
Log(1+AG)	0.78	0.29	-0.25	-0.17
	(1.22)	(0.48)	(-0.71)	(-0.49)
β		0.78*		0.22
		(1.72)		(0.66)
Log(ME)		0.07		-0.21***
		(1.13)		(-4.48)
Log(BM)		0.26*		0.34***
		(1.94)		(3.79)
Log(1+OP)		1.25**		0.97***
		(2.41)		(2.61)
Adj. R^2	0.05	0.16	0.01	0.03
N	297.71	284.86	297.71	284.86

Table IA.19: FM Regressions: Asset Growth and Refinancing Intensitites

This table presents the results of Fama and MacBeth (1973) regressions of future excess returns on the logarithm of asset growth (AG), refinancing intensities (RI), and their interaction. For the cross-sectional regressions, I use either ordinary least squares estimates (equal-weighted) or weighted least squares with the market value of equity as the weighting scheme (value-weighted). In specifications (2) and (4), I also include beta (β), the logarithm of the market value of equity (ME), the logarithm of the book-to-market ratio (BM), and the logarithm of operating profitability (OP) in the regressions. I estimate β as in Fama and French (1992) while BM and OP are calculated as in Fama and French (2015). Panel A presents the results for excess returns and Panel B shows the results for unlevered excess returns. I follow Doshi et al. (2018) and calculate unlevered excess returns as $R_{E,i}(t)(1 - L_i(t-1))$ where $R_{E,i}(t)$ is the excess return for firm i in month t and $L_i(t-1)$ is the leverage ratio of firm i at the end of month $t-1$. The sample period is from July 1970 to June 2016 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The t-statistics in parenthesis are adjusted following Newey and West (1987) using six lags. The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, and *** when $p < 0.01$.

	Value-weighted		Equal-weighted	
	(1)	(2)	(3)	(4)
	Panel A: Excess Returns			
Log(1+AG)	-0.73**	-0.33*	-1.45***	-1.07***
	(-2.47)	(-1.80)	(-7.42)	(-7.63)
RI	0.41	0.40	0.45**	0.42***
	(1.18)	(1.52)	(2.12)	(3.13)
Log(1+AG)*RI	-0.96	-1.30	-0.11	-0.48
	(-1.16)	(-1.48)	(-0.28)	(-1.06)
Controls	N	Y	N	Y
Adj. R^2	0.02	0.10	0.01	0.03
N	2643.23	2428.12	2643.23	2428.12
	Panel B: Unlevered Excess Returns			
Log(1+AG)	-0.50*	-0.20	-0.77***	-0.63***
	(-1.90)	(-1.28)	(-5.52)	(-6.64)
RI	0.43	0.43*	0.50**	0.65***
	(1.39)	(1.76)	(2.33)	(4.62)
Log(1+AG)*RI	-0.69	-1.02	-0.23	-0.56
	(-0.96)	(-1.34)	(-0.80)	(-1.57)
Controls	N	Y	N	Y
Adj. R^2	0.02	0.11	0.01	0.03
N	2643.23	2428.12	2643.23	2428.12

Chapter 2

Why Does Debt Dispersion Affect Yield Spreads?

Thomas Kjær Poulsen*

Abstract

I study predictions of rollover risk models and strategic debt service models on the negative relationship between corporate bond yield spreads and debt dispersion. Rollover risk models predict a more negative relationship for financially constrained firms, whereas strategic debt service models predict a less negative relationship. To test these predictions I run panel regressions of yield spreads on debt dispersion interacted with measures of financial constraints. I find that the relationship between yield spreads and debt dispersion is more negative for financially constrained firms consistent with rollover risk models.

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1 Introduction

A central question in the corporate bond literature is why some bonds have higher yield spreads than others. Yield spreads directly determine firms' debt financing costs and influence both financing and investment decisions. Understanding the determinants of yield spreads is therefore important not only for finance academics but also for finance professionals to inform corporate financial policies. In the literature there is a well-established negative relationship between yield spreads and debt dispersion (see e.g. Davydenko and Strebulaev (2007), Dass and Massa (2014), and Nagler (2019)). In this paper, I examine two possible explanations for this negative relationship: rollover risk and strategic debt service. According to both theories debt dispersion reduces yield spreads but for different reasons.

Theories of rollover risk argue that firms with more dispersed debt maturities have lower yield spreads because they are less likely to default (e.g. Choi et al. (2018)). Theories of strategic debt service argue that higher renegotiation frictions, which determine how difficult it is to renegotiate the firm's debt, reduce equity holders' incentive to default strategically and therefore results in lower yield spreads (e.g. Davydenko and Strebulaev (2007)). Empirically, measures of debt maturity dispersion and proxies for renegotiation frictions are often highly correlated. I therefore refer to these measures jointly as debt dispersion.

To disentangle these two candidate explanations from each other I examine how the relationship between yield spreads and debt dispersion depends on the level of financial constraints. I exploit the fact that financially constrained firms are more exposed to capital market conditions (see e.g. Gomes et al. (2006), Whited and Wu (2006), Livdan et al. (2009), and Li (2011)). In rollover risk models yield spreads should decrease more with debt maturity dispersion for financially constrained firms because they are more exposed to capital market conditions. In strategic debt service models the relationship between yield spreads and renegotiation frictions should be less negative for financially constrained firms. To derive this hypothesis I extend the strategic debt service model by Davydenko and Strebulaev (2007).

Davydenko and Strebulaev (2007) show that the relationship between yield spreads and renegotiation frictions is determined by a trade-off between two opposing effects. On the one hand, renegotiation frictions reduce the incentive for equity holders to threaten to default strategically with a view to obtain debt concessions. This strategic default effect decreases yield spreads because the probability of default decreases. On the other hand, renegotiation frictions also increase expected liquidation costs in bankruptcy because renegotiations are more likely to fail. This recovery effect increases yield spreads because expected recovery rates decrease. When equity holders have high bargaining power vis-á-vis debt holders, the strategic default effect dominates and vice versa.

To analyze the effects of financial constraints in strategic debt service models I make two extensions to the Davydenko and Strebulaev (2007) model. First, I assume that financially constrained firms borrow at higher rates consistent with the empirical evidence that financially constrained firms face higher costs of capital because they are more exposed to capital market conditions (see e.g. Gomes et al. (2006), Whited and Wu (2006), Livdan et al. (2009), and Li (2011)). Second, I assume that firms refinance maturing debt by issuing new debt.

The model shows that financial constraints strengthen the recovery effect because equity holders default more often as higher borrowing costs make it more expensive to refinance maturing debt. When equity holders have low bargaining power and the recovery effect dominates, higher financial constraints increase the recovery effect and make the relationship between yield spreads and renegotiation frictions more positive. When equity holders have high bargaining power, the relationship between yield spreads and renegotiation frictions should be *less negative* for financially constrained firms because the higher recovery effect offsets the strategic default effect. In fact the higher recovery effect may dominate for high levels of financial constraints such that the relationship between yield spreads and renegotiation frictions becomes positive.

In the empirical analysis I use Enhanced TRACE transaction data from 1 July 2002 to 30 June 2017 to compute yield spreads. I follow Choi et al. (2018) and measure debt maturity dispersion based on an inverse Herfindahl index of the firm's outstanding debt principal shares within specific maturity buckets. To proxy for renegotiation frictions I use the normalized number of bond issues similar to Davydenko and Strebulaev (2007). These two variables have a correlation coefficient of 0.76. My results are robust to using other measures of debt maturity dispersion and proxies for renegotiation frictions.

I regress yield spreads on either debt maturity dispersion or the normalized number of bond issues and control for well-known determinants from the literature. The coefficient estimates are negative and statistically significant. A one standard deviation increase in debt maturity dispersion (normalized number of bond issues) decreases yield spreads by 14.4 (12.7) basis points (bps) on average, which corresponds to almost 10% of the median yield spread. I also divide the sample into four groups based on bond ratings and run the same regression within each rating group. The absolute value of the coefficient estimates on debt maturity dispersion and the normalized number of bond issues increase with credit risk and remain statistically significant except for bonds rated AAA-AA. These findings are consistent with Davydenko and Strebulaev (2007), Dass and Massa (2014), and Nagler (2019).

To analyze the effects of financial constraints I consider three of the most widely used indexes of financial constraints. The WW index from Whited and Wu (2006), the SA index by Hadlock and Pierce (2010), and the KZ index used in Lamont et al. (2001) which builds on Kaplan and Zingales (1997). Higher index values correspond to higher levels of financial constraints. I interact these measures of financial constraints with either maturity dispersion or the normalized number of bond issues and regress yield spreads on the interaction variable and a set of controls. For all three measures, the coefficient estimate on the interaction variable is negative and mostly statistically significant. The relationship between yield spreads and debt dispersion is therefore more negative for financially constrained firms consistent with theories of rollover risk. For example, a one standard deviation increase in debt maturity dispersion (normalized number of bond issues) decreases yield spreads by up to 47.4 (22.2) bps on average for financially constrained firms.

Taken together, my findings show that the negative relationship between yield spreads and debt dispersion reflects rollover risk rather than strategic debt service concerns. My results are useful for understanding the survey evidence in Servaes and Tufano (2006) that firms' debt maturity decisions are mainly driven by a desire to mitigate rollover risk.

1.1 Related Literature

This paper belongs to the literature on debt maturity dispersion. Choi et al. (2018) study the firm's decision to spread out debt maturity dates across time. They document that firms increase debt maturity dispersion when they anticipate higher rollover risk and that maturities on newly issued debt depend on pre-existing maturity profiles. Dass and Massa (2014) find that firms with more dispersed maturities have lower yield spreads and attribute this finding to higher demand from institutional investors that economize on information-collection costs. Nagler (2019) also finds a negative relationship between yield spreads and maturity dispersion using a sample of S&P 500 firms. Davydenko and Strebulaev (2007) study the effects of strategic actions on yield spreads and argue that dispersed debt proxies for renegotiation frictions. They document a negative relationship between yield spreads and renegotiation frictions and show how this finding is consistent with strategic debt service models. None of these papers consider the impact of financial constraints.

My paper also contributes to the literature on debt maturity choice and rollover risk. Barclay and Smith (1995), Guedes and Opler (1996), and Stohs and Mauer (1996) study the determinants of average debt maturities while Gopalan et al. (2014) analyze the relationship between yield spreads and rollover risk. Diamond and He (2014) examine the effects of short and long-term debt on the debt overhang problem. He and Xiong (2012b), He and Milbradt (2014), and Chen et al. (2018) investigate how bond market illiquidity affects yield spreads through the debt rollover channel. Xu (2017) shows that firms often use early refinancing to extend debt maturity especially among speculative-grade firms. Harford et al. (2014) find that firms with more refinancing risk increase their cash holdings to mitigate rollover risk. None of these papers focus on debt maturity dispersion.

Finally, my paper also relates to the literature on strategic debt service. Anderson and Sundaresan (1996), Mella-Barral and Perraudin (1997), Fan and Sundaresan (2000), and Hege and Mella-Barral (2005) study how strategic debt service influences the pricing of debt and equity in contingent claims models. Christensen et al. (2014) consider strategic debt service when debt holders can reject non-credible threats by equity holders. Hackbarth et al. (2007) analyze the optimal mixture of public debt and bank debt when firms can renegotiate the bank debt outside of formal bankruptcy. Arnold and Westermann (2017) develop a model in which the firm can renegotiate debt both in financial distress and outside of distress.

2 Testable Hypotheses

This section presents testable hypotheses to guide the empirical analysis. I hypothesize the relationship between yield spreads and debt dispersion based on theories of rollover risk and strategic debt service. In Appendix A and B I formally derive the testable hypotheses in extended versions of the rollover risk model by Choi et al. (2018) and the strategic debt service model by Davydenko and Strebulaev (2007).

2.1 Rollover Risk

In rollover risk models firms face the risk that capital market conditions deteriorate when they have to redeem maturing debt. If conditions in capital markets deteriorate, the cost of refinancing maturing debt increases and in the most extreme case it may be impossible to raise new financing. The firm could therefore be forced to cut back on investments and/or liquidate assets to repay maturing debt. When the firm cannot repay its debt, debt holders recover less than their principal value due to liquidation costs in bankruptcy.

To mitigate the adverse effects of deteriorating capital market conditions firms can divide their total debt financing needs into smaller debt issues and spread out their maturity dates across time. If capital markets deteriorate, firms with dispersed debt maturities are less likely to default compared to firms with concentrated debt maturities that have to refinance a larger amount of debt. All else equal, bonds issued by firms with dispersed debt maturities therefore have lower yield spreads relative to firms with concentrated debt maturities.

Financially constrained firms are more exposed to capital market conditions and find it more difficult and/or costly to raise new financing in capital markets. All else equal, the effect of debt maturity dispersion on yield spreads is therefore more pronounced for financially constrained firms.

This prediction supports the following hypothesis:

HYPOTHESIS 1: *The relationship between yield spreads and debt maturity dispersion is more negative for financially constrained firms.*

2.2 Strategic Debt Service

In strategic debt service models equity holders can threaten to default strategically with a view to obtain debt concessions. Debt holders have incentives to renegotiate the debt because they can avoid liquidation costs in bankruptcy. Hart and Moore (1998) and Fan and Sundaresan (2000) identify two opposing effects that determine how the *possibility* to renegotiate debt affects yield spreads. On the one hand, the possibility to renegotiate enables debt holders to avoid liquidation cost they would otherwise incur ex post default. This recovery effect reduces yield spreads because expected recovery rates increase. On the other hand, the possibility to renegotiate may induce equity holders to default strategically more often. This strategic default effect increases yield spreads because the probability of default increases. The possibility to renegotiate therefore has an ambiguous impact on yield spreads.

Davydenko and Strebulaev (2007) examine the relationship between yield spreads and renegotiation frictions to infer how the possibility to renegotiate the firm's debt affects yield spreads. Renegotiation frictions determine how difficult it is to renegotiate between equity and debt holders. Suppose that q measures the difficulty of renegotiating and let s denote the yield spread. The derivative $\phi = \partial s/\partial q$ measures the sensitivity of yield spreads to renegotiation frictions. Davydenko and Strebulaev (2007) argue that if $\phi > 0$, it can either be because the strategic default effect is non-existent or because the recovery effect dominates the strategic default effect. Intuitively, higher renegotiation frictions reduce equity holders' incentives to default strategically which decrease yield spreads (i.e. the strategic default effect). However, higher renegotiation frictions also increase expected liquidation costs which increase yield spreads (i.e. the recovery effect). Davydenko and Strebulaev (2007) also argue that if $\phi < 0$, it must indicate that the strategic default effect exists and dominates the recovery effect.

If liquidation costs are strictly positive, the relative bargaining power of debt and equity holders determines whether the strategic default effect or the recovery effect dominates. When equity holders have all the bargaining power, they capture the entire bargaining surplus. In this case there is no recovery effect because debt holders cannot capture any surplus from bargaining. The strategic default effect therefore dominates meaning that $\phi < 0$. Under these conditions higher renegotiation frictions decrease yield spreads because equity holders have lower incentives to default strategically (i.e. the default probability decreases).

Suppose instead that debt holders have all the bargaining power. Equity holders have no incentive to default strategically as they cannot capture any surplus from bargaining. In this case there is no strategic default effect meaning that the recovery effect dominates and $\phi > 0$. Under these conditions higher renegotiation frictions increase yield spreads because the expected liquidation costs increases (i.e. the recovery rate decreases).

Gertner and Scharfstein (1991) and Bolton and Scharfstein (1996) show that free-rider and coordination problems make renegotiations more difficult when they involve many parties with competing interests. Davydenko and Strebulaev (2007) construct proxies for renegotiation frictions based on the firm's debt structure. Their measures include the normalized number of outstanding bond issues, a dispersion measure based on outstanding principal values, the ratio of outstanding public debt to total debt, and the ratio of short-term debt to total debt. In the Internet Appendix I show that empirically these proxies for renegotiations frictions are often highly correlated with measures of debt maturity dispersion.

Importantly, the trade-off between the recovery and the strategic default effect depends on the level of financial constraints. Suppose that financially constrained firms borrow at higher rates and that firms refinance maturing debt by issuing new debt. Financial constraints then strengthen the recovery effect because equity holders default more often as higher borrowing costs increase the cost of refinancing maturing debt. When equity holders have low bargaining power such that $\phi > 0$, higher financial constraints increase the recovery effect and make the relationship between yield spreads and renegotiation frictions more positive. When equity holders have high bargaining power, the relationship between yield spreads and renegotiation frictions should be *less negative* for financially constrained firms because the higher recovery effect offsets the strategic default effect. I summarize this prediction in the following hypothesis:

HYPOTHESIS 2: *The relationship between yield spreads and renegotiation frictions is less negative for financially constrained firms.*

3 Data and Variables

This section describes the data, sample requirements, and how I construct the main variables used in the empirical analysis. I also present summary statistics and correlations.

3.1 Data Sources

I obtain bond characteristics and ratings together with the amount outstanding from Mergent Fixed Income Securities Database (FISD). The amount outstanding data is available from April 1995 and records all changes in the principal amount outstanding for each bond issue over its lifetime. At a given point in time, I use the most recent rating from Standard & Poor's. If this rating is not available, I use the most recent rating from Moody's. If this rating is also missing, I use the most recent Fitch rating. For bonds that are initially rated by Moody's or Fitch, I keep the initial rating until a rating becomes available from Standard & Poor's. I collect bond transaction data from Enhanced TRACE and follow Dick-Nielsen (2014) to filter out erroneous trades as well as retail-sized transactions (trades below $100,000). The transaction data is available from 1 July 2002 to 30 June 2017. Finally, I obtain quarterly firm characteristics from COMPUSTAT, daily stock returns and the annual consumer price index from CRSP together with Treasury rates from the Federal Reserve Bank.

3.2 Sample Selection

The sample consists of bonds with fixed coupon rates and I exclude bonds that are callable at a fixed price, putable, convertible, denoted in foreign currency, or have sinking fund provisions. Similar to Powers and Tsyplakov (2008) and Bao and Hou (2017) I keep bonds with make-whole call provisions[1] in the sample because make-whole calls have little effect on bond prices.

In addition to bonds that are make-whole callable over their entire lifetime, there also exist a substantial number of hybrid bonds that have both make-whole and fixed-price call provisions. These hybrid bonds feature a make-whole call provision for the first part of their lifetime and eventually become callable at a fixed price after some pre-specified date listed in the bond indenture. They are often issued by speculative grade firms and these firms are typically more financially constrained. I therefore include bonds that are both make-whole callable and callable at a fixed price in the sample provided that they are in their make-whole call period and there is at least one year to the first date at which the bond can be called at a fixed price.

I exclude utilities and financial firms (SIC codes 4900-4999 and 6000-6999) from the sample because they are regulated and have special capital structures. I only consider non-defaulted bonds and exclude bonds with time-to-maturities less than one year or greater than 30 years. Lastly, a bond must have all data items necessary to calculate the main variables below to be included in the sample.

[1]The call price for a bond with a make-whole provision is the greater of (1) the principal value or (2) the sum of the present values of remaining scheduled payments of coupons and principal discounted with the yield-to-maturity on a similar maturity Treasury bond plus a fixed spread typically between 10 to 50 bps.

3.3 Main Variables

Yield Spreads

I use Enhanced TRACE data to calculate a bond's yield-to-maturity as the volume-weighted yield-to-maturity for all trades on the last day in each quarter where the bond traded. I calculate bond yields from transaction prices instead of using reported yields in TRACE because these can be unreliable (see Bao and Hou (2017)). The yield spread is then given by the yield-to-maturity minus the interpolated maturity-matched Treasury rate from the Federal Reserve Bank.

Debt Maturity Dispersion

I follow Choi et al. (2018) and use the Herfindahl index to measure the concentration of firms' debt structures from Mergent FISD. At the end of each quarter, I consider all the firm's outstanding bonds and aggregate them into the nearest integer maturity bucket measured in years. Let x_i denote firm j's principal amount maturing in maturity bucket i. The fraction of principal maturing in maturity bucket i relative to the firm's entire principal outstanding is therefore given by $w_i = x_i / \sum_i x_i$. I calculate a Herfindahl index of the firm's principal shares and measure the dispersion in the firm's debt structure as:

$$Maturity\ dispersion_j = 1/Herfindahl_j$$

where

$$Herfindahl_j = \sum_i (w_i)^2$$

Renegotiation Frictions

I use the main proxy for renegotiation frictions from Davydenko and Strebulaev (2007) which is the normalized number of bond issues. This proxy for renegotiation frictions measures the bond structure complexity per dollar of debt. At the end of each quarter, I count the firm's number of outstanding bond issues from Mergent FISD and determine the total principal value of outstanding debt from COMPUSTAT. The normalized number of bond issues for firm j is:

$$Norm.\ no.\ of\ issues_j = \frac{Log\,(Number\ of\ outstanding\ bond\ issues_j)}{Log\,(DLCQ_j + DLTTQ_j)}$$

where $DLCQ$ is "Debt in Current Liabilities" and $DLTTQ$ is "Long-Term Debt - Total" both from quarterly COMPUSTAT.

Financial Constraints

The literature on firms' financial constraints remains undecided on the superior measure of financial constraints. For this reason, I consider several different measures and focus on three of the most widely used in the literature. In particular, I use the WW index from Whited and Wu (2006), the SA index from Hadlock and Pierce (2010), and the KZ index from Lamont et al. (2001) which is based on Kaplan and Zingales (1997). These indexes include a specific set of accounting and market variables such as profitability, cash holdings, leverage, dividend payments etc. I explain the detailed construction of each index in Appendix C. For all three measures, higher index values correspond to higher levels of financial constraints.

Control Variables

The control variables include the following bond characteristics from Mergent FISD: coupon rate, time-to-maturity, bond age, and the principal amount outstanding. I also calculate a transaction based bid-ask spread to measure the illiquidity of each bond. To construct this variable I use historical buy-sell side information from Enhanced TRACE which requires at least one buy and one sell transaction on the same day for a given bond. The daily bid-ask spread is the volume-weighted ask price minus the volume-weighted bid price divided by the mid-price. For each bond, I define the quarterly bid-ask spread as the median daily bid-ask spread during each quarter.

I also include a set of firm characteristics typically used in the credit risk literature (see e.g. Davydenko and Strebulaev (2007), Dick-Nielsen et al. (2012), and Bao and Hou (2017)). In particular, I estimate equity volatility at the end of each quarter as the standard deviation of daily stock returns from CRSP over the preceding 60 trading days. I compute the firm's market leverage, the ratio of cash to total debt, the return on assets, and the book-to-market ratio from quarterly COMPUSTAT data. For each firm, I also compute the average maturity of all currently outstanding bonds weighted by their principal shares at the end of each quarter. I include a detailed description of all variables in Appendix C.

3.4 Merging the Data

I align a yield spread measured on the last day where the bond traded in quarter t with the bid-ask spreads measured within the same quarter[2]. The debt maturity dispersion, the normalized number of bond issues, and the estimated equity volatility are measured at the end of quarter $t-1$. I use

[2] By construction, the bid-ask spread is typically lagged in time compared to the yield spread because I use the median of daily bid-ask spreads within the same quarter. It may happen, however, that bid-ask spreads and yield spreads are measured on the same day.

the linking table from Wharton Research Data Services (WRDS Bond Returns) to merge bond-level information with equity volatility from CRSP for bonds/firms with non-overlapping linking dates. At the end of quarter $t-1$, I use the CRSP-COMPUSTAT linking table to merge the estimated equity volatility from CRSP with firm characteristics from COMPUSTAT for the fiscal quarter ending in calendar quarter $t-2$. This methodology ensures that COMPUSTAT data are lagged by 3-5 months compared to observations of yield spreads such that accounting information should be available to market participants when I observe market prices.

3.5 Summary Statistics and Correlations

Before calculating summary statistics, I winsorize the top and bottom 1% of yield spreads, normalized number of bond issues, bid-ask spreads, equity volatility, cash-to-debt ratios, return on assets, book-to-market ratios, and both the WW and KZ indexes[3] to mitigate the influence of outliers.

[INSERT TABLE 1]

Table 1 presents summary statistics for the entire sample and for four groups based on bond rating (AAA-AA, A, BBB, and SPEC). The table shows that average yield spreads increase monotonically with credit risk: the average yield spread is 76 bps for bonds rated AAA-AA, 110 bps for A, 190 bps for BBB, and 451 bps for SPEC. These estimates are somewhat higher compared to Feldhütter and Schaefer (2018) because they use swap rates to calculate yield spreads whereas I use Treasury rates. The positive relationship between yield spreads and credit risk, however, is well-known in the literature (see e.g. Longstaff et al. (2005), Davydenko and Strebulaev (2007), and Huang and Huang (2012)).

Table 1 also shows that on average, debt maturity dispersion decreases with the level of credit risk from 6.09 for AAA-AA rated bonds to 3.14 for SPEC rated bonds. The degree of maturity dispersion remains fairly similar between investment grade bonds, whereas issuers of speculative grade bonds have considerably less dispersed maturities. The average normalized number of bond issues shows the same patterns. The relatively flat relationship between average bid-ask spreads and credit risk partly reflects the fact that bonds with low credit risk on average have longer time-to-maturity relative to bonds with high credit risk. Since long-term bonds are typically more illiquid than short-term bonds it is not clear how bid-ask spreads should vary with credit risk without conditioning on time-to-maturity[4]. While average bond age remains fairly similar across rating groups, the average firm-level debt maturity decreases with credit risk. On average, bond

[3]The SA index is already winsorized by construction. See the detailed construction in Appendix C.

[4]See Feldhütter and Poulsen (2018) for a detailed analysis on the cross-sectional variation of bid-ask spreads across bond rating and maturity in the US corporate bond market.

size decreases substantially with credit risk: AAA-AA rated bonds have an average principal value of $827 millions compared to $437 millions for SPEC rated bonds. Both average equity volatility and leverage increase monotonically with credit risk while the average cash/debt ratio decreases with credit risk. Lastly, return on assets decreases with credit risk while the book/market ratio increases.

[INSERT TABLE 2]

Table 2 presents summary statistics on the financial constraints indexes. All three indexes increase monotonically with credit risk. This pattern highlights that issuers of lower-rated bonds are more financially constrained relative to issuers of higher-rated bonds. The fact that the average index values are negative reflects that firms in my sample (listed firms with rated corporate bonds) are typically less financially constrained relative to the remaining population of firms.

[INSERT TABLE 3]

I present correlation coefficients in Table 3. The correlations between yield spreads and the explanatory variables all have the expected sign. Yield spreads are positively correlated with bid-ask spreads, coupon rate, time-to-maturity, equity volatility, leverage, the book-to-market ratio, and indexes of financial constraints. The correlations with maturity dispersion, normalized number of bond issues, bond age, average firm maturity, amount outstanding, the cash-to-debt ratio, and return on assets are negative. These correlations, however, do not consider potential interaction effects with the remaining variables which I take into account in the next section. Maturity dispersion and the normalized number of bond issues are highly correlated with a correlation coefficient of 0.76. The correlation coefficients between measures of financial constraints are all positive: 0.29 between WW and SA, 0.07 between WW and KZ, and 0.03 between SA and KZ. The modest magnitude of these correlation coefficients mirrors the lack of agreement in the literature on how to measure financial constraints.

4 Empirical Results

In this section, I test the hypotheses from Section 2. First, I confirm the negative relationship between yield spreads and debt dispersion consistent with the existing literature. Second, I examine how this relationship depends on firms' financial constraints with a view to distinguish rollover risk from strategic debt service explanations. Third, I discuss robustness checks.

4.1 Yield Spreads and Debt Dispersion

I begin by analyzing the relationship between yield spreads and debt dispersion by estimating the following regression:

$$Yield\ spread_{ijt} = \beta_0 + \beta_1 Dispersion_{j,t-1} + \delta Controls_{ij,t-1} + \gamma_{it} + \epsilon_{ijt} \quad (1)$$

where $Yield\ spread_{ijt}$ is the yield spread on bond i issued by firm j measured in quarter t, and $Dispersion_{j,t-1}$ is either the debt maturity dispersion or the normalized number of bond issues measured at the end of quarter $t-1$, $Controls_{ij,t-1}$ is a vector of control variables, and γ_{it} is a quarter times rating fixed effect. Control variables include the bid-ask spread, coupon rate, time-to-maturity, bond age, the firm's average debt maturity, the bond's amount outstanding, equity volatility, leverage, cash/debt, return on assets, and book/market. In all regressions I cluster standard errors by firm and quarter to take into account that a firm may have several bonds outstanding at the same point in time. Rollover risk models predict that the coefficient estimate of β_1 is negative and strategic debt service models can generate the same prediction when the strategic default effect dominates.

[INSERT TABLE 4]

Table 4 presents estimates of equation (1) for the full sample and by bond rating when I use debt maturity dispersion as explanatory variable. The coefficient estimate of β_1 for the full sample is -0.048 and highly statistically significant. A one standard deviation increase in the dispersion measure decreases the yield spread by 14.4 bps on average which corresponds to almost 10% of the median yield spread (145.6 bps). For AAA-AA rated bonds, the coefficient estimate of β_1 is close to zero and statistically insignificant. The coefficient estimate remains negative and statistically significant for lower-rated bonds while the absolute magnitude of the coefficient estimate increases with the level of credit risk. For example, a one standard deviation increase in the dispersion measure decreases the average yield spread by 27 bps for speculative grade bonds. These findings are consistent with rollover risk models.

The remaining coefficient estimates are in line with the existing literature. The coefficient estimate on *Bid-ask spread* is positive and statistically significant consistent with the findings by e.g. Chen et al. (2007), Bao et al. (2011), and Dick-Nielsen et al. (2012) who also document a positive relationship between yield spreads and bond illiquidity measures. I obtain positive and statistically significant coefficient estimates on *Coupon rate* and *Log(time-to-maturity)* similar to Chen et al. (2007). The coefficient estimates on *Avg. firm maturity* are negative as in Bao and Hou (2017). Similar to Chen et al. (2007) and Bao et al. (2011) I obtain a negative coefficient estimate on *Log(amount outstanding)*. The coefficients on *Equity volatility* and *Leverage* are positive and statistically significant consistent with e.g. Davydenko and Strebulaev (2007). The results also show that firms with high cash-to-debt ratios typically have higher yield spreads consistent with Harford et al. (2014) who show that risky firms choose higher cash holdings to mitigate rollover risk. I also find that more profitable firms with higher return on assets have lower yield spreads while the coefficient estimates on book-to-market is mainly positive but statistically insignificant except for A-rated bonds.

[INSERT TABLE 5]

Table 5 presents estimates of equation (1) for the full sample and by bond rating when I use the normalized number of bond issues to proxy for renegotiation frictions. The results are almost identical to those in Table 4 because debt maturity dispersion and the normalized number of bond issues are highly positively correlated. For example, the coefficient estimate of β_1 is -1.273 and highly statistically significant for the full sample. A one standard deviation increase in the normalized number of bond issues decreases the yield spread by 12.7 bps on average. This economic magnitude is substantially higher compared to Davydenko and Strebulaev (2007) who find that a one standard deviation increase in their proxies for renegotiation frictions decrease average yield spreads by $1 - 8$ bps. I also find that the absolute magnitude of the coefficient estimate on the normalized number of bond issues tends to increase with the level of credit risk. These findings are consistent with strategic debt service models.

My results confirm that yield spreads decrease with debt dispersion. In rollover risk models this negative relationship reflects that firms with dispersed debt maturities have less rollover risk and therefore lower default risk and yield spreads. In models of strategic debt service higher renegotiation frictions reduce equity holders' incentive to default strategically because bargaining is more difficult. When this strategic default effect dominates, higher renegotiation frictions result in lower yield spreads. The results in Table 4 and 5 are therefore consistent with both explanations.

4.2 The Effect of Financial Constraints

I now investigate how the relationship between yield spreads and debt dispersion depends on the level of firms' financial constraints. Whited and Wu (2006), Hadlock and Pierce (2010), and Kaplan and Zingales (1997) divide firms into five groups based on financial constraints when they construct their indexes. In each quarter, I divide my sample into five groups based on the level of each financial constraint index. I construct a dummy variable which equals one when the firm belongs to the top quintile of the financial constraints index and equals zero otherwise. Next, I estimate the following regression:

$$
\begin{aligned}
Yield\ spread_{ijt} = {} & \beta_0 + \beta_1 Dispersion_{j,t-1} + \beta_2 HFC_{j,t-1} + \beta_3 Dispersion_{j,t-1} HFC_{j,t-1} \\
& + \delta Controls_{ij,t-1} + \gamma_{it} + \epsilon_{ijt} \qquad (2)
\end{aligned}
$$

where $Yield\ spread_{ijt}$ is the yield spread on bond i issued by firm j measured in quarter t, and $Dispersion_{j,t-1}$ is either the debt maturity dispersion or the normalized number of bond issues measured at the end of quarter $t-1$, $HFC_{j,t-1}$ is a dummy variable equal to one when the firm belongs to the high-financial-constraints quintile, $Controls_{ij,t-1}$ is a vector of control variables, and γ_{it} is a quarter times rating fixed effect. I use the same set of control variables and fixed effects as in equation (1) and continue to cluster standard errors by firm and quarter.

In addition, I also use the financial constraints index values themselves to estimate the following regression:

$$
\begin{aligned}
Yield\ spread_{ijt} = {} & \beta_0 + \beta_1 Dispersion_{j,t-1} + \beta_2 FCI_{j,t-1} + \beta_3 Dispersion_{j,t-1} FCI_{j,t-1} \\
& + \delta Controls_{ij,t-1} + \gamma_{it} + \epsilon_{ijt} \qquad (3)
\end{aligned}
$$

where $FCI_{j,t-1}$ is the financial constraint index value for firm j at time $t-1$. The remaining variables are the same as in equation (2). For equations (2) and (3), the coefficient estimate of β_3 should be negative according to Hypothesis 1 but positive according to Hypothesis 2.

[INSERT TABLE 6]

Panel A in Table 6 presents estimates of equation (2) for the three different measures of financial constraints when I use debt maturity dispersion as explanatory variable. The coefficient estimates on *Maturity dispersion* remain negative and statistically significant in all specifications when controlling for financial constraints. This finding means that debt maturity dispersion is not simply another measure of financial constraints already captured by the three indexes. The coefficient estimates on both the WW and SA indexes are positive and statistically significant meaning that more financially constrained firms on average have higher yield spreads. The KZ index has a negative coefficient estimate in some specifications akin to the finding by Lamont et al. (2001) that firms with higher KZ index values have lower average stock returns.

Importantly, the coefficient on the interaction variable between *Maturity dispersion* and *HFC* is negative using all three measures of financial constraints. This finding means that the relationship between yield spreads and debt maturity dispersion is more negative for financially constrained firms consistent with rollover risk models. For example, a one standard deviation increase in debt maturity dispersion decreases yield spreads by 47.4 bps on average $(3.00 * (-0.035 - 0.123) = -0.474)$ for financially constrained firms using the WW index. In Panel B, I use the actual index values of financial constraints to estimate equation (3) and obtain virtually the same results as in Panel A.

The coefficient estimate on β_3 using the SA index is statistically insignificant in Panel A. The SA index is based on a combination of firm age and firm size measured by total assets. To calculate the index firm age is capped at 37 years while total assets are capped at $4.5 billions measured in 2004 dollars. These thresholds may not be reasonable for my sample of listed firms with rated corporate bonds because these firms are much older and larger than the average firm. In fact 45% of the observations in my sample have the lowest possible SA index value because firms exceed the size and/or age thresholds. In untabulated results I replace the FCI variable in equation (3) with either firm size or firm age. The coefficient estimates on β_3 are now positive (because larger firms and older firms are less constrained) and have t-statistics of 5.62 when I use firm size and 1.86 when I use firm age. When I use dummy variables instead as in equation (2) the coefficient estimates on β_3 remain positive and have t-statistics of 2.39 for both size and age. These results provide additional evidence on the effects of financial constraints consistent with Hennessy and Whited (2007) who argue that firm size is the most important proxy for financial constraints.

[INSERT TABLE 7]

Table 7 presents estimates of equation (2) and (3) when I use the normalized number of bond issues as explanatory variable. Again, the results are almost identical to Table 6 because of the high correlation between debt maturity dispersion and the normalized number of bond issues. For example, the coefficient estimate on the interaction variable between *Norm. no. of issues* and *HFC* is negative using all three measures of financial constraints. A one standard deviation increase in the normalized number of bond issues decreases yield spreads by 22.2 bps on average $(0.10 * (-1.062 - 1.174) = -0.222)$ for financially constrained firms using the KZ index. Panel B shows that the coefficient estimates on β_3 remain negative when I use the actual index values of financial constraints to estimate equation (3). In untabulated results I replace FCI with firm size or firm age and obtain positive coefficient estimates with t-statistics of 1.86 and 1.59, respectively. These findings show that the relationship between yield spreads and renegotiation frictions is more negative for financially constrained firms in contrast to the prediction from strategic debt service models.

Taken together, my findings support Hypothesis 1 and are inconsistent with Hypothesis 2. The empirical evidence supports rollover risk models in which the effect of debt maturity dispersion on yield spreads is more pronounced for financially constrained firms. My results are inconsistent with strategic debt service models because these models predict a less negative relationship between yield spreads and renegotiation frictions for firms with higher levels of financial constraints.

4.3 Robustness Checks

In the main analysis I use the inverse Herfindahl measure to quantify debt maturity dispersion. Choi et al. (2018) point out that this measure may not capture all aspects of firms' debt maturity profiles. For example, this measure does not distinguish between maturity dates in the near future and maturity dates in the more distant future. Moreover, the inverse Herfindahl measure may be affected by the longest feasible maturity a firm can issue. For example, if a firm cannot issue debt with maturities greater than five years then the Herfindahl index will be greater than or equal to 0.2. To alleviate these concerns, Choi et al. (2018) develop two additional dispersion measures: an inverse weighted Herfindahl index that gives more weight to short-term debt and a dispersion measure based on the distance from a perfectly dispersed debt maturity profile. As a robustness check I repeat the main analysis using both of these dispersion measures. The results are similar to those presented above and a full summary can be found in the Internet Appendix together with a detailed explanation on how to construct the additional dispersion measures.

I also consider other proxies for renegotiation frictions than the normalized number of bond issues. Davydenko and Strebulaev (2007) also use an inverse Herfindahl index of bond principal values, the fraction of public debt to total debt, and the fraction of short-term debt to total debt to proxy for renegotiation frictions. I present the results using these proxies in the Internet Appendix which are broadly similar to those presented above.

5 Conclusion

In this paper, I document that the negative relationship between yield spreads and debt dispersion is more pronounced for financially constrained firms. I show that this finding supports theories of rollover risk where dispersed debt maturities reduce default risk and therefore also yield spreads. The negative relationship is more pronounced for financially constrained firms because they are more exposed to capital market conditions.

The negative relationship between yield spreads and debt dispersion could also be consistent with theories of strategic debt service. In these models dispersed debt proxies for renegotiation frictions which reduce equity holders' incentive to default strategically. This strategic default effect tends to decrease yield spreads. However, renegotiation frictions also increase expected liquidation costs in bankruptcy. This recovery effect tends to increase yield spreads. I show that the recovery effect is more pronounced for financially distressed firms because they have higher default risk. As a result, the relationship between yield spreads and renegotiation frictions should be less negative for financially constrained firms. This prediction is inconsistent with the empirical evidence found in this paper.

Taken together, my results shed new light on how and why debt maturity profiles are priced in the cross-section of yield spreads. My results are useful for understanding the survey evidence in Servaes and Tufano (2006) that firms' debt maturity decisions are mainly driven by a desire to mitigate rollover risk. Moreover, the empirical evidence rationalizes the findings by Choi et al. (2018) that firms increase debt maturity dispersion when they anticipate higher rollover risk and explains why maturities on newly issued debt depend on pre-existing maturity profiles. It remains an interesting question to explore how demand from institutional investors as in Dass and Massa (2014) may be related to firms' financial constraints. I leave this question for future research.

Appendices

A Rollover Risk Model

In this section, I include liquidation costs and risky debt into the rollover risk model by Choi et al. (2018) to derive Hypothesis 1. For ease of exposition, I do not consider growth options and issuance costs of debt as in Choi et al. (2018) but only focus on the pricing of debt. The model has three time periods separated by four dates t_0, t_1, t_2, and t_3. The firm is initially all-equity financed and has assets in place with a market value of A. At time t_0, the firm invests in a project which requires a capital outlay of $I > A$. This project generates three cash flows: an intermediate cash flow c at both times t_1 and t_2 together with a final cash flow I at time t_3. The risk-free rate is zero.

The firm finances the required investment spending $I - A$ at time t_0 by issuing one- or two-period debt with the same seniority. In turn the firm must roll over its debt before time t_3. At times t_1 and t_2, the debt market may freeze with probability δ. If the debt market freezes, the firm cannot roll over maturing debt and must repay the debt holders from intermediate cash flows or default on the debt. The principal value of maturing debt is B so the firm repays the debt when $B \leq c$ and defaults when $B > c$ in case the debt market freezes. When the firm defaults, debt holders recover a fraction $(1 - \alpha)$ of the debt principal where α reflects liquidation costs in bankruptcy.

Now, consider two firms with different initial debt structures. Firm D issues two bonds at time t_0 with the same principal value $B_1^D = B_2^D = (I - A)/2$. Bond 1 matures at time t_1 and bond 2 matures at time t_2 such that the firm has a perfectly *dispersed* debt maturity profile. Firm C only issues one bond with principal value $B^C = (I - A)$ and therefore has a perfectly *concentrated* debt maturity profile. This firm is indifferent between choosing maturity date t_1 or t_2 because the probability of a debt market freeze remains the same in both periods. Without loss of generality I therefore assume that the bond matures at time t_2.

I require that $I - A > c > (I - A)/2$ and that any excess cash remaining after rolling over debt is paid out as dividends to the equity holders in each time period together with the restriction that the firm cannot issue new equity. The first inequality entails that the intermediate cash flow c is insufficient to repay the debt principal for Firm C. Firm C will therefore default in case the debt market freezes. The second inequality states that firm D can repay the debt principal out of the intermediate cash flow and therefore do not default if the debt market freezes.

Firm D's debt is risk-free because the firm never defaults. The market value of its total debt D^D is therefore equal to the total principal value:

$$D^D = B_1^D + B_2^D = I - A \tag{A.1}$$

Firm C may default at time t_2 in which case the debt holders recover less than the principal value due to liquidation costs. Firm C's debt is therefore risky and has a market value of:

$$D^C = (I - A) - \delta\alpha(I - A) \tag{A.2}$$

where the first term is the risk-free value and the second term is the expected present value of liquidation costs.

Firm D and C represent the two extremes of perfectly dispersed and perfectly concentrated debt maturity profiles, respectively. One way to think about firms with intermediate debt maturity dispersion is to consider a weighted average between these two extremes. Let D^I denote the market value of a bond issued by a firm with intermediate debt maturity dispersion:

$$\begin{aligned} D^I &= qD^D + (1 - q)D^C \\ &= q(I - A) + (1 - q)\Big((I - A) - \delta\alpha(I - A)\Big) \end{aligned} \tag{A.3}$$

where q denotes the weight in the perfectly dispersed debt maturity profile. Differentiating D^I with respect to q yields:

$$\frac{\partial D^I}{\partial q} = \delta\alpha(I - A) > 0 \tag{A.4}$$

meaning that bond prices increase with the level of debt maturity dispersion. Conversely, yield spreads decrease with debt maturity dispersion.

Gomes et al. (2006), Whited and Wu (2006), Livdan et al. (2009), and Li (2011) find that financially constrained firms face higher cost of capital. Based on their findings, I assume that the probability that a given firm experiences a debt market freeze has two components: $\delta = \delta_M + \delta_I$ where δ_M reflects the market-wide probability and δ_I reflects an idiosyncratic part. Since financially constrained firms are more exposed to capital market conditions, I assume that δ_I increases with the level of financial constraints.

HYPOTHESIS 1: *Differentiating* $\frac{\partial D^I}{\partial q}$ *with respect to* δ *yields*

$$\frac{\partial D^I}{\partial q \partial \delta} = \alpha(I - A) > 0 \tag{A.5}$$

meaning that bond prices increase more with debt maturity dispersion when δ *is higher i.e. when the firm is more financially constrained. Conversely, the relationship between yield spreads and debt maturity dispersion is more negative for financially constrained firms.*

I note that the model also gives rise to an additional testable hypothesis on the effect of liquidation costs. The derivative $\frac{\partial D^I}{\partial q \partial \alpha} = \delta(I - A) > 0$ meaning that the relationship between yield spreads and debt maturity dispersion should be more negative the higher the level of liquidation costs. I do not focus on this hypothesis in the paper because strategic debt service models generate the same prediction and it is therefore not possible to distinguish the two models from each other based on this prediction.

B Strategic Debt Service Model

In this section, I extend the strategic debt service model by Davydenko and Strebulaev (2007) by introducing costly financial constraints. In particular, I assume that financially constrained firms borrow at higher rates and that firms refinance maturing debt by issuing new debt. I then use the extended model to derive Hypothesis 2.

The firm has assets-in-place that follows a geometric Brownian motion under the equivalent martingale measure $\mathbb{Q}$:

$$dV_t = (r - \beta)V_t dt + \sigma V_t dZ_t \tag{B.1}$$

where r is the risk-free rate, β is the payout ratio, σ is the volatility, and dZ_t is the increment of a standard Brownian motion $\{Z_t : 0 \leq t < \infty\}$ under $\mathbb{Q}$.

The firm is financed by both debt and equity. If the firm defaults and the claims are settled in bankruptcy court, the firm incurs proportional liquidation costs of αV where V is the market value of assets at default. Alternatively, the debt and equity holders can renegotiate the debt contract at no cost by agreeing on a debt-for-equity swap. Renegotiation fails with probability q for exogenous reasons in which case the claims are settled in bankruptcy court according to the absolute priority rule. The parameter q reflects frictions that impede the renegotiation process such as having dispersed debt holders. In renegotiation, the equity and debt holders play a Nash bargaining game with bargaining power η and $1-\eta$ respectively. Fan and Sundaresan (2000) show that this game results in an optimal sharing rule where equity holders get $\eta\alpha V_R$ and debt holders get $(1 - \eta\alpha)V_R$ where V_R denotes the market value of assets at the endogenous debt renegotiation boundary.

The firm issues zero-coupon bonds with an aggregate principal value B. Each bond mature with Poisson intensity m meaning that the expected time-to-maturity is $\frac{1}{m}$ as in Cheng and Milbradt (2012), He and Xiong (2012a), Chen et al. (2018), Friewald et al. (2018), and Nagler (2019). The firm commits to keep the aggregate principal value constant through time. At each instant in time, the firm therefore repays an expected principal amount mB and immediately issues new bonds to keep the aggregate principal value constant. Debt holders may require a premium δ in excess of the risk-free rate when they discount cash flows. The parameter δ reflects that debt holders require higher compensation when they lend to financially constrained firms. This assumption is consistent with my empirical findings in Table 6 and 7 that bonds issued by financially constrained firms typically have higher yield spreads.

The market value of debt $D(V)$ is the solution to the ordinary differential equation (ODE):

$$(r+\delta)D = \frac{1}{2}\sigma^2 V^2 D_{VV} + (r-\beta)VD_V + m(B-D) \tag{B.2}$$

where subscripts denote partial derivatives. The equation states that the required return on the left-hand side must equal the expected return on the right-hand side. The first two terms is the expected change in the value of debt when V fluctuates. The third term is the change in debt value from retiring maturing debt at principal value and issuing new debt at market value.

The general solution to equation (B.2) is given by:

$$D(V) = d_2 V^\gamma + \frac{mB}{r+m+\delta} \tag{B.3}$$

where

$$\gamma = \left[\frac{1}{2} - \frac{r-\beta}{\sigma^2}\right] - \sqrt{\left[\frac{1}{2} - \frac{r-\beta}{\sigma^2}\right]^2 + \frac{2(r+m+\delta)}{\sigma^2}} < 0 \tag{B.4}$$

and the coefficient d_2 is determined by the value-matching condition at the renegotiation boundary V_R:

$$D(V_R) = (1-q)(1-\eta\alpha)V_R + q(1-\alpha)V_R \tag{B.5}$$

which is given by:

$$d_2 = (1 + q\alpha(\eta-1) - \eta\alpha)V_R^{1-\gamma} - \frac{mB}{r+m+\delta}V_R^{-\gamma} \tag{B.6}$$

The market value of debt is therefore given by:

$$D(V) = \frac{mB}{r+m+\delta} - \left[\frac{mB}{r+m+\delta} - (1 + q\alpha(\eta-1) - \eta\alpha)V_R\right]\left(\frac{V}{V_R}\right)^\gamma \tag{B.7}$$

where the first term is the risk-free value of debt and the second term is the expected present value of renegotiation and liquidation costs.

The market value of equity $E(V)$ is the solution to the differential equation:

$$rE = \frac{1}{2}\sigma^2 V^2 E_{VV} + (r-\beta)VE_V + \beta V - m(B-D) \tag{B.8}$$

The equation states that the required return on the left-hand side must equal the expected return on the right-hand side. The first two terms is the expected change in the value of equity when V fluctuates. The third term is the cash flow paid to equity holders per unit time and the fourth term is debt rollover costs.

The general solution to equation (B.8) is given by[5]:

$$E(V) = e_2 V^{\lambda} + V - \frac{mB}{r} + m\left(\frac{d_2 V^{\gamma}}{r - \gamma(r-\beta) - \frac{1}{2}(\gamma - 1)\gamma\sigma^2} + \frac{mB}{r(r+m+\delta)}\right) \tag{B.9}$$

where

$$\lambda = \left[\frac{1}{2} - \frac{r-\beta}{\sigma^2}\right] - \sqrt{\left[\frac{1}{2} - \frac{r-\beta}{\sigma^2}\right]^2 + \frac{2r}{\sigma^2}} < 0 \tag{B.10}$$

and the coefficient e_2 is determined by the value-matching condition at the renegotiation boundary V_R:

$$E(V_R) = (1-q)\eta\alpha V_R \tag{B.11}$$

which is given by:

$$e_2 = \left[(1-q)\eta\alpha V_R - V + \frac{mB}{r} - m\left(\frac{d_2 V^{\gamma}}{r - \gamma(r-\beta) - \frac{1}{2}(\gamma - 1)\gamma\sigma^2} + \frac{mB}{r(r+m+\delta)}\right)\right] V_R^{-\lambda} \tag{B.12}$$

where d_2 is defined in equation (B.6). The market value of equity is therefore available in closed form and the endogenous renegotiation boundary V_R is determined by the smooth pasting condition:

$$\left.\frac{\partial E(V)}{\partial V}\right|_{V=V_R} = (1-q)\eta\alpha \tag{B.13}$$

The yield spread s on the firm's bonds is given by:

$$s = \frac{m(B - D(V))}{D(V)} - r \tag{B.14}$$

The model is entirely solved in closed-form including the endogenous renegotiation boundary. To derive the testable hypothesis, I parametrize the model using parameter values from the credit risk literature. In particular, I use $r = 0.05$, $\beta = 0.03$, $\sigma = 0.2$, $\alpha = 0.45$, $m = 0.2$, $B = 0.75$, and $V_0 = 1$. In Figure A.1, I study the effects of renegotiation frictions and financial constraints on yield spreads. The dashed line denotes a firm with low financial constraints $\delta = 0$ and the solid line is a firm with high financial constraints $\delta = 0.02$.

[INSERT FIGURE A.1]

Panel A in figure A.1 shows that the renegotiation boundary V_R increases with renegotiation frictions q for both firms when equity holders have low bargaining power ($\eta = 0.05$). The reason is that higher renegotiation frictions increase the probability that renegotiation fails in which case

[5] Dick-Nielsen et al. (2018) derive this type of general solution to the differential equation for equity.

the debt holders have to incur liquidation costs. Since equity holders have low bargaining power, they have low incentives to default strategically because they cannot capture much bargaining surplus. As a result, the higher expected liquidation costs increase yield spreads and make debt rollover more costly. Equity holders therefore default sooner meaning that V_R increases with q because the recovery effect dominates.

Panel C indeed shows that the recovery effect dominates i.e. yield spreads increase with renegotiation frictions. This graph also shows that the more financially constrained firm ($\delta = 0.02$) pay higher yield spreads relative to the other firm because debt holders require a premium to hold bonds in financially constrained firms. It is difficult to see from the graph but the slope of the curve for the financially constrained firm is higher compared to the firm with $\delta = 0$. Panel E plots the derivative of the yield spread with respect to renegotiation frictions for a firm with $q = 0.2$ and a firm with $q = 0.8$. In both cases the derivative increases with δ meaning that yield spreads increase more with renegotiation frictions the higher the level of financial constraints. The reason is that the recovery effect increases with δ.

Panel B in figure A.1 shows that the renegotiation boundary decreases with renegotiation frictions for the two firms with high equity bargaining power $\eta = 0.95$. This relationship reflects that higher renegotiation frictions make it less attractive for equity holders to default strategically because bargaining becomes more difficult. Panel D shows that the strategic default effect dominates for the financially unconstrained firm ($\delta = 0$) meaning that the yield spread decreases with q. In contrast, the yield spread for the financially constrained firm ($\delta = 0.02$) first increases and then decreases with q. The reason is that this firm has higher default risk cf. Panel B which makes the recovery effect more pronounced. For low values of q, the recovery effect dominates whereas for higher values of q the strategic default effect dominates. Importantly, the slope of the curve for the financially constrained firm remains less negative (and positive for low values of q) relative to the firm with $\delta = 0$. Panel F shows this feature more clearly by plotting the derivative of the yield spread with respect to renegotiation frictions. This derivative increases with the level of δ meaning that yield spreads decrease less (or even increase) with q the higher the level of financial constraints.

Notice that the derivative of the yield spread with respect to renegotiation frictions increase with δ in both panel E and F i.e. regardless of the level of equity holders' bargaining power. I summarize this result in the following hypothesis:

HYPOTHESIS 2: *The recovery effect increases with δ. For low values of η where the recovery effect dominates and the derivative $\frac{\partial s}{\partial q}$ is positive when $\delta = 0$, the derivative $\frac{\partial s}{\partial q \partial \delta} > 0$. Yield spreads therefore increase more with renegotiation frictions the higher the level of financial constraints. For* *high values of η where the strategic default effect dominates and the derivative $\frac{\partial s}{\partial q}$ is negative when $\delta = 0$, the derivative $\frac{\partial s}{\partial q \partial \delta} > 0$. The relationship between yield spreads and renegotiation frictions is therefore less negative (and may become positive) the higher the level of financial constraints.*

C Definition of Variables

This section contains the detailed variable descriptions. The capitalized acronyms correspond to quarterly COMPUSTAT data items and subscripts refer to the calendar time.

Bond Characteristics

BA_t	The bond's bid-ask spread in quarter t is the median of daily bid-ask spreads in the same quarter calculated as: $$BA_t = \frac{A_t - B_t}{\frac{1}{2}(A_t + B_t)}$$ where A_t and B_t are volume-weighted ask and bid prices from Enhanced TRACE.
CR_t	The coupon rate from Mergent FISD.
MAT_t	The remaining time-to-maturity as of the trade day where the yield spread is calculated.
AGE_t	The bond's age as of the trade day where the yield spread is calculated.
AMT_t	The bond's amount outstanding from Mergent FISD on the day where the yield spread is calculated.

The table continues on the next page.

Firm Characteristics

$FMAT_t$	The firm's average debt maturity is the principal-weighted time-to-maturity of all the firm's outstanding bond's at the end of quarter t.
VOL_t	Equity volatility at the end of quarter t is the standard deviation of daily stock returns from CRSP over the preceding 60 trading days. I only consider common stocks (SHRCD equal to 10 or 11 in CRSP) and require at least 20 observations in the estimation window. If a firm has several share classes, I calculate the weighted equity volatility based on the market capitalization of each share class.
LEV_t	The leverage ratio at the end of quarter t is: $$LEV_t = \frac{DLCQ_t + DLTTQ_t}{DLCQ_t + DLTTQ_t + CSHOQ_t * PRCCQ_t}$$ where $DLCQ_t$ is "Debt in Current Liabilities", $DLTTQ_t$ is "Long-Term Debt - Total", $CSHOQ_t$ is "Common Shares Outstanding", and $PRCCQ_t$ is "Price Close - Quarter".
CD_t	The cash/debt ratio at the end of quarter t is: $$CD_t = \frac{CHEQ_t}{DLCQ_t + DLTTQ_t}$$ where where $DLCQ_t$ is "Debt in Current Liabilities", $DLTTQ_t$ is "Long-Term Debt - Total", and $CHEQ_t$ is "Cash and Short-Term Investments".
ROA_t	The return on assets in quarter t is: $$ROA_t = \frac{OIBDPQ_t}{ATQ_{t-1}}$$ where $OIBDPQ_t$ is "Operating Income Before Depreciation - Quarterly", and ATQ_t is "Assets - Total".
BM_t	The book/market ratio at the end of quarter t is: $$BM_t = \frac{CEQ_t}{CSHOQ_t * PRCCQ_t}$$ where CEQ_t is "Common/Ordinary Equity - Total", $CSHOQ_t$ is "Common Shares Outstanding", and $PRCCQ_t$ is "Price Close - Quarter".

The table continues on the next page.

Financial Constraints Indexes

WW_t The Whited and Wu (2006) index in quarter t is:

$$WW_t = -0.091 * \frac{IBQ_t + DPQ_t}{ATQ_t} - 0.062 * \mathbb{1}_{\{DVY_t + DVPQ_t > 0\}} + 0.021 * \frac{DLTTQ_t}{ATQ_t}$$
$$-0.44 * log(ATQ_t) + 0.102 * ISG_t - 0.035 * \frac{SALEQ_t}{SALEQ_{t-1}}$$

where IBQ_t is "Income Before Extraordinary Items", DPQ_t is "Depreciation and Amortization - Total", and ATQ_t is "Assets - Total", DVY_t is "Cash Dividends", $DVPQ_t$ is "Dividends/Preferred/Preference", $DLTTQ_t$ is "Long Term Debt - Total", ISG_t is the three-digit industry-average sales growth based on SIC codes, and $SALEQ_t$ is "Sales/Turnover (Net)".

SA_t The Hadlock and Pierce (2010) index in quarter t is:

$$SA_t = -0.737 * SIZE_t + 0.043 * SIZE_t^2 - 0.040 * AGE_t$$

where $SIZE_t$ is the logarithm of inflation-adjusted ATQ_t "Assets - Total" measured in 2004 dollars and AGE_t is the number of years the firm has a non-missing stock price in COMPUSTAT i.e. $PRCCQ_t$ which is "Price Close - Quarter". Following Hadlock and Pierce (2010) $SIZE_t$ is capped at log($4.5 billion) and AGE_t is capped at 37 years in case the actual values exceed these thresholds. I use the $CPIIND_t$ variable from CRSP which is "Index Level Associated with Consumer Price Index" to inflation-adjust total assets.

KZ_t The Kaplan and Zingales (1997) index from Lamont et al. (2001) is calculated based on annual COMPUSTAT data:

$$KZ_t = -1.002 * \frac{IB_t + DP_t}{PPENT_{t-1}} + 0.283 * \frac{AT_t + CSHO_t * PRCC\_F_t - CEQ_t - TXDB_t}{AT_t}$$
$$+3.139 * \frac{DLTT_t + DLC_t}{DLTT_t + DLC_t + SEQ_t} - 39.368 * \frac{DVC_t + DVP_t}{PPENT_{t-1}} - 1.315 * \frac{CHE_t}{PPENT_{t-1}}$$

where IB_t is "Income Before Extraordinary Items", DP_t is "Depreciation and Amortization", $PPENT_t$ is "Property, Plant and Equipment - Total (Net)", AT_t is "Assets - Total", $CSHO_t$ is "Common Shares Outstanding", $PRCC\_F_t$ is "Price Close - Annual - Fiscal", CEQ_t is "Common/Ordinary Equity - Total", $TXDB_t$ is "Deferred Taxes Balance Sheet", $DLTT_t$ is "Long Term Debt - Total", DLC_t is "Debt in Current Liabilities - Total", SEQ_t is "Stockholders' Equity - Total", DVC_t is "Dividends Common/Ordinary", DVP_t is "Dividends - Preferred/Preference", and CHE_t is "Cash and Short-Term Investments".

Table 1: Summary Statistics on Bonds

This table presents summary statistics for the entire sample and by bond rating. The data frequency is quarterly and Appendix C contains a detailed description of how I construct all variables. *Yield spread*, *Bid-ask spread*, and *Coupon rate* are measured in percent. *Time-to-maturity*, *Bond age*, and *Avg. firm maturity* are measured in years. *Amount outstanding* is in millions of US dollars and *Equity volatility* is in annualized percent. *Leverage*, *Cash/debt*, and *Return on assets* are measured in percent. Data are from Enhanced TRACE, Federal Reserve Bank, Mergent FISD, COMPUSTAT, and CRSP. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). I report sample averages and include standard deviations in parentheses.

		Bond Rating			
	All	AAA-AA	A	BBB	SPEC
Yield spread	2.15	0.76	1.10	1.90	4.51
	(2.01)	(0.53)	(0.78)	(1.37)	(2.47)
Maturity dispersion	5.00	6.09	5.63	5.33	3.14
	(3.00)	(2.71)	(2.86)	(3.17)	(2.05)
Norm. no. of issues	0.21	0.25	0.23	0.22	0.15
	(0.10)	(0.09)	(0.09)	(0.10)	(0.10)
Bid-ask spread	0.38	0.36	0.38	0.37	0.39
	(0.44)	(0.42)	(0.43)	(0.46)	(0.44)
Coupon rate	5.97	4.70	5.37	5.91	7.35
	(1.83)	(1.88)	(1.69)	(1.66)	(1.43)
Time-to-maturity	9.32	9.51	9.94	9.82	7.52
	(8.01)	(8.77)	(8.81)	(8.40)	(5.05)
Bond age	4.40	4.67	4.67	4.26	4.19
	(3.98)	(4.75)	(4.13)	(3.65)	(4.03)
Avg. firm maturity	9.93	10.88	10.98	10.27	7.57
	(4.28)	(4.19)	(4.35)	(4.29)	(3.15)
Amount outstanding	574.95	827.18	638.93	551.99	436.54
	(514.30)	(711.49)	(527.03)	(500.92)	(358.58)
Equity volatility	30.37	21.28	25.16	29.88	41.54
	(17.20)	(9.77)	(12.63)	(15.28)	(21.73)
Leverage	28.53	15.84	20.57	28.54	43.71
	(16.88)	(11.42)	(11.22)	(13.67)	(18.89)
Cash/debt	36.79	82.68	44.54	28.94	23.38
	(55.82)	(91.05)	(60.81)	(43.95)	(36.70)
Return on assets	3.66	4.61	4.13	3.53	2.91
	(1.87)	(2.00)	(1.67)	(1.73)	(1.98)
Book/market	0.47	0.29	0.35	0.50	0.63
	(0.31)	(0.15)	(0.19)	(0.29)	(0.41)
Firms	1,153	75	286	527	616
Bonds	5,785	631	1,828	2,683	1,694
N	60,012	5,147	17,181	24,411	13,273

Table 2: Summary Statistics on Financial Constraints Indexes

This table presents summary statistics for the entire sample and by bond rating. The data frequency is quarterly and Appendix C contains a detailed description of how I construct the variables. The indexes for financial constraints are from Whited and Wu (2006) (WW), Hadlock and Pierce (2010) (SA), and Kaplan and Zingales (1997) (KZ). Data are from COMPUSTAT. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). I report sample averages and include standard deviations in parentheses.

		Bond Rating			
	All	AAA-AA	A	BBB	SPEC
WW index	-4.35	-4.95	-4.62	-4.31	-3.84
	(0.61)	(0.57)	(0.51)	(0.50)	(0.52)
SA index	-4.30	-4.49	-4.41	-4.29	-4.07
	(0.43)	(0.27)	(0.34)	(0.44)	(0.49)
KZ index	-4.37	-12.61	-5.16	-3.61	-1.54
	(9.67)	(13.25)	(7.88)	(9.17)	(9.13)
Firms	1,153	75	286	527	616
Bonds	5,785	631	1,828	2,683	1,694
N	60,012	5,147	17,181	24,411	13,273

Table 3: Correlations

This table shows Pearson correlation coefficients between all variables. Appendix C contains a detailed description of how I construct all variables. Data are from Enhanced TRACE, Federal Reserve Bank, Mergent FISD, COMPUSTAT, and CRSP. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999).

	YS	MD	NNI	BA	CR	MAT	AGE	FMAT	AMT	VOL	LEV	CD	ROA	BM	WW	SA	KZ
Yield spread (YS)	1.00																
Maturity dispersion (MD)	-0.28	1.00															
Norm. no. of issues (NNI)	-0.26	0.76	1.00														
Bid-ask spread (BA)	0.26	-0.03	-0.01	1.00													
Coupon rate (CR)	0.44	-0.23	-0.21	0.11	1.00												
Log(time-to-maturity) (MAT)	0.08	0.12	0.02	0.22	0.14	1.00											
Log(bond age) (AGE)	-0.00	0.04	0.02	0.16	0.37	-0.09	1.00										
Avg. firm maturity (FMAT)	-0.20	0.42	0.25	0.10	-0.08	0.42	0.11	1.00									
Log(amt. outstanding) (AMT)	-0.14	0.15	0.01	-0.17	-0.26	0.12	-0.25	0.16	1.00								
Equity volatility (VOL)	0.63	-0.18	-0.13	0.21	0.30	-0.03	-0.01	-0.13	-0.13	1.00							
Leverage (LEV)	0.52	-0.05	-0.01	0.07	0.39	-0.05	0.03	-0.17	-0.10	0.38	1.00						
Cash/debt (CD)	-0.14	-0.02	-0.05	-0.00	-0.18	0.03	-0.04	0.08	0.10	-0.05	-0.41	1.00					
Log(1+ret. on assets) (ROA)	-0.29	-0.00	-0.04	-0.06	-0.18	0.03	-0.08	0.08	0.07	-0.22	-0.45	0.12	1.00				
Log(book/market) (BM)	0.28	-0.10	-0.08	0.06	0.26	-0.00	0.05	-0.05	-0.08	0.29	0.40	-0.09	-0.48	1.00			
WW index (WW)	0.36	-0.45	-0.37	-0.01	0.27	-0.06	-0.11	-0.34	-0.41	0.25	0.14	-0.08	0.02	0.01	1.00		
SA index (SA)	0.24	-0.29	-0.29	-0.05	0.18	-0.03	-0.14	-0.19	-0.03	0.14	0.15	-0.03	0.03	0.01	0.29	1.00	
KZ index (KZ)	0.15	-0.07	-0.04	0.03	0.26	-0.02	0.05	-0.06	-0.14	0.14	0.29	-0.44	-0.12	0.19	0.07	0.03	1.00

Table 4: Yield Spreads and Debt Maturity Dispersion

This table presents pooled OLS regression results with the quarterly yield spread in percent as the dependent variable. Appendix C contains a detailed description of how I construct all variables. Data are from Enhanced TRACE, Federal Reserve Bank, Mergent FISD, COMPUSTAT, and CRSP. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The regression for the full sample includes quarter times rating fixed effects (QTR*RAT) while regressions for each rating group include quarter fixed effects (QTR). Standard errors are clustered by firm and quarter with t-statistics in parenthesis. The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, and *** when $p < 0.01$.

		Bond Rating			
	All	AAA-AA	A	BBB	SPEC
Maturity dispersion	-0.048***	0.001	-0.034***	-0.048***	-0.090***
	(-5.83)	(0.08)	(-4.59)	(-3.76)	(-3.33)
Bid-ask spread	0.407***	0.074***	0.183***	0.390***	0.774***
	(7.82)	(2.62)	(5.06)	(5.12)	(8.17)
Coupon rate	0.198***	0.078***	0.112***	0.154***	0.330***
	(14.59)	(6.39)	(9.36)	(10.17)	(9.62)
Log(time-to-maturity)	0.150***	0.199***	0.188***	0.199***	0.218**
	(5.27)	(8.54)	(7.42)	(5.34)	(2.41)
Log(bond age)	-0.130***	-0.009	-0.017	-0.067***	-0.176***
	(-6.99)	(-0.57)	(-1.09)	(-3.21)	(-5.11)
Avg. firm maturity	-0.014***	-0.009*	-0.005	-0.018***	-0.030*
	(-3.57)	(-1.74)	(-1.06)	(-3.58)	(-1.91)
Log(amount outstanding)	-0.104***	-0.041**	-0.066***	-0.121***	-0.110*
	(-4.20)	(-2.38)	(-3.19)	(-3.91)	(-1.71)
Equity volatility	0.032***	0.015***	0.009***	0.027***	0.038***
	(10.78)	(4.60)	(3.77)	(7.27)	(11.26)
Leverage	0.024***	0.014***	0.009***	0.019***	0.031***
	(11.00)	(4.25)	(3.10)	(6.28)	(10.49)
Cash/debt	0.001***	-0.000	-0.000	0.001***	0.002**
	(3.10)	(-0.52)	(-0.00)	(2.78)	(2.00)
Log(1+return on assets)	-3.747***	0.952	-1.592**	-5.266***	-8.740***
	(-3.41)	(0.81)	(-2.10)	(-3.92)	(-3.81)
Log(book/market)	-0.008	0.012	0.060**	-0.011	0.040
	(-0.30)	(0.48)	(1.99)	(-0.27)	(0.79)
Fixed effects	QTR*RAT	QTR	QTR	QTR	QTR
N	60,012	5,147	17,181	24,411	13,273
Adj. R^2	0.788	0.682	0.653	0.639	0.670

Table 5: Yield Spreads and Renegotiation Frictions

This table presents pooled OLS regression results with the quarterly yield spread in percent as the dependent variable. Appendix C contains a detailed description of how I construct all variables. Data are from Enhanced TRACE, Federal Reserve Bank, Mergent FISD, COMPUSTAT, and CRSP. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The regression for the full sample includes quarter times rating fixed effects (QTR*RAT) while regressions for each rating group include quarter fixed effects (QTR). Standard errors are clustered by firm and quarter with t-statistics in parenthesis. The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, and *** when $p < 0.01$.

		Bond Rating			
	All	AAA-AA	A	BBB	SPEC
Norm. no. of issues	-1.273***	-0.115	-0.918***	-1.350***	-1.321**
	(-6.39)	(-0.39)	(-3.79)	(-5.88)	(-2.44)
Bid-ask spread	0.414***	0.073***	0.185***	0.399***	0.796***
	(7.94)	(2.60)	(5.15)	(5.29)	(8.37)
Coupon rate	0.196***	0.077***	0.111***	0.156***	0.334***
	(15.00)	(6.34)	(8.96)	(10.61)	(9.75)
Log(time-to-maturity)	0.149***	0.199***	0.187***	0.196***	0.222**
	(5.17)	(8.47)	(7.35)	(5.20)	(2.45)
Log(bond age)	-0.135***	-0.011	-0.023	-0.076***	-0.186***
	(-7.45)	(-0.68)	(-1.40)	(-3.50)	(-5.56)
Avg. firm maturity	-0.019***	-0.008*	-0.008*	-0.023***	-0.040**
	(-4.99)	(-1.78)	(-1.81)	(-4.46)	(-2.53)
Log(amount outstanding)	-0.119***	-0.044**	-0.079***	-0.140***	-0.127*
	(-4.76)	(-2.31)	(-3.85)	(-4.43)	(-1.95)
Equity volatility	0.033***	0.015***	0.010***	0.028***	0.038***
	(11.08)	(4.60)	(3.86)	(7.60)	(11.36)
Leverage	0.023***	0.014***	0.008***	0.019***	0.030***
	(10.97)	(3.62)	(2.59)	(6.39)	(10.24)
Cash/debt	0.001***	-0.000	-0.000	0.001***	0.002*
	(3.04)	(-0.39)	(-0.03)	(2.87)	(1.84)
Log(return on assets)	-3.874***	0.822	-1.743**	-5.001***	-8.608***
	(-3.62)	(0.76)	(-2.16)	(-3.78)	(-3.66)
Log(book/market)	-0.008	0.008	0.069**	-0.007	0.035
	(-0.30)	(0.33)	(2.21)	(-0.17)	(0.70)
Fixed effects	QTR*RAT	QTR	QTR	QTR	QTR
N	60,012	5,147	17,181	24,411	13,273
Adj. R^2	0.788	0.683	0.651	0.638	0.668

Table 6: Debt Maturity Dispersion and Financial Constraints

This table presents pooled OLS regression results with the quarterly yield spread in percent as the dependent variable. Appendix C contains a detailed description of how I construct all variables. The indexes for financial constraints are from Whited and Wu (2006) (WW), Hadlock and Pierce (2010) (SA), and Kaplan and Zingales (1997) (KZ). In Panel A, I use a dummy variable (HFC) that equals 1 when the financial constraints index level in a given quarter belongs to the top quintile and equals zero otherwise. In Panel B, I use the actual values of the financial constraints indexes. Data are from Enhanced TRACE, Federal Reserve Bank, Mergent FISD, COMPUSTAT, and CRSP. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). All regressions include quarter times rating fixed effects and all control variables from Table 4. Standard errors are clustered by firm and quarter with t-statistics in parenthesis. The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, and *** when $p < 0.01$.

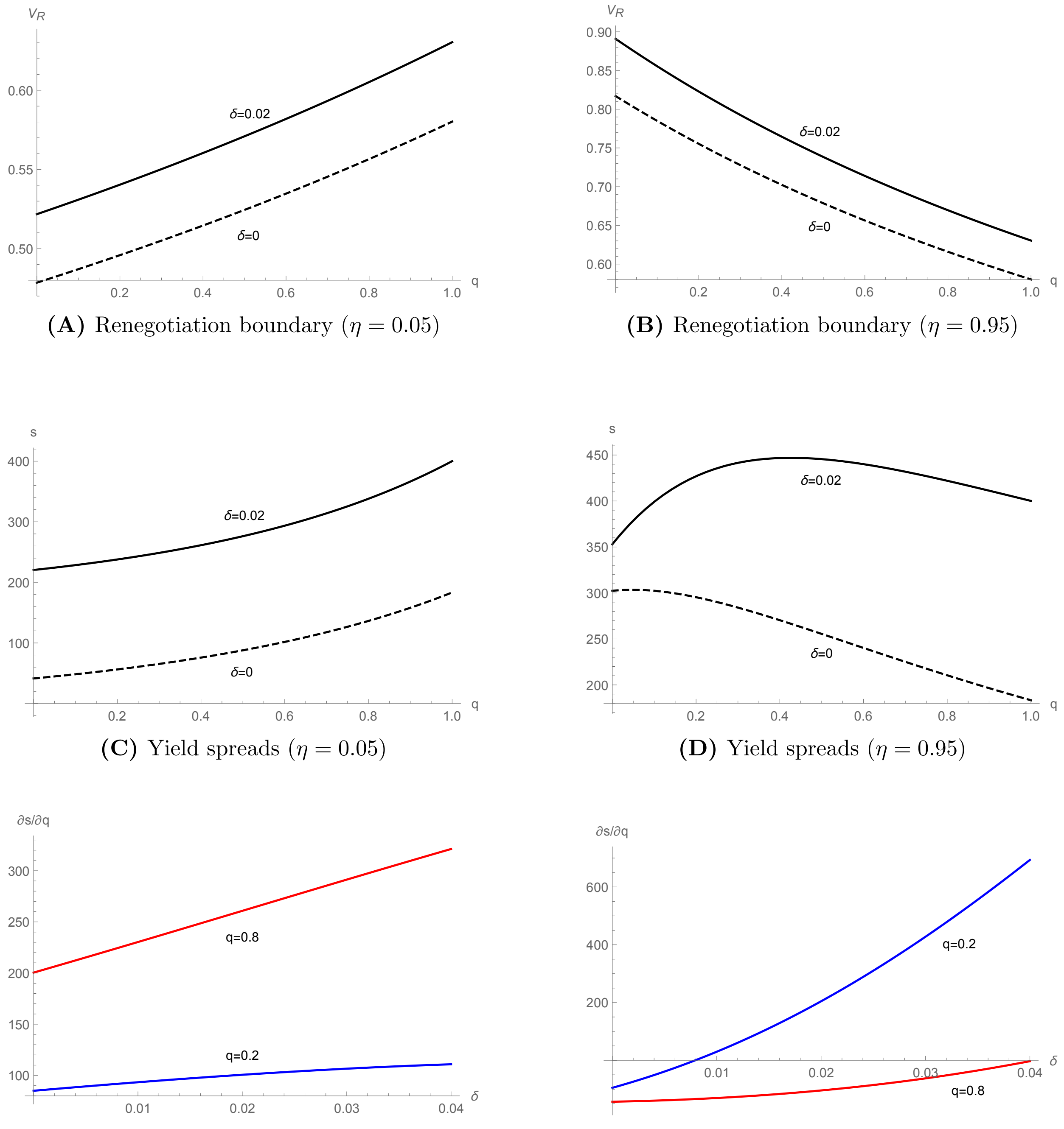
	WW Index		SA Index		KZ Index	
	Panel A: Financial Constraints Dummy					
Maturity dispersion	-0.041***	-0.035***	-0.045***	-0.043***	-0.048***	-0.037***
	(-5.13)	(-4.51)	(-5.46)	(-5.16)	(-5.92)	(-4.54)
High fin. constraints (HFC)	0.215***	0.551***	0.178***	0.292***	-0.066	0.211**
	(4.20)	(6.42)	(4.06)	(3.76)	(-1.18)	(2.54)
Maturity dispersion*HFC		-0.123***		-0.030		-0.057***
		(-5.27)		(-1.51)		(-4.25)
Controls	Y	Y	Y	Y	Y	Y
Quarter*Rating FE	Y	Y	Y	Y	Y	Y
N	60,012	60,012	60,012	60,012	60,012	60,012
Adj. R^2	0.790	0.791	0.789	0.790	0.788	0.790
	Panel B: Financial Constraints Index					
Maturity dispersion	-0.040***	-0.339***	-0.044***	-0.198**	-0.048***	-0.052***
	(-4.72)	(-6.40)	(-5.23)	(-2.25)	(-5.83)	(-5.64)
Fin. constraints index (FCI)	0.185***	0.424***	0.164***	0.307***	-0.004**	0.001
	(3.67)	(6.58)	(3.61)	(3.97)	(-2.03)	(0.51)
Maturity dispersion*FCI		-0.065***		-0.035*		-0.001**
		(-5.90)		(-1.79)		(-2.23)
Controls	Y	Y	Y	Y	Y	Y
Quarter*Rating FE	Y	Y	Y	Y	Y	Y
N	60,012	60,012	60,012	60,012	60,012	60,012
Adj. R^2	0.790	0.792	0.789	0.790	0.789	0.789

Table 7: Renegotiation Frictions and Financial Constraints

This table presents pooled OLS regression results with the quarterly yield spread in percent as the dependent variable. Appendix C contains a detailed description of how I construct all variables. The indexes for financial constraints are from Whited and Wu (2006) (WW), Hadlock and Pierce (2010) (SA), and Kaplan and Zingales (1997) (KZ). In Panel A, I use a dummy variable (HFC) that equals 1 when the financial constraints index level in a given quarter belongs to the top quintile and equals zero otherwise. In Panel B, I use the actual values of the financial constraints indexes. Data are from Enhanced TRACE, Federal Reserve Bank, Mergent FISD, COMPUSTAT, and CRSP. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). All regressions include quarter times rating fixed effects and all control variables from Table 4. Standard errors are clustered by firm and quarter with t-statistics in parenthesis. The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, and *** when $p < 0.01$.

	WW Index		SA Index		KZ Index	
	Panel A: Financial Constraints Dummy					
Norm. no. of issues	-1.036***	-0.877***	-1.186***	-1.111***	-1.271***	-1.062***
	(-5.36)	(-4.15)	(-5.99)	(-5.51)	(-6.45)	(-5.54)
High fin. constraints (HFC)	0.219***	0.335***	0.181***	0.258***	-0.076	0.163
	(4.25)	(4.30)	(4.11)	(3.22)	(-1.31)	(1.40)
Norm. no. of issues*HFC		-0.729*		-0.432		-1.174**
		(-1.75)		(-0.92)		(-2.16)
Controls	Y	Y	Y	Y	Y	Y
Quarter*Rating FE	Y	Y	Y	Y	Y	Y
N	60,012	60,012	60,012	60,012	60,012	60,012
Adj. R^2	0.789	0.789	0.789	0.789	0.788	0.788
	Panel B: Financial Constraints Index					
Norm. no. of issues	-1.034***	-3.204***	-1.134***	-4.078**	-1.283***	-1.370***
	(-5.30)	(-2.74)	(-5.63)	(-2.16)	(-6.51)	(-6.26)
Fin. constraints index (FCI)	0.197***	0.293***	0.162***	0.291***	-0.004**	0.002
	(3.98)	(4.41)	(3.54)	(3.99)	(-2.24)	(0.53)
Norm. no. of issues*FCI		-0.499*		-0.684		-0.030*
		(-1.95)		(-1.61)		(-1.67)
Controls	Y	Y	Y	Y	Y	Y
Quarter*Rating FE	Y	Y	Y	Y	Y	Y
N	60,012	60,012	60,012	60,012	60,012	60,012
Adj. R^2	0.789	0.790	0.789	0.789	0.788	0.788

Figure A.1: The Effects of Renegotiation Frictions



(A) Renegotiation boundary ($\eta = 0.05$) **(B)** Renegotiation boundary ($\eta = 0.95$)

(C) Yield spreads ($\eta = 0.05$) **(D)** Yield spreads ($\eta = 0.95$)

(E) Spread sensitivity ($\eta = 0.05$) **(F)** Spread sensitivity ($\eta = 0.95$)

This figure shows the effects of renegotiation frictions q on yield spreads for different levels of financial constraints δ. Panel A, C, and E have $\eta = 0.05$ while Panel B, D, and F have $\eta = 0.95$. The remaining parameter values are $r = 0.05$, $\beta = 0.03$, $\sigma = 0.2$, $\alpha = 0.45$, $m = 0.2$, $B = 0.75$, and $V_0 = 1$. The y-axes in panels C to F are in basis points.

Internet Appendix for:
Why Does Debt Dispersion Affect Yield Spreads?

Abstract

This Internet Appendix contains the robustness checks mentioned in the paper. First, I explain the construction of the additional measures of debt maturity dispersion and renegotiation frictions. Second, I present summary statistics and correlations. Third, I repeat the regression analysis from the paper with the additional measures of debt maturity dispersion and renegotiation frictions.

Definition of Variables

This section contains the detailed variable descriptions. The capitalized acronyms correspond to quarterly COMPUSTAT data items and subscripts refer to the calendar time.

Debt Maturity Dispersion

$WMD1_t$	The weighted maturity dispersion measure gives more weight to short-term debt. I use the weighting scheme from Choi et al. (2018), namely, $y_i = \frac{1}{i} / \left(\sum_{i=1}^{25} \frac{1}{i} \right)$ for maturities up to $i = 25$ years and $y_i = 0$ otherwise. Let $\omega_i = y_i x_i / \sum_i y_i x_i$ denote the weighted principal share of bond i such that the $Weighted\ Herfindahl_j = \sum_i (\omega_i)^2$ and the weighted dispersion for firm j is: $$WMD1_j = 1/Weighted\ Herfindahl_j$$
$MD2_t$	This maturity dispersion distance measure from Choi et al. (2018) is based on the average squared deviation between the firm's observed debt maturity profile and a perfectly dispersed debt maturity profile. The perfectly dispersed profile has a principal share of $1/t_j^{max}$ maturing in each maturity bucket where t_j^{max} is the longest maturity of the currently outstanding bonds measured at the time of issuance. The distance from the perfectly dispersed debt maturity profile is: $$DIST_j = \frac{1}{t_j^{max}} \sum_{i=1}^{t_j^{max}} \left(w_{j,i} - \frac{1}{t_j^{max}} \right)^2$$ where $w_{j,i}$ is firm j's principal share maturing in bucket i. The dispersion measure at time t is then given by $MD2_j = -log(DIST_j + 0.001)$.

Renegotiation Frictions

BD_t	The bond dispersion measure is based on the principal shares of outstanding bonds. Let B_i denote the principal value of bond i issued by firm j such that the principal shares are $z_i = B_i / \sum_i B_i$. The bond dispersion measure is then given by: $$BD_t = 1 - \sum_i (z_i)^2$$
PD_t	The ratio of public debt to total debt at the end of quarter t is: $$PD_t = \frac{\sum_i B_i}{DLCQ_t + DLTTQ_t}$$ where B_i is the principal value of bond i, $DLCQ_t$ is "Debt in Current Liabilities", and $DLTTQ_t$ is "Long-Term Debt - Total".
STD_t	The ratio of short-term debt to total debt at the end of quarter t is: $$STD_t = \frac{DLCQ_t}{DLCQ_t + DLTTQ_t}$$ where $DLCQ_t$ is "Debt in Current Liabilities" and $DLTTQ_t$ is "Long-Term Debt - Total".

Table IA.1: Summary Statistics

This table presents summary statistics for the entire sample and by bond rating. The data frequency is quarterly and section 1 in the Internet Appendix contains a detailed description of how I construct the variables. *Maturity dispersion* and *Norm. no. of issues* are defined in section 3.3 in the paper. Data are from Mergent FISD and COMPUSTAT. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). I report sample averages and include standard deviations in parentheses.

		Bond Rating			
	All	AAA-AA	A	BBB	SPEC
Maturity dispersion	5.00	6.09	5.63	5.34	3.14
	(3.00)	(2.71)	(2.85)	(3.17)	(2.05)
Weigthed mat. dispersion	2.96	2.99	3.02	3.13	2.54
	(1.45)	(1.25)	(1.41)	(1.50)	(1.39)
Maturity dispersion distance	4.56	5.00	4.86	4.68	3.76
	(1.03)	(0.77)	(0.86)	(0.97)	(1.04)
Norm. no. of issues	0.21	0.25	0.23	0.22	0.15
	(0.10)	(0.09)	(0.09)	(0.09)	(0.10)
Bond dispersion	0.72	0.83	0.77	0.74	0.55
	(0.26)	(0.19)	(0.22)	(0.23)	(0.31)
Public debt/total debt	0.58	0.46	0.55	0.62	0.58
	(0.28)	(0.27)	(0.29)	(0.26)	(0.28)
Short-term debt/total debt	0.11	0.24	0.14	0.09	0.06
	(0.13)	(0.15)	(0.13)	(0.11)	(0.11)
Firms	1,153	75	286	527	616
Bonds	5,785	631	1,828	2,683	1,694
N	60,012	5,147	17,181	24,411	13,273

Table IA.2: Correlations

This table shows Pearson correlation coefficients between the measures of debt maturity dispersion and renegotiation frictions. Section 1 in the Internet Appendix contains a detailed description of how I construct the variables. *Maturity dispersion* and *Norm. no. of issues* are defined in section 3.3 in the paper. Data are from Mergent FISD and COMPUSTAT. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999).

	MD1	WMD1	MD2	NNI	BD	PD	STD
Maturity dispersion (MD1)	1.00						
Weigthed mat. dispersion (WMD1)	0.74	1.00					
Maturity dispersion distance (MD2)	0.87	0.67	1.00				
Norm. no. of issues (NNI)	0.76	0.63	0.83	1.00			
Bond dispersion (BD)	0.74	0.64	0.89	0.87	1.00		
Public debt/total debt (PD)	0.21	0.23	0.19	0.28	0.23	1.00	
Short-term debt/total debt (STD)	0.04	-0.08	0.08	0.11	0.10	-0.18	1.00

Table IA.3: Yield Spreads and Debt Dispersion

This table presents pooled OLS regression results with the quarterly yield spread in percent as the dependent variable. Section 1 in the Internet Appendix contains a detailed description of how I construct the variables. *Maturity dispersion* and *Norm. no. of issues* are defined in section 3.3 in the paper. Data are from Enhanced TRACE, Federal Reserve Bank, Mergent FISD, COMPUSTAT, and CRSP. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). The regression for the full sample includes quarter times rating fixed effects (QTR*RAT) while regressions for each rating group include quarter fixed effects (QTR). All regressions include the control variables from Table 4. Standard errors are clustered by firm and quarter with t-statistics in parenthesis. The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, and *** when $p < 0.01$.

		Bond Rating			
	All	AAA-AA	A	BBB	SPEC
Panel A: Maturity Dispersion					
Maturity dispersion	-0.048***	0.001	-0.034***	-0.048***	-0.090***
	(-5.83)	(0.08)	(-4.59)	(-3.76)	(-3.33)
Weighted mat. dispersion	-0.066***	0.001	-0.040***	-0.062***	-0.100***
	(-5.19)	(0.10)	(-3.57)	(-3.39)	(-3.14)
Maturity dispersion distance	-0.179***	-0.016	-0.101***	-0.178***	-0.239***
	(-7.61)	(-0.41)	(-4.09)	(-5.89)	(-4.57)
Panel B: Renegotiation Frictions					
Norm. no. of issues	-1.273***	-0.115	-0.918***	-1.350***	-1.321**
	(-6.39)	(-0.39)	(-3.79)	(-5.88)	(-2.44)
Bond dispersion	-0.559***	-0.035	-0.373***	-0.515***	-0.666***
	(-7.50)	(-0.24)	(-4.44)	(-5.41)	(-4.89)
Public debt/total debt	0.100	0.070	-0.198**	0.004	0.387**
	(1.33)	(0.99)	(-2.21)	(0.04)	(2.46)
Short-term debt/total debt	-0.085	-0.368***	-0.344***	-0.265*	0.859**
	(-0.69)	(-5.33)	(-2.91)	(-1.68)	(2.23)
Controls	Y	Y	Y	Y	Y
Fixed effects	QTR*RAT	QTR	QTR	QTR	QTR
N	60,012	5,147	17,181	24,411	13,273

Table IA.4: Debt Dispersion and Financial Constraints

This table presents the coefficient estimates of β_3 in equation (2) and (3) i.e. on the interaction variable between financial constraints and either debt maturity dispersion or renegotiation frictions. Appendix C in the paper and section 1 in the Internet Appendix contain detailed descriptions of how I construct the variables. *Maturity dispersion* and *Norm. no. of issues* are defined in section 3.3 in the paper. The indexes for financial constraints are from Whited and Wu (2006) (*WW*), Hadlock and Pierce (2010) (*SA*), and Kaplan and Zingales (1997) (*KZ*). HFC denotes a dummy variable that equals 1 when the financial constraints index level in a given quarter belongs to the top quintile and equals zero otherwise. Data are from Enhanced TRACE, Federal Reserve Bank, Mergent FISD, COMPUSTAT, and CRSP. The sample period covers 1 July 2002 to 30 June 2017 where I have excluded financials (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). All regressions include quarter times rating fixed effects and all control variables from Table 4. Standard errors are clustered by firm and quarter with t-statistics in parenthesis. The convention for p-values is: * when $p < 0.10$, ** when $p < 0.05$, and *** when $p < 0.01$.

	HFC Dummy			Index Value		
	WW	SA	KZ	WW	SA	KZ
Panel A: Maturity Dispersion						
Maturity dispersion	-0.123***	-0.030	-0.057***	-0.065***	-0.035*	-0.001**
	(-5.27)	(-1.51)	(-4.25)	(-5.90)	(-1.79)	(-2.23)
Weighted mat. dispersion	-0.033***	-0.054***	-0.049***	-0.447***	-0.270**	-0.074***
	(-2.75)	(-4.20)	(-3.71)	(-4.93)	(-1.98)	(-5.17)
Maturity dispersion distance	-0.165***	-0.043	-0.158***	-0.125***	-0.066	-0.004**
	(-4.29)	(-0.99)	(-3.99)	(-5.28)	(-1.58)	(-2.53)
Panel B: Renegotiation Frictions						
Norm. no. of issues	-0.729*	-0.432	-1.174**	-0.499*	-0.684	-0.030*
	(-1.75)	(-0.92)	(-2.16)	(-1.95)	(-1.61)	(-1.67)
Bond dispersion	-0.393***	-0.028	-0.548***	-0.299***	-0.120	-0.007
	(-2.95)	(-0.19)	(-3.81)	(-3.45)	(-0.87)	(-1.30)
Public debt/total debt	0.061	0.042	-0.026	0.347***	0.052	-0.000
	(0.44)	(0.25)	(-0.15)	(3.90)	(0.36)	(-0.04)
Short-term debt/total debt	0.530**	0.394	-0.609	0.239	0.278	-0.014*
	(2.19)	(1.28)	(-1.24)	(1.35)	(1.07)	(-1.69)
Controls	Y	Y	Y	Y	Y	Y
Quarter*Rating FE	Y	Y	Y	Y	Y	Y
N	60,012	60,012	60,012	60,012	60,012	60,012

Chapter 3

What Determines Bid-Ask Spreads in Over-the-Counter Markets?

Peter Feldhütter and Thomas Kjær Poulsen*

Abstract

We document cross-sectional variation in bid-ask spreads in the U.S. corporate bond market and use the variation to test OTC theories of the bid-ask spread. Bid-ask spreads, measured by realized transaction costs, increase with maturity for investment grade but not for speculative grade bonds. For short-maturity bonds, spreads increase with credit risk while long-maturity bonds rated AAA/AA+ have significantly higher spreads than other investment grade bonds. We find that dealer inventory is the most important determinant of the variation in bid-ask spreads. How bond sales travel through the network of dealers also explains part of the variation, particularly for speculative grade bonds. In contrast, search-and-bargaining frictions and asymmetric information have limited explanatory power.

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1 Introduction

Market liquidity of the corporate bond market is important as it affects bond prices and thus the funding cost of firms, and bid-ask spreads (measured as realized transaction costs) are typically used when measuring liquidity.[1] Despite the importance of the bid-ask spread in understanding the functioning of the market, we have a limited understanding of why it arises in the first place. There are a number of theories of over-the-counter (OTC) frictions that have been proposed as explanations for the size and cross-sectional variation of bond bid-ask spreads, but despite the extensive theoretical literature, there is little empirical literature examining the relative importance of different theories in explaining bid-ask spreads. We fill this gap by presenting new evidence on the cross-sectional variation in corporate bond bid-ask spreads and testing leading theories' ability to explain this variation.

The paper begins by documenting new facts about bid-ask spreads in the U.S. corporate bond market using the Academic TRACE dataset for U.S. corporate bonds for the period 2002-2015. This data set has anonymized dealer identities and allows us to follow the trail through the dealer network of a bond being sold by an investor until the bond is ultimately being bought by another investor, so-called round-trip intermediation chains. For each chain we calculate the investor buy price minus the investor sell price divided by the mid-price. Schestag et al. (2016) show that there is a high correlation between realized transaction costs and dealer bid-ask spreads in the U.S. corporate bond market, and we therefore call our estimates for bid-ask spreads.

We sort bid-ask spreads according to bond maturity and rating. Sorting in one dimension we find that average spreads increase in bond maturity and credit risk, confirming previous results in the literature. When double-sorting on maturity and rating, a surprising pattern emerges. Spreads for investment grade bonds increase strongly in maturity, while spreads for speculative grade bonds show no clear relation. For short-maturity bonds spreads increase in credit risk, while for long-maturity bonds spreads for bonds rated AA+ or AAA, which we call Safe bonds, are substantially higher than other investment grade bonds. We show that these patterns are robust to excluding the financial crisis, adding time fixed effects, and holds separately for bonds issued by financial and non-financial firms.

We use the documented patterns in bid-ask spreads to test theories of the bid-ask spread in OTC markets. To do so, we construct proxies motivated by theories of OTC frictions and examine the extent to which the variation in proxies explains the variation in bid-ask spreads.

[1] Examples of research finding that liquidity impacts bond prices include Bao et al. (2011), Friewald et al. (2012), Dick-Nielsen et al. (2012), and Acharya et al. (2013). Recent research that uses transaction costs to measure corporate bond liquidity include Aquilina and Suntheim (2016), Adrian et al. (2017), Trebbi and Xiao (2017), Bessembinder et al. (2018), and Choi and Huh (2018).

In *inventory models* the dealer acts as an intermediary providing immediacy for investors and the bid-ask spread arises as a compensation for inventory risk. The bid-ask spread in the classic models of Stoll (1978) and Ho and Stoll (1983) is proportional to asset volatility and we use bond return volatility as a proxy for inventory risk. We regress actual bid-ask spreads on bond volatilities and calculate predicted bid-ask spreads from the regression estimates. Predicted spreads are increasing in maturity for investment grade bonds. Also, predicted spreads are increasing in credit risk for short-maturity bonds and show a U-shaped pattern for long-maturity bonds. Thus, patterns in predicted spreads are consistent with those in actual spreads. The average difference between predicted and actual spreads grows for increasingly credit risky speculative grade bonds, showing that the importance of other factors than inventory increases in credit risk.

Duffie et al. (2005) introduce *search-and-bargaining models* to explain bid-ask spreads in OTC markets. A seller searches for dealers sequentially, and once a seller meets a dealer, they negotiate bilaterally over the price and their strength of negotiation depends on their outside options, in particular how easily the seller can find other dealers. We use completion time of round-trip intermediation chains as a proxy for the easy of finding counterparties. As a proxy for dealer bargaining power we follow Friewald and Nagler (2018) and compute a bond-specific Herfindahl-Hirschman (HH) index based on dealers' trading volume in the past month. We find that neither proxy, and thus predicted spreads based on any of them, varies much across maturity. Furthermore, we analyse matched intermediation chains, i.e. where the chain is completed within one minute and likely prearranged by the dealer(s). Search-and-bargaining models predict that there is no difference between spreads of matched chains vs unmatched chains, but actual spreads of matched chains are much smaller than those of unmatched chains. Taken together, our results suggest that search-and-bargaining frictions have limited explanatory power in explaining bid-ask spreads.

In *information-based models*, such as Copeland and Galai (1983) and Glosten and Milgrom (1985), the market maker's concern is that some investors have private information about the value of the security and she does not know whether she trades with an informed or uninformed investor. To protect herself, the market maker charges a bid-ask spread. To construct our proxy, we exploit that debt and equity are claims on the same asset, the firm, and therefore private information should affect both equity and bond bid-ask spreads, albeit to a different degree. Specifically, we calculate the equity bid-ask spread of the bond issuer and compute an implied bond bid-ask spread based on the equity spread and the ratio of bond and equity price sensitivities to changes in firm value. We find that predicted spreads are much smaller than actual spreads for all maturities and ratings. The reason for this underprediction is twofold. First, the size of equity spreads is an upper bound on the size of bond spreads, because equity is more information-sensitive than debt, and equity spreads are on average more than three times smaller than bond spreads. Second, bond returns are much less sensitive to changes in firm value than equity returns.

Finally, recent empirical research, among others Li and Schürhoff (2018), Maggio et al. (2017), and Hollifield et al. (2017), finds that how a bond travels through the *dealer network* is important for bid-ask spreads. In particular, how many dealers are involved in an intermediation chain and the centrality of those dealers have an impact on spreads. We calculate the average markup charged by each dealer and for each chain we calculate a predicted spread by adding the average markups of the dealers involved in the chain. Predicted spreads for long-maturity bonds show a U-shaped pattern in the relation between spreads and rating, broadly consistent with the pattern in actual spreads. Furthermore, the positive relation between actual spreads and credit risk for short-maturity bonds is also largely matched by predicted spreads. In both cases, however, the slope in the relation is smaller for predicted spreads than for actual spreads. In stark contrast to actual spreads, there is no relation between spreads and bond maturity for investment grade bonds. Overall, our results suggest that the network of dealers plays a significant role in determining spreads across rating but not across maturity.

We also examine the relation between actual spreads and our measures in a panel regression. Two measures stand out in terms of R^2, bond volatility and predicted dealer network spread. This is consistent with our results when we average across rating and maturity, namely that dealer inventory and dealer network are most important in explaining spreads. When we estimate the regression separately for investment grade and speculate grade bonds, dealer inventory is most important for investment grade bonds while the dealer network is dominant in explaining spreads of speculative grade bonds.

Taken together, we find that inventory models explain a significant amount of the variation of bid-ask spreads, in particular across bond maturity. The network of dealers provides additional explanatory power, mainly for speculative grade bonds. We find that search-and-bargaining and asymmetric information have limited explanatory power.

Our paper relates to several strands of literature. One strand tests OTC theories and the relation to bid-ask spreads. Feldhütter (2012) and He and Milbradt (2014) estimate parameters in search-and-bargaining models by calibrating to actual bid-ask spreads in the credit markets and comparing model-implied spreads to actual spreads across either maturity or rating. We investigate a number of alternative theories, provide more extensive comparisons across maturity and rating, and present further evidence using matched trades. Benmelech and Bergman (2018) test several implications of Dang et al. (2015)'s theory of asymmetric information and find that corporate bond bid-ask spreads (and other liquidity measures) increase in a non-linear pattern as credit quality deteriorates, consistent with the theory. Similar to their results we also document a non-linear relation when we investigate asymmetric information models. However, using another prediction of Dang et al. (2015), that debt is less information-sensitive than equity, we find that only a small part of the bond bid-ask spread can be explained by unlevered equity bid-ask spreads.

Another strand of literature investigates the relation between OTC frictions and prices. Using corporate bond data, Friewald and Nagler (2018) study theories of inventory and search-and-bargaining, Han and Zhou (2014) study asymmetric information, and Dick-Nielsen and Rossi (2018) study dealer inventory around index exclusions. These papers focus on prices/returns and do not investigate bid-ask spreads.

A third strand of literature studies the relation between the dealer network and the bid-ask spread and these papers include Li and Schürhoff (2018), Maggio et al. (2017), and Hollifield et al. (2017). We contribute to this literature by studying how dealer network spreads relate to credit quality and bond maturity. Our paper is also related to a large literature that examines the bid-ask spread of corporate bonds such as Goldstein and Hotchkiss (2018), Edwards et al. (2007), Bessembinder et al. (2006), Goldstein et al. (2007), Schultz (2001), Hong and Warga (2000) and others. We contribute to this literature by studying bid-ask spreads across both bond maturity and rating and testing OTC theories of the bid-ask spread.

2 Data

We use a transaction data set for the U.S. corporate bond market, called Academic TRACE, which is provided by the Financial Industry Regulatory Authority (FINRA) and covers all transactions conducted by designated dealers. The data contain dealer identities, in anonymised form, for every transaction. FINRA provides the data with a three-year lag and the data cover the period 2002:07-2015:06. We account for reporting errors using Dick-Nielsen (2014)'s filter and since our focus is on transaction costs of institutional investors we delete trades with a par value below $100,000 as these are commonly viewed as retail transactions. We do, however, also support our findings with results based on retail-sized transactions.

We restrict our sample to bonds with fixed coupon rates including zero-coupon bonds and exclude bonds that are callable at a fixed price, putable, convertible, denoted in foreign currency, or have sinking fund provisions. We keep bonds with a make-whole call provision since make-whole calls have little effect on bond prices (see Powers and Tsyplakov (2008) and Bao and Hou (2017)). We collect information on bond characteristics and bond ratings from Mergent Fixed Income Securities Database (FISD).[2]

[2] We use Mergent FISD's ISSUER ID as firm identifier. At a given point in time, we use the most recent rating

Table 1 shows summary statistics of our data sample for institutional-sized transactions. In total, our sample includes 18.1 million transactions in 23,626 bonds issued by 3,178 firms. We sort bonds into three maturity groups (0-4 years, 4-8 years, and more than 8 years) which we call short, medium, and long maturity. The number of transactions in each maturity group are similar: for short-, medium-, and long-maturity bonds the number is 6.4, 5.5, and 6.2 million, respectively. We divide our sample into seven rating groups (Safe [AAA and AA+], AA [AA and AA-], A, BBB, BB, B, and C [C, CC, and CCC]). Table 1 shows that most transactions, 82%, occur in investment grade bonds. There is broad coverage across rating and maturity. For example, the rating/maturity combination with fewest firms, long-maturity bonds issued by Safe firms, nevertheless has 310,568 transactions in 586 bonds issued by 71 firms over the sample period. Examples of Safe bond issuers are Microsoft, Johnson & Johnson, Yale University, Harvard University, New York University, Stanford University, and MIT.

Finally, when needed, we obtain firm characteristics from COMPUSTAT, Treasury rates from the Federal Reserve Bank, and equity data from the Center for Research in Security Prices (CRSP).

3 Cross-Sectional Variation in Bid-Ask Spreads

We calculate bid-ask spreads by tracking bond prices as a bond travels from a selling investor through the network of dealers until the bond ends in the inventory of a buying investor. Thus, we follow a recent literature on intermediation chains (Maggio et al. (2017), Li and Schürhoff (2018), and Friewald and Nagler (2018)). Specifically, we use the round-trip match algorithm from Li and Schürhoff (2018) to compute realized transaction costs from round-trip intermediation chains.

A round-trip intermediation chain starts from an investor who sells bonds to a dealer (*CD* leg). If the dealer sells all the bonds to another investor (*DC* leg) then the chain is a *CDC* chain. If the dealer sells less than all the bonds to a single investor or sells some or all the bonds to several investors then the chain is a *CDC-Split* chain. The dealer may also sell all the bonds to another dealer (*DD* leg) who can then sell the bonds either to investors or another dealer. These chains are classified as *C(N)DC* or *C(N)DC-Split* where (N) denotes the number of dealers and the name reflects if the initial par size from the *CD* leg is split into smaller lots in the last leg of the chain i.e. in the *DC* leg. As in Li and Schürhoff (2018) we restrict order splitting to the last leg of the chain and not in interdealer trades. In case of order splitting, we calculate the par-weighted sales price and the par-weighted transaction date of the *DC* leg.

We use our sample of round-trip intermediation chains to calculate bid-ask spreads from realized

from Standard & Poor's. If this rating is not available, we use the most recent rating from Moody's. If this rating is also missing, we use the most recent Fitch rating. For bonds that are initially rated by Moody's or Fitch, we keep the initial rating until a rating becomes available from Standard & Poor's.

transaction costs. For each chain, we calculate the bid-ask spread as the sales price the tail dealer receives from the investor minus the purchase price the head dealer pays to the investor divided by the mid-price of the two.

A round-trip intermediation chain may take up to several days to complete during which the bond's time-to-maturity decreases and its rating can change. We use the first date of the chain (i.e. the day where the dealer buys from the investor) to determine the bond's time-to-maturity and rating. If a bond has several chains beginning on the same day, we calculate the volume-weighted bid-ask spread using the trading volume from the last leg in the chain. Since we divide our sample into three maturity groups and seven rating groups, we end up with a cross-section of 21 groups in total. Within each of the 21 groups, we winsorize bid-ask spreads at the 1st and 99th percentiles over the entire sample period to mitigate the influence of outliers. We use these winsorized bid-ask spreads in the subsequent analysis.

Table 2 shows summary statistics of the round-trip intermediation chains for institutional-sized transactions. As was the case with the number of transactions, 82% of the chains are in investment grade bonds. Panel A shows that the average bond age increases with credit risk. For example, the average bond age is 5.65 years when a C-rated bond trades while it is only 2.99 years for a Safe bond. Panel A also shows that the average amount outstanding decreases with credit risk. The average amount outstanding of Safe bonds is more than three times that of C-rated bonds. Finally, we see that the average trade size is higher for Safe bonds and C-rated bonds, but otherwise shows no relation with rating.

Table 3 presents average bid-ask spreads across maturity and rating for institutional-sized transactions. On average, bid-ask spreads increase with bond maturity: the average bid-ask spread for short-, medium-, and long-maturity bonds is 23.1bps, 36.4bps, and 45.8bps, respectively. The positive relation between bond maturity and bid-ask spreads is well-known in literature (see for example Chakravarty and Sarkar (2003), Edwards et al. (2007), and Feldhütter (2012)), and for all investment grade ratings we see the same pattern of increasing bid-ask spreads as maturity increases. However, for speculative grade ratings, there is no clear pattern: although long-maturity bonds have the highest bid-ask spreads, short-maturity bonds have higher bid-ask spreads than medium-maturity bonds. For example, for BB-rated bonds the average bid-ask spread for short-, medium-, and long-maturity bonds is 39.8bps, 33.7bps, and 42.8bps, respectively.

Turning to the relation between rating and bid-ask spreads, Table 3 reveals a surprising pattern. For short-maturity bonds, the bid-ask spread is 16.3-17.3 bps for ratings above BBB while for lower ratings there is a positive relation between rating and bid-ask spread, increasing from 25.6 bps for BBB bonds to 63.8 bps for the most risky C-rated bonds. For medium-maturity bonds we see that

Safe bonds have higher average bid-ask spreads (38.4 bps) than bonds rated AA, A, BBB, and BB (33.7-37.3 bps), while long-maturity Safe bonds have higher spreads (50.4 bps) than bonds in other rating classes (40.2-49.8 bps) except the most risky bonds rated C.[3]

The finding that long-maturity bonds of the lowest credit risk have substantially higher bid-ask spreads than other investment grade bonds is surprising. Theoretically, research articles studying the relation between credit risk and illiquidity in the corporate bond market imply a positive relation between credit risk and illiquidity (Ericsson and Renault (2006), He and Milbradt (2014), Chen et al. (2018)). Empirically, Edwards et al. (2007) and Goldstein and Hotchkiss (2018) find a monotone and positive relation between bid-ask spreads and credit risk.

There are at least two reasons why the high bid-ask spreads for long-maturity Safe bonds has gone unnoticed. First, we double-sort on rating and maturity and the high bid-ask spreads only become apparent for longer-maturity bonds. Second, previous research articles such as Edwards et al. (2007) and Goldstein and Hotchkiss (2018) have a coarser grouping of ratings making the high bid-ask spreads for Safe bonds more difficult to discern.

A concern when using average bid-ask spreads over the period 2002-2015 is that bonds with low credit risk trade more often in periods when transaction costs are higher. For example, Acharya et al. (2013) find that there is a flight-to-safety in the U.S. corporate bond market in stress periods, i.e. investors prefer safe corporate bonds in crisis periods. However, Table 4 shows that the pattern is present both in the financial crisis 2007-2009 and in the sample period excluding the financial crisis.

To further examine the impact of time variation in bid-ask spreads, we estimate a regression with month fixed effects in Table 5. Time fixed effects soak up potential effects of having more observations of bid-ask spreads from bonds with low credit risk in stress periods where bid-ask spreads are generally high. For short-maturity bonds, we see that bid-ask spreads now monotonically increase with credit risk, while the pattern that medium- and long-maturity Safe bonds have higher bid-ask spreads than other investment grade bonds remains unchanged. The standard errors show that the differences in bid-ask spreads for long-maturity Safe bonds and other investment grade bonds are statistically significant.

We estimate bid-ask spreads for both financial and non-financial firms and a potential concern is that high bid-ask spreads of long-maturity Safe bonds may be caused by many observations of highly rated financial bonds with high bid-ask spreads and lower-rated non-financial bonds

[3] Formally, we need to carry out a t-test of differences in mean rather than look at standard errors in individual groups to claim statistical significance. If we do so we find significant differences; a t-test of the difference in mean between the long-maturity Safe and AA groups is 3.11, between long-maturity Safe and A groups is 1.54, between long-maturity Safe and BBB groups is 2.00, and between long-maturity Safe and BB groups is 2.16. Further t-tests are available on request.

with low bid-ask spreads. We therefore estimate bid-ask spreads separately for financial and non-financial firms in Table 6. The size of bid-ask spreads is similar across maturity and rating (except for C-rated bonds) and, in particular, long-maturity Safe bonds have higher bid-ask spreads than other investment grade bonds for both financials and non-financials.

In Table 7, we present average bid-ask spreads for retail-sized transactions (trade sizes below \$100,000) across maturity and rating. Our results show that the average bid-ask spread for retail-sized transactions is 155.6 bps compared to 34.1 bps for institutional-sized transactions. The finding that bid-ask spreads decrease substantially with trade size is well-documented in the literature by e.g. Edwards et al. (2007) and Schestag et al. (2016).

The cross-sectional variation in bid-ask spreads for retail-sized transactions show the same patterns as institutional-sized transactions. The average bid-ask spread for short-, medium-, and long-maturity bonds is 114.3 bps, 158.1 bps, and 240 bps, respectively. For short-maturity bonds, average bid-ask spreads increase with credit risk from 76.5 bps for Safe bonds to 369.6 bps for C-rated bonds. For medium-maturity bonds, the average bid-ask spread for Safe bonds is 151.7 bps which is higher than bonds rated either AA (132 bps) or A (134.4 bps). Also for long-maturity bonds, Safe bonds have higher average bid-ask spreads (224.7 bps) compared to bonds rated AA or A (210.4 and 219.8 bps). Unlike our results for institutional-sized transactions, however, we find that average bid-ask spreads increase with maturity for both investment and speculative grade bonds.

4 Empirical Measures

In this section, we discuss theories of the bid-ask spread and define our empirical measures. We leave the implementation details of our measures to Appendix A.

4.1 Measures

Inventory costs. In inventory models, the market maker acts as an intermediary providing immediacy for investors by absorbing an imbalanced order flow. Since the asset entails price risk, the market maker has inventory risk and as a compensation for this risk the market maker earns a bid-ask spread. In the classic models of Stoll (1978) and Ho and Stoll (1983) the relative bid-ask spread is proportional to the volatility in the asset's returns and volatility is the only asset specific component. We therefore test the classic models of inventory by examining the extent to which differences in bond return volatility explains differences in bid-ask spreads.

Search and bargaining. Duffie et al. (2005) introduce search-based models to explain bid-ask spreads in OTC markets and these models are used extensively to explain different aspects of bid-ask spreads and liquidity in general.[4] In the models, a seller searches for dealers sequentially and trade does not occur immediately. Once a seller meets a dealer, they negotiate bilaterally over the price and their strength of negotiation depends on their outside options, in particular how often they meet other counterparties.

A key prediction of search models is that the bid-ask spread is decreasing in the speed with which counterparties find trading partners. This implies that if it is difficult to find counterparties when trading a particular bond, it will take a longer time for the bond to travel from a selling investor through the interdealer network to a buying investor, and bid-ask spreads will be higher. Therefore, we use the average time it takes for a bond to complete a round-trip intermediation chain as a measure for the inverse search intensity and we expect bid-ask spreads to be positively related to the chain time.

Another central feature of search based models is the importance of the bargaining power of the dealer in the bilateral negotiation between dealer and investor. We follow Friewald and Nagler (2018) and use a bond-specific Herfindahl-Hirschman index based on customer trading volume of dealers. The intuition is that in a more concentrated market with fewer dealers, the bargaining power of investors is worse and therefore bid-ask spreads are higher.

Asymmetric information. Information-based models are introduced in Bageshot (1971), Copeland and Galai (1983), and Glosten and Milgrom (1985). The market maker's concern is that some investors have private information about the value of the security and she does not know whether she trades with an informed or uninformed investor. To protect herself, the market maker charges a bid-ask spread such that losses from trading with informed investors are offset by gains from trading with uninformed investors, and more private information leads to a larger bid-ask spread.

To test the prediction of asymmetric information, we exploit that private information is about the value of the firm and this information therefore affects the bid-ask spread of both equity and debt, albeit to different degrees. Specifically, we measure the bid-ask spread in the equity market and unlever this bid-ask spread to a corresponding predicted bid-ask spread in the bond market. We do so in Merton (1974)'s model of credit risk where we add asymmetric information to the model following Copeland and Galai (1983); we leave the details of the model and the implementation details to Appendix A. The intuition for the bid-ask spread in the model is: if the equity return is three times as sensitive to a change in firm value as the debt return, the bid-ask spread

[4] Feldhütter (2012), He and Milbradt (2014), Vayanos and Weill (2008), Lagos and Rocheteau (2009), Lagos et al. (2009), Duffie et al. (2007), Sambalaibat (2018) and many others.

in the equity market is three times as large as in the bond market because a piece of private information moves equity prices three times as much as debt prices.[5]

Dealer networks. There is a recent empirical literature finding that the network of dealers is central to understanding liquidity in OTC markets (Li and Schürhoff (2018), Maggio et al. (2017), and Hollifield et al. (2017) among others). In particular, the kind of dealer investors trade with, periphery or central dealer, as well as the number of dealers involved in an intermediation chain is important for bid-ask spreads.

We examine the importance of the dealer network by estimating a predicted bid-ask spread for a given bond transaction based on how this bond travels through the network.[6] Specifically, for each dealer we calculate four average markups, across time and bonds, depending on whether the dealer buys from an investor or another dealer and whether the dealer sells to another investor or another dealer. We use the average markups as a proxy for predicted markups. For each round-trip intermediation chain, we then estimate a predicted bid-ask spread by aggregating the predicted markups of the individual dealers involved in the chain.

As an example, consider a chain where an investor sells to dealer A, dealer A sells to dealer B, and dealer B ultimately sells to another investor. Assume that on average dealer A earns a markup of 10 bps when buying from an investor and selling to another dealer, while dealer B on average earns a markup of 15 bps when buying from another dealer and selling to an investor. In this case, the predicted bid-ask spread is 25 bps.

4.2 Relation Between Measures

Table 8 shows the correlations between our measures for institutional-sized transactions. We calculate correlations using observations for which we can calculate all measures, and in particular this implies that the correlations are based on a subset of bonds for which the firm is a public company (since our proxy for asymmetric information requires an equity bid-ask spread).

The highest correlation of 31.5% is between unlevered equity bid-ask spreads as a proxy for asymmetric information and bond volatility as a proxy for inventory costs. The positive correlation reflects that they are clearly related, but they also have distinctly different predictions. For instance, consider a firm with low leverage that have issued a safe bond with near-zero default risk. The theoretical prediction from asymmetric information models is a near-zero bid-ask spread

[5]The prediction of our model is consistent with Dang et al. (2015) who show that debt is less information sensitive than equity.

[6]We take the structure of the network as exogeneously given. The network structure may arise because of search frictions (Hugonnier et al. (2017), Neklyudov (2014)), relationships (Colliard and Demange (2018)), asymmetric information (Glode and Opp (2016), Babus and Kondor (2018), Chang and Zhang (2018)), or inventory (Üslü (2018)).

and the empirical prediction from the unlevered equity bid-ask spread will likewise be a near-zero spread because of the low leverage. In contrast, both the theoretical prediction from inventory models and the empirical prediction from bond return volatility predict a positive bid-ask spread because of interest rate risk related to movements in the risk-free rate.

Dealer concentration has negative (but in most cases modest) correlations with the other measures. This implies that dealer concentration is higher for bonds with lower volatility, small unlevered equity bid-ask spreads, intermediation chains with shorter completion times, and lower predicted dealer network markups.

5 Empirical Results

In this section, we examine to what extent different theories explain the cross-sectional variation of bid-ask spreads for institutional-sized transactions. In Section 5.1 we estimate a predicted bid-ask spread implied by each theory in turn and evaluate how well predicted bid-ask spreads match actual bid-ask spreads across maturity and rating groups. In Section 5.2 we evaluate the theories jointly in a panel regression. In Section 5.3 we investigate bid-ask spreads of matched chains i.e. round-trip intermediation chains completed within one minute.

5.1 Testing Theories of the Bid-Ask Spread

We use bond volatility, chain time, and dealer concentration as proxies for theories of the bid-ask spread in Section 4 and for each proxy in turn, we calculate a predicted bid-ask spread as follows. We estimate the regression

$$BA_{it} = \beta_0 + \beta_1 p_{it} + \epsilon_{it} \tag{1}$$

where BA_{it} is the actual bid-ask spread of bond i at day t and p_{it} is the specific proxy. The intercept in the regression should be zero: for example when we estimate equation (1) using bond return volatility as a proxy, inventory models predict that the bid-ask spread is zero if bond volatility is zero because there is no inventory risk. However, we include an intercept in the regression to allow for a fixed cost of market making.

We use the estimated regression parameters from equation (1) to calculate a predicted bid-ask spread as

$$\hat{BA}_{it} = \hat{\beta}_0 + \hat{\beta}_1 p_{it} \tag{2}$$

and calculate average predicted bid-ask spreads grouped according to rating and maturity in the same way as for the actual bid-ask spreads. For asymmetric information and dealer network theories, we calculate an implied bond bid-ask spread and use this directly when comparing to actual bid-ask spreads.

Note that the average actual bid-ask spreads in some tables are different from those in Table 3 because proxies may not exist for all observations of actual bid-ask spreads. In the tables, we therefore calculate an average actual bid-ask spread based on bid-ask spread observations for which we have values of the proxy and report the difference between average predicted and average actual bid-ask spreads in brackets.

Inventory

Standard models of inventory costs imply that bond bid-ask spreads increase with bond return volatility, since higher volatility implies larger fluctuations in the value of inventory. Table 9 shows annualized bond return volatility. Average bond volatility is 8.3% which is similar to the average bond volatility of 6.9% in Bao and Pan (2013). On average bond volatility increases in rating: volatility is 5.3% for Safe bonds increasing to 25.1% for C-rated bonds. We also see that average bond volatility increases in bond maturity from 5.2% for short maturities to 13.2% for long maturities. The positive relation between bond volatility and maturity is present in all rating categories except for the most risky C-rated, where the relation is flat. Likely, this is because prices of the most credit risky bonds depend primarily on the expected bond recovery value and for a given firm the expected recovery value is the same across bonds with different maturities.

Table 10 shows the estimated parameters from equation (2). The estimate $\hat{\beta}_0 = 9.067$ implies that the fixed cost of market making is 9.1 bps and $\hat{\beta}_1 = 278.124$ implies that a one percentage point increase in annualized bond volatility increases the bid-ask spread by 2.8 bps.

Table 11 shows predicted spreads when using bond volatility as the single explanatory variable for bond bid-ask spreads. Consistent with actual bid-ask spreads, average predicted spreads increase in bond maturity: the average implied (actual) spread for short-maturity bonds is 23.5 (19.8) bps and 45.9 (51.5) bps for long-maturity bonds.

Turning to the relation between bid-ask spreads and rating, Table 11 shows that there is a positive relation between predicted spreads and credit risk consistent with the actual relation. For example, the average predicted spread is 23.7 bps for Safe bonds and 78.8 bps for C-rated bonds. However, predicted spreads are too high for speculative grade bonds and increasingly so for more credit risky bonds: average predicted spreads are higher than average actual spreads by 2.5 bps for BB-rated bonds, 11.7 bps for B-rated bonds, and 29.0 bps for C-rated bonds. For investment grade bonds, predicted spreads are broadly in line with actual spreads. The predicted spread for long-maturity Safe bonds is 4.6 bps higher than for AA bonds, which is also in line with actual spreads.

Overall, variation in bond volatilities captures a large fraction of the variation in bid-ask spreads.

Search and bargaining

A major implication of search-based models is that there is a positive relation between bid-ask spreads and the time it takes dealers to intermediate bonds. Table 10 shows that this is indeed the case since the slope coefficient $\hat{\beta}_1$ in the regression of bid-ask spreads on chain times is significantly positive.

Table 9 shows the average time it takes dealers to complete a round-trip intermediation chain. Depending on bond maturity and rating, it takes dealers on average between 5.7 and 9.4 days to complete a chain. The table shows that it takes longer to intermediate long-maturity bonds compared to short-maturity bonds; for example it takes on average 7.7 days to intermediate long-maturity BBB bonds while the corresponding time is 6.4 days for short-maturity BBB bonds. Across rating, chain time is lower for speculative grade bonds compared to investment grade bonds.

Table 12 shows average bid-ask spreads predicted by chain times. Inconsistent with actual bid-ask spreads, there is little variation in predicted bid-ask spreads both across rating and maturity, due to the modest variation in average chain times combined with a low loading on chain times. Predicted bid-ask spreads range from 33.0 bps to 35.3 bps while actual bid-ask spreads range from 24.2 bps to 78.7 bps.

Turning to bargaining, we see in Table 9 that depending on rating and maturity the average dealer concentration is between 24.4% and 39.4%. To interpret this range, note that if there are three dealers with an equal market share, the Herfindahl-Hirschman index is 33.3%. The dealer concentration in the U.S. corporate market is substantially higher than in other OTC markets such as the markets for options, forwards, and interest rate swaps (see Cetorelli et al. (2007)).

Table 13 shows average predicted bid-ask spreads from bargaining. Predicted bid-ask spreads range from 32.4 bps to 35.6 bps, far below the actual range. The low range is, as is the case with search frictions, due to the low variation of dealer concentration combined with the low loading on dealer concentration.

Our results imply that search and bargaining frictions are unable to explain bid-ask spreads across rating and maturity.

Asymmetric information

If some investors have private information, dealers charge a positive bid-ask spread and obtain a positive profit from uninformed investors to offset losses arising from trading with the informed investors. In Appendix A we derive an unlevered bond bid-ask spread from the Merton (1974) model where we include asymmetric information as in Copeland and Galai (1983). In the model, the bond bid-ask spread is equal to the equity bid-ask spread times the sensitivity of bond returns to equity returns.

We calculate an equity bid-ask spread for each observation of the bond bid-ask spread and Table 9 shows average equity bid-ask spreads. Equity bid-ask spreads increase with credit risk, similar to the pattern in bond bid-ask spreads. However, the size of equity bid-ask spreads is smaller than in the bond market. For example, the average equity bid-ask spread for firms with Safe (BBB-rated) bonds is 6.9 (10.7) bps while the corresponding average bond spread in Table 3 is 28.4 (36.3) bps. In models with asymmetric information, the bid-ask spread on equity is larger than the bid-ask spread on debt (see for example Dang et al. (2015)).

Table 14 shows the bond bid-ask spread unlevered from the equity market. We see that unlevered bid-ask spreads are small, in particular for investment grade bonds. For example, the average predicted bond bid-ask spread for Safe bonds is only 0.1 bps, far from the average actual spread of 32.7 bps. The reason is that the sensitivity of bond returns to equity returns is too low to generate a significant unlevered bond bid-ask spread. As an example, the 10-year cumulative default rate for safe bonds is less than 0.23% and such small default rates have very modest effects on bond prices.[7] In this case, private information about a safe bond issuer can have a sizeable effect on equity prices but will have almost no effect on bond prices. This in turn implies a sizeable equity bid-ask spread and a close-to-zero bond bid-ask spread.

Consistent with actual bond spreads, predicted bond spreads increase in maturity and rating, but the sizes of predicted spreads are substantially lower than actual spreads. Overall, the results show that asymmetric information only accounts for a minor fraction of bond bid-ask spreads.

Dealer network

Theories of dealer networks predict that how bonds are traded throughout the network of dealers is crucial for the bid-ask spread. As outlined earlier, we calculate an average markup for each dealer and then estimate a predicted bid-ask spread for each round-trip intermediation chain by adding the average markups of the dealers involved in the chain. If, for example, central dealers on average charge higher markups, predicted bid-ask spreads will be higher for chains involving

[7] See Moody's (2018) Exhibition 35.

central dealers.

Table 15 presents predicted bid-ask spreads based on dealer network. We see that for long-maturity bonds, predicted spreads show a U-shaped pattern across rating consistent with actual bid-ask spreads: Safe bonds have substantially higher spreads than other investment grade bonds and for lower rated bonds there is a gradual increase in spreads. Thus, the dealer network is important in explaining the variation in bid-ask spreads for long-maturity bonds. For short-maturity bonds predicted spreads appear less consistent with actual spreads. In particular, average spreads predicted by the dealer network decrease in maturity which is in stark contrast to the increasing pattern in actual spreads. Overall, the results show that the dealer network is important for understanding spreads for long-maturity bonds across rating, while spreads across maturity remain unexplained by the dealer network.

5.2 Joint Prediction in Panel Regression

In Section 5.1, we investigate variation in bid-ask spreads across bond maturity and rating. There may be other dimensions in which there is important variation in spreads, and we therefore examine the ability of models to capture the spread in a panel regression. We restrict the sample to bond spread observations for which all five empirical measures are available and present the results for institutional-sized transactions in Table 16 and for retail-sized transactions in Table 17.

Panel A in Table 16 shows the results for all bonds based on institutional-sized transactions. There are two models that stand out in terms of their ability to explain spreads: inventory and dealer network models. R^2's of inventory and dealer networks models are 3 and 3.5%, respectively, while the remaining models have R^2's of 0.5% or below. The t-statistics also point to inventory and dealer network models as most important in explaining spreads.[8] The R^2 of 6.0% in the joint regression shows that inventory and dealer network models capture distinct aspects of the spread.

Focusing on investment grade bonds, we see in Panel B that inventory and dealer network models stand out even more than in the full sample with R^2's of 6.1% and 5.0%, respectively. Thus, for investment grade bonds inventory risk is the main determinant of spreads followed by the dealer network. Our asymmetric information measure has a sizeable R^2 of 2.6% but we note that the coefficient is 30.172, far from one as predicted by our model. A potential explanation for this is that the measure is correlated with bond volatility and to a certain extent captures inventory effects. Consistent with this explanation, we see in specification (6) that the coefficient on asymmetric information is substantially smaller when included in a joint regression with bond volatility.

[8] Since standard errors are clustered, there is not a one-to-one correspondence between t-statistics and R^2.

For speculative grade bonds, we see in Panel C that inventory and dealer network models have the highest explanatory power, consistent with the results on investment grade bonds. However, for speculative grade bonds the dealer network stands out as the most important determinant of bid-ask spreads.

Panel A in Table 17 shows the results for all bonds based on retail-sized transactions. Similar to our findings for institutional-sized transactions, we also find that inventory and dealer network models have the highest R^2's of 15.6% and 15%, respectively. When we use bond volatility to proxy for dealer inventory risk, the relatively high R^2 partly reflects that higher levels of bid-ask spreads induce more noise in bond prices and leads to higher volatility estimates. Since retail-sized transactions have higher bid-ask spreads than institutional-sized transactions, the relation between bid-ask spreads and bond volatility becomes more pronounced. We confirm this relation using simulations and refer the details to Appendix B. In addition, we also find that our asymmetric information measure has a sizeable R^2 of 6.3% for retail-sized transactions but the coefficient estimate remains far from one as predicted by our model. Surprisingly, we obtain a negative coefficient estimate on chain time unlike our results with institutional-sized transactions. The statistical significance of this estimate, however, is substantially below our other proxies and the R^2 of the regression is essentially zero. The joint regression in column 6 has an R^2 of 25.1% meaning that our proxies also capture distinct aspects of the spread for retail-sized transactions.

For investment grade bonds in Panel B, we again find that inventory and dealer network models stand out even more than in the full sample with R^2's of 19.1% and 19.5%, respectively. Panel C presents the results for speculative grade bonds where inventory and dealer network models continue to have the highest highest R^2's of 6.3% and 6.1%. The coefficient estimate on dealer concentration is negative and statistically significant in column 5 but the R^2 remains close to zero. In column 6 where we include all proxies, this coefficient estimate becomes positive but statistically insignificant. Taken together, our results for retail-sized transactions support our conclusions from institutional-sized transactions that inventory and dealer network models have the highest explanatory power for the variation in bid-ask spreads.

5.3 Matched Trades

There is a recent literature finding that matched trades are different in nature than other trades in the corporate bond market (see among others Schultz (2017), Bao et al. (2018), and Bessembinder et al. (2018)). Matched trades are riskless principal trades arranged by a dealer such that trades offset each other, typically within one minute, and the dealer does not have inventory risk.

The theories we test above have distinct predictions on the bid-ask spread of matched trades. In standard search-and-bargaining models, the main drivers of spreads is the search for counterparties and bilateral bargaining and the models abstain from modelling inventory of dealers. A standard feature of the models is that dealers have immediate access to an interdealer market in which they unload their positions, so that they have no inventory at any time (see for example Duffie et al. (2005), Lagos and Rocheteau (2009), Feldhütter (2012), and He and Milbradt (2014)). In such models, dealers immediately unload bonds in the interdealer market and all transactions appear as prematched. Therefore, we do not expect to see different bid-ask spreads of matched and unmatched trades.

In inventory models, the bid-ask spread arises because the dealer is compensated for the risk that the bond price decreases while the dealer has the bond in inventory. In matched trades there is no such risk and the bid-ask spread in matched trades should be constant across rating and maturity.

Bid-ask spreads in asymmetric information models arise because the dealer has to earn a positive profit when trading with uninformed investors to offset trading loses when trading against informed investors. In matched trades, there is no such potential trading losses regardless of whether the counterparty is informed or uninformed and therefore the models predict that the bid-ask spread of matched trades is constant.

As noted in footnote 6, there are a number of theories that may explain the network structure, for example search frictions and asymmetric information, and therefore dealer network models do not have clear predictions on matched trades.

In our sample, we define matched trades as round-trip intermediation chains completed within one minute. We calculate bid-ask spreads in the same way as for the full sample. Specifically, if a bond has several chains beginning on the same day, we calculate the volume-weighted bid-ask spread. This implies that the sum of matched and unmatched chains is higher than the sum of all chains in Table 1, because if a bond trades in both a matched and in a unmatched chain on a given day, this gives rise to only one volume-weighted chain in the full sample. Finally, we divide our samples of matched and unmatched chains into seven rating groups and three maturity groups similar to our previous analysis. We winsorize bid-ask spreads within each of the 21 rating-maturity groups, for matched and unmatched chains separately, at the 1st and 99th percentiles over the entire sample.

Table 18 shows the bid-ask spread for matched and unmatched chains, respectively. For investment grade bonds, the bid-ask spread of matched chains is a small fraction of the spread of unmatched chains. For example, the bid-ask spread of matched chains for Safe bonds is 5.9 bps while the spread is 31.8 bps for unmatched chains. Furthermore, the spread does not consistently become larger as bond maturity increases. For example, the spread for BBB bonds shows little relation to maturity for matched chains. Since search-and-bargaining models predict that there is no difference in bid-ask spreads of matched and unmatched chains, these results suggest that these models cannot explain the size of bid-ask spreads for speculative grade bonds. In contrast, the large difference between matched and unmatched chains is consistent with models of inventory and asymmetric information.

For speculative grade bonds, we see that bid-ask spreads of matched chains increase substantially as credit quality deteriorates and for the lowest C-rated bonds the average bid-ask spread of matched chains is 46.1 bps which is a sizeable 66% of the bid-ask spread of unmatched chains of 69.7 bps. This is consistent with the importance of search-and-bargaining frictions increasing as bonds become more credit risky.

6 Conclusion

We estimate bid-ask spreads in the U.S. corporate bond market using realized transaction costs from round-trip intermediation chains and document variation across credit quality and bond maturity. Spreads increase in bond maturity for investment grade bonds, but there is no clear relation for speculative grade bonds. For short-maturity bonds, spreads increase with credit risk while long-maturity Safe bonds have significantly higher spreads than other investment grade bonds. We use the documented patterns to test prominent theories of the bid-ask spread in OTC markets: inventory, search-and-bargaining, asymmetric information, and dealer networks.

A key implication of dealer inventory models is that the bid-ask spread is proportional to bond return volatility, and consistent with this implication we find that variation in bond volatilities explains a large part of the variation in bond bid-ask spreads, in particular for investment grade bonds. We also calculate a predicted spread from the dealer network by calculating an average markup for each dealer and estimating a predicted spread for each round-trip intermediation chain by adding the markups of the involved dealers. We find that predicted spreads can also explain part of the variation, especially for speculative grade bonds.

We do not find much support for search-and-bargaining models. Our proxies for search-and-bargaining models, the time it takes to complete a round-trip intermediation chain and dealer concentration, do not exhibit much variation across bond maturity or rating. Furthermore, we find that matched chains, i.e. chains that are completed within one minute, have much smaller spreads than unmatched chains. Search-based models predict that there is no difference in spreads of matched and unmatched chains.

Finally, asymmetric information models predict that the equity bid-ask spread is larger than the bond bid-ask spread because the equity price is more sensitive to information than the bond price, and we exploit this feature to derive a predicted bond bid-ask spread by unlevering the equity bid-ask spread. We find that predicted bond spreads are much too small, in particular for investment grade bonds, suggesting that asymmetric information, at least for investment grade bonds, is not important for determining bid-ask spreads.

Appendices

A Empirical Measures: Implementation Details

This appendix explains implementation details of the measures we use to proxy for central predictions from theories on frictions in OTC markets.

A.1 Inventory: bond return volatility

We use the WRDS Bond Returns dataset to estimate bond return volatility. This dataset contains monthly bond returns based on cleaned transaction prices from Enhanced and Standard TRACE. We use the monthly return based on the last price at which a bond traded in a given month provided that day falls within the last 5 trading days of the month. If there are no trades in the last five days of the current month or the previous month, the bond return is missing for the month. We estimate bond return volatility as the standard deviation of monthly bond returns in the past 24 months and require at least 12 monthly observations in the two-year estimation window. We use bond return volatility instead of bond return variance as implied by Stoll (1978) and Ho and Stoll (1983) because the distribution of bond volatilities is less skewed. To account for outliers, we winsorize the bond-month observations of bond volatility one-sided at the 98% level. We have also done our analysis using the monthly return based on either (1) the last price at which the bond traded in a given month or (2) the price on the last trading day of the month and these choices give similar results.

A.2 Search: chain time

We measure chain time as the number of days it takes to complete a round-trip intermediation chain. A chain starts when the head dealer buys bonds from an investor and ends when the tail dealer sells bonds to an investor. The chain time is the number of days between the first and last transaction in the chain. In case of order splitting, we calculate the par-weighted transaction date of the last leg in the chain. For example, assume an investor sells $1mio in par value to a dealer on a Monday. This dealer sells half the amount to an investor on the following Wednesday and the rest to another investor on the following Friday. In this case the chain time is $\frac{1}{2} * 2 + \frac{1}{2} * 4 = 3$ days.

A.3 Bargaining: Herfindahl-Hirschman index for dealer concentration

For each bond, we calculate a Herfindahl-Hirschman (HH) index based on bond transactions in the past month. Assume that there are N dealers transacting in bond j over the last month and dealer i transacts a par value of v_i. The market share of dealer i is $s_i = \frac{v_i}{\sum_{i=1}^{N} v_i}$ and the HH index at time t is

$$DC_{j,t} = \sum_{i=1}^{N} s_i^2. \tag{A.1}$$

A.4 Dealer network: predicted bond bid-ask spreads based on the dealer network

For each dealer we find all instances in the round-trip intermediation chains where the dealer

- buys from an investor and sells to another investor
- buys from an investor and sells to a dealer
- buys from a dealer and sells to another dealer
- buys from a dealer and sells to an investor

and in each of the four cases we calculate a dealer-specific average markup, across all chains, where the markup in each leg of the chain is estimated as

$$\frac{\text{dealer sell price } - \text{dealer buy price}}{\text{mid-price}} \tag{A.2}$$

where the mid-price is the average of the investor sell price and the investor buy price in the chain. In case of order splitting, the investor buy price is the par-weighted average of investor buy prices. The average markup in each of the four cases serves as the predicted markup for this particular dealer.

For each round-trip intermediation chain, we calculate a bid-ask spread predicted by the dealer network in the following way. For each dealer in the chain, we replace the actual markup with the predicted markup, and then calculate the total round-trip markup based on the sum of the predicted dealer markups. As in example, consider a chain where an investor sells to dealer A, dealer A sells to dealer B, and dealer B ultimately sells to another investor. Assume that on average dealer A earns a markup of 10 bps when buying from an investor and selling to another dealer, while dealer B on average earns a markup of 15 bps when buying from another dealer and selling to an investor. In this case the predicted markup is 25 bps.

We winsorize predicted bid-ask spreads at the 1% and 99% level.

A.5 Asymmetric information: predicted bond bid-ask spread extracted from the equity bid-ask spread

We use a model to calculate predicted bond bid-ask spreads from equity bid-ask spreads for the issuing firm. Our model follows Copeland and Galai (1983). We assume that V_0 is the current value of the firm as perceived by a risk-neutral dealer. The dealer trades a claim on the value of the firm C_0 and commits to sell a fixed quantity of the claim for K_A and buy a fixed quantity for K_B within a short period of time.

Firm value can take on two values in the next period, $V_u > V_0$ and $V_d < V_0$, and each value is equally likely. We assume that claim value is monotone in firm value and therefore $C_u > C_0$ and $C_d < C_0$. An investor arrives and trades before the next period; after the transaction firm value in the next period is revealed. With probability p the investor is informed about the value of the firm while with probability $1 - p$ the investor trades for liquidity-reasons and is uninformed. It is equally likely that the liquidity-trader will buy or sell. The dealer's expected revenue from the transaction if the investor is a liquidity-trader is

$$\frac{1}{2}(K_A - C_0) + \frac{1}{2}(C_0 - K_B) \tag{A.3}$$

while the expected revenue if the investor is informed is

$$\frac{1}{2}(K_A - C_u) + \frac{1}{2}(C_d - K_B) \tag{A.4}$$

The dealer revenue in equation (A.4) is negative because the informed investor only trades if he gains a profit. We assume that dealer markets are competitive and therefore the expected dealer profit is zero

$$(1-p)\left(\frac{1}{2}(K_A - C_0) + \frac{1}{2}(C_0 - K_B)\right) + p\left(\frac{1}{2}(K_A - C_u) + \frac{1}{2}(C_d - K_B)\right) = 0 \tag{A.5}$$

and simplifying the expression yields

$$K_A - K_B = p(C_u - C_d). \tag{A.6}$$

Assume that dealer A trades equity while dealer B trades debt and the probabilities in the two markets (of the investor being informed and the liquidity-trader selling) are the same. In this case equation (A.6) holds for both dealers and the ratio between the bid-ask spread in the equity and the debt market is

$$\frac{K_A^E - K_B^E}{K_A^D - K_B^D} = \frac{E_u - E_d}{D_u - D_d} \tag{A.7}$$

while the ratio between the relative bid-ask spreads is

$$\frac{(K_A^E - K_B^E)/E_0}{(K_A^D - K_B^D)/D_0} = \frac{(E_u - E_d)/E_0}{(D_u - D_d)/D_0}. \tag{A.8}$$

Equation (A.8) shows that the relative spreads depend on the price sensitivity of debt and equity to changes in firm value: if the percentage change in equity value is twice the percentage change in debt value, the relative bid-ask spread of equity is twice that of debt.

Assume now that firm value follows a Geometric Brownian Motion and that the firm has issued one zero-coupon bond with maturity date T, i.e. this is the Merton (1974) model. It is well-known that the value of equity is equal to the value of a call option while the value of debt is equal to the value of a risk-free bond minus the value of a put option.

Consider the above model as one period in a discrete-time binomial tree version of the Merton model. We know that as the time period in the binomial model shrinks, the value of debt, equity, and deltas converge to the Black-Scholes values (Walsh (2003)). Therefore, the ratio between the relative bid-ask spreads converges to

$$\frac{(K_A^E - K_B^E)/E_0}{(K_A^D - K_B^D)/D_0} \to \frac{N(d_1)/C(V_0)}{\big(1 - N(d_1)\big)/(D - P(V_0))} \tag{A.9}$$

where $C(V_0)$ and $P(V_0)$ are Black-Scholes call and put option values, D is the value of a risk-free zero-coupon bond with maturity date T and face value equal to the face value of the risky debt, $N(.)$ is the standard normal distribution function, and

$$d_1 = \frac{1}{\sigma\sqrt{T}}\left(\log(V_0/d) + (r_t - \delta_t - \frac{1}{2}\sigma^2)T\right) \tag{A.10}$$

where σ is asset volatility, T is the time-to-maturity of the bond, d is the default point, r_t is the yield at time t for a Treasury bond with maturity T, and δ_t is the payout rate at time t.

We use data from several sources to estimate the model parameters. For a given bond on a given day, we use data from Mergent FISD to determine time-to-maturity T and calculate r_t as the interpolated maturity-matched Treasury rate using data from the Federal Reserve Bank. To estimate the remaining parameters, we combine annual accounting information from COMPUSTAT with daily stock market data from CRSP. We align each firm's fiscal year with the calendar year and lag accounting data by six months when we merge the two datasets using the CRSP-

COMPUSTAT linking table. We only consider common stocks (SHRCD equal to 10 or 11 in CRSP) and calculate the daily market value of equity and the daily equity bid-ask spread from CRSP. If a firm has more than one share class, we compute a weighted bid-ask spread based on the market capitalization of each share class.

We use the approach from Feldhütter and Schaefer (2018) to estimate firms' asset volatilities as

$$\sigma_t = R(L_t)(1 - L_t)\sigma_{E,t} \tag{A.11}$$

where $\sigma_{E,t}$ is equity volatility and L_t is the market leverage ratio at time t, and R is a step-function of L_t that is 1 if $L_t < 0.25$, 1.05 if $0.25 < L_t \leq 0.35$, 1.10 if $0.35 < L_t \leq 0.45$, 1.20 if $0.45 < L_t \leq 0.55$, 1.40 if $0.55 < L_t \leq 0.75$, and 1.80 if $L_t > 0.75$. The firm's daily market leverage is the ratio of total debt to the sum of total debt and the market value of equity. The equity volatility is the annualized standard deviation of daily stock returns from CRSP measured over the past three years. We require return observations on at least half the trading days in the three-year window before we compute the equity volatility. If a firm has more than one share class, we compute the weighted equity volatility based on the market capitalization of each share class. For a given firm, we calculate the average asset volatility over the entire sample period and use this constant asset volatility σ for every day in the sample period.

We follow Feldhütter and Schaefer (2018) and calculate daily payout rates as the sum of interest payments to debt, dividend payments to equity, and net stock repurchases divided by the sum of total debt and the market value of equity. We also use the estimated default point $d = 0.8944 * F$ from Feldhütter and Schaefer (2018) where F is the total debt face value from COMPUSTAT. We use the linking table from Wharton Research Data Services (WRDS) to merge bond-level information with firm characteristics for bonds/firms with non-overlapping linking dates.

Finally, we imply out firm value V_0 such that the value of the call option $C(V_0)$ equals the market value of equity at time t and subsequently we calculate the ratio in equation (A.9) and multiply the equity bid-ask spread with this ratio to derive a predicted bond bid-ask spread. Predicted bond bid-ask spreads are winsorized at the 1% and 99% level.

B Regression Results with Simulated Transaction Prices

In this section, we analyze the relationship between bid-ask spreads and bond return volatility using simulated transaction prices. Let m_{it} denote the mid-price for bond i at time t

$$m_{it} = m_{i,t-1} + u_{it}, \qquad u_{it} \sim N(0, \sigma) \tag{B.1}$$

such that the transaction price p_{it} for bond i at time t is

$$p_{it} = m_{it} + q_{it}c_i, \qquad c_i \sim unif(a, b) \tag{B.2}$$

where q_{it} is the trade indicator (+1 for buys and -1 for sells) and c_i is the half spread. We assume q_{it} is independent of u_{it} and $P(q_{it} = 1) = P(q_{it} = -1) = 0.5$. Let $m_{i0} = 100$ for all $i = \{1, \ldots N\}$ bonds and consider $t = \{1, \ldots T\}$ months. The monthly bond return is

$$r_{it} = log(p_{it}) - log(p_{i,t-1}) \tag{B.3}$$

and the estimated monthly bond volatility for bond i is

$$\hat{\sigma_i} = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(r_{it} - \hat{\mu_i})^2} \tag{B.4}$$

where

$$\hat{\mu_i} = \frac{1}{T}\sum_{t=1}^{T} r_{it} \tag{B.5}$$

We calculate bid-ask spreads measured in bps as

$$BA_i = 2 * c_i \tag{B.6}$$

and estimate the regression

$$BA_i = \beta_0 + \beta_1\hat{\sigma_i} + \epsilon_i \tag{B.7}$$

For $N = 10,000$ bonds and $T = 36$ months, we only draw one set of random numbers and consider different combinations of underlying parameter values. In Table B.1, we present the regression results. Panel A shows that for institutional-sized bid-ask spreads (0-70 bps), it requires a small annualized bond volatility of 4% to generate a meaningful R^2. For comparison, the average annualized bond volatility is 8.3% in our sample. Panel B shows the results for retail-sized bid-ask spreads (0-220 bps). Both the magnitudes of the coefficient estimates $\hat{\beta}_1$ and the R^2's are substantially higher for retail-sized transactions compared to institutional-sized transactions. These features are consistent with our findings in Table 16 and 17.

Table B.1: Regressions Results Based on Simulated Transaction Prices

This table presents regression results of the equation $BA_i = \beta_0 + \beta_1 \hat{\sigma_i} + \epsilon_i$ based on simulated transaction prices. The bid-ask spread is measured in bps and annualized bond volatility is in percent. Panel A shows the results for (institutional-sized) bid-ask spreads between 0 og 70 bps while Panel B presents the results for (retail-sized) bid-ask spreads between 0-220 bps.

	Annualized σ		
	4%	8%	12%
Panel A: Spreads from 0-70 BPS			
$\hat{\beta}_0$	15.23	29.1	31.85
	(8.95)	(16.95)	(18.60)
$\hat{\beta}_1$	487.51	72.12	25.22
	(11.62)	(3.37)	(1.77)
Adj. R^2	0.013	0.001	0.000
Panel B: Spreads from 0-220 BPS			
$\hat{\beta}_0$	-161.11	-23.90	43.20
	(-51.30)	(-4.72)	(8.14)
$\hat{\beta}_1$	6006.51	1622.00	547.90
	(87.21)	(26.55)	(12.59)
Adj. R^2	0.432	0.066	0.016

Table 1: Sample composition

This table shows the number of trades, bonds, firms, and dealers in our sample. The data are for U.S. corporate bonds with fixed coupons and bonds that are callable at a fixed price, putable, convertible, denoted in foreign currency, or have sinking fund provisions are excluded. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Data are from Academic TRACE and the sample period is 1 July 2002 to 30 June 2015.

	Safe	AA	A	BBB	BB	B	C	All
	Panel A: All Bonds							
Trades	1,150,127	1,617,763	6,132,073	5,996,227	1,878,930	919,741	451,125	18,145,986
Bonds	1,692	3,289	10,591	10,375	3,881	1,760	984	23,626
Firms	200	391	1,290	1,843	810	507	254	3,178
Dealers	1,752	1,794	2,288	2,367	1,895	1,653	1,437	2,867
	Panel B: Short Maturity (0-4 Years)							
Trades	551,520	806,902	2,278,409	1,727,149	515,662	306,705	193,688	6,380,035
Bonds	1,131	2,317	6,810	6,569	2,481	1,113	657	16,931
Firms	172	319	1,066	1,411	566	355	199	2,671
Dealers	1,432	1,536	1,901	2,041	1,577	1,352	1,195	2,509
	Panel C: Medium Maturity (4-8 Years)							
Trades	288,039	454,844	1,813,048	1,713,405	717,313	359,942	170,759	5,517,350
Bonds	772	1,305	4,867	4,763	1,451	675	300	12,030
Firms	114	256	941	1,420	560	358	158	2,537
Dealers	1,299	1,351	1,832	1,843	1,403	1,234	1,018	2,350
	Panel D: Long Maturity (>8 Years)							
Trades	310,568	356,017	2,040,616	2,555,673	645,955	253,094	86,678	6,248,601
Bonds	586	698	3,583	3,958	1,051	427	202	8,370
Firms	71	210	831	1,309	458	215	90	2,037
Dealers	1,252	1,113	1,716	1,803	1,330	1,093	833	2,385

Table 2: Round-trip intermediation chain summary statistics

This table shows summary statistics for our sample of round-trip intermediation chains (RTICs). *Maturity* is the time-to-maturity and *Age* is the time since issuance, both measured in years. *Amount outstanding* and *Trade size* are in millions of US dollars. We use the last leg in RTICs to measure *Trade size*. N is the number of RTICs. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Data are from Academic TRACE and the sample period is 1 July 2002 to 30 June 2015.

	Safe	AA	A	BBB	BB	B	C	All
				Panel A: All Bonds				
Maturity	6.12	5.71	7.65	9.24	7.55	7.09	6.74	7.85
Age	2.99	3.31	3.34	3.32	3.49	4.55	5.65	3.44
Amt. Out.	1,953	1,252	1,124	885	744	685	621	1,028
Trade size	2.83	2.21	2.26	2.51	2.24	2.29	2.64	2.38
N	95,933	172,235	625,917	591,137	193,252	94,045	38,641	1,811,160
				Panel B: Short Maturity (0-4 Years)				
Maturity	1.87	1.83	1.93	2.08	2.29	2.31	2.17	2.00
Age	3.30	4.00	4.25	4.47	4.71	5.44	6.00	4.33
Amt. Out.	1,767	1,165	990	799	667	570	474	966
Trade size	3.17	2.04	1.94	2.20	2.29	2.42	2.54	2.18
N	54,842	97,019	276,465	192,586	55,049	32,973	16,401	725,335
				Panel C: Medium Maturity (4-8 Years)				
Maturity	5.57	5.39	5.64	5.81	5.95	5.86	5.72	5.73
Age	2.60	2.36	2.74	2.99	2.75	3.12	3.95	2.85
Amt. Out.	1,863	1,334	1,261	841	760	692	710	1,026
Trade size	2.25	2.19	2.20	2.47	2.17	2.09	2.60	2.29
N	20,459	40,224	161,885	164,093	75,890	36,775	14,914	514,240
				Panel D: Long Maturity (>8 Years)				
Maturity	17.95	16.84	17.82	17.53	14.15	15.42	19.07	17.16
Age	2.54	2.50	2.51	2.60	3.30	5.51	8.35	2.84
Amt. Out.	2,538	1,401	1,204	987	794	833	771	1,109
Trade size	2.50	2.72	2.78	2.79	2.29	2.44	2.95	2.70
N	20,632	34,992	187,567	234,458	62,313	24,297	7,326	571,585

Table 3: Bid-ask spread estimates

For all bonds in the sample, we calculate daily bid-ask spreads from round-trip intermediation chains, as a percentage of the mid-price and measured in basis points and report the average bid-ask spread across rating and maturity. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). We report standard errors clustered at the bond level in parentheses and the number of observations in brackets. Data are from Academic TRACE and the sample period is 1 July 2002 to 30 June 2015.

	Maturity			
	Short	Medium	Long	All
Safe	16.3	38.4	50.4	28.4
	(0.95)	(2.52)	(2.84)	(1.15)
	[54,842]	[20,459]	[20,632]	[95,933]
AA	17.3	37.2	40.2	26.6
	(0.67)	(2.19)	(1.67)	(0.83)
	[97,019]	[40,224]	[34,992]	[172,235]
A	16.7	34.5	45.8	30.0
	(0.36)	(0.88)	(0.91)	(0.45)
	[276,465]	[161,885]	[187,567]	[625,917]
BBB	25.6	37.3	44.5	36.3
	(0.55)	(0.84)	(0.92)	(0.49)
	[192,586]	[164,093]	[234,458]	[591,137]
BB	39.8	33.7	42.8	38.4
	(1.23)	(1.28)	(2.11)	(0.96)
	[55,049]	[75,890]	[62,313]	[193,252]
B	43.5	41.8	49.8	44.4
	(2.81)	(2.87)	(4.59)	(1.91)
	[32,973]	[36,775]	[24,297]	[94,045]
C	63.8	43.0	116.3	65.7
	(8.20)	(8.47)	(17.03)	(5.78)
	[16,401]	[14,914]	[7,326]	[38,641]
All	23.1	36.4	45.8	34.1
	(0.37)	(0.60)	(0.70)	(0.11)
	[725,335]	[514,240]	[571,585]	[1,811,160]

Table 4: Bid-ask spread estimates: crisis vs non-crisis

For all bonds in the sample, we calculate daily bid-ask spreads from round-trip intermediation chains, as a percentage of the mid-price and measured in basis points and report the average bid-ask spread across rating and maturity. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). The crisis period is from 1 April 2007 to 30 June 2009. We report standard errors clustered at the bond level in parentheses and the number of observations in brackets. Data are from Academic TRACE and the sample period is 1 July 2002 to 30 June 2015.

	Non-Crisis			Crisis		
	Short	Medium	Long	Short	Medium	Long
Safe	11.3	32.7	47.6	47.5	64.9	65.6
	(0.44)	(2.02)	(2.83)	(3.18)	(7.06)	(6.00)
	[47,204]	[16,868]	[17,388]	[7,638]	[3,591]	[3,244]
AA	12.0	29.3	36.2	48.2	79.2	61.0
	(0.39)	(1.68)	(1.58)	(2.41)	(5.06)	(4.09)
	[82,878]	[33,887]	[29,374]	[14,141]	[6,337]	[5,618]
A	13.0	29.8	41.3	50.1	69.9	70.5
	(0.28)	(0.79)	(0.87)	(1.38)	(2.19)	(1.92)
	[248,523]	[142,787]	[158,622]	[27,942]	[19,098]	[28,945]
BBB	21.9	33.8	41.7	57.8	67.5	63.5
	(0.52)	(0.83)	(0.97)	(1.71)	(2.16)	(1.95)
	[173,181]	[146,841]	[205,033]	[19,405]	[17,252]	[29,425]
BB	36.8	33.3	44.2	62.1	37.2	32.4
	(1.20)	(1.36)	(2.28)	(3.54)	(3.34)	(4.48)
	[48,528]	[67,629]	[54,675]	[6,521]	[8,261]	[7,638]
B	46.3	43.4	56.6	31.8	28.9	12.6
	(2.99)	(3.06)	(4.11)	(6.68)	(7.69)	(18.51)
	[26,497]	[32,681]	[20,544]	[6,476]	[4,094]	[3,753]
C	55.2	45.8	105.3	105.6	28.8	154.1
	(8.50)	(9.22)	(15.84)	(23.10)	(19.69)	(51.68)
	[13,586]	[12,428]	[5,678]	[2,815]	[2,486]	[1,648]

Table 5: Bid-ask spread estimates with time fixed effects

This table shows bid-ask spread estimates from a regression with time fixed effects. For all bonds in the sample, we calculate daily bid-ask spreads from round-trip intermediation chains, as a percentage of the mid-price and measured in basis points. We then estimate the regression:

$$BA_{it} = \sum_{r=1}^{7}\sum_{m=1}^{3} \alpha_{rm} D_{itrm} + \delta_t + \epsilon_{it}$$

where BA_{it} is the bid-ask spread for bond i at day t, D_{itrm} is a dummy variable that equals one if bond i at time t belongs to rating group r and maturity group m and equals zero otherwise, and δ_t denotes month fixed effects. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). Estimates of α_{rm} represent the average bid-ask spread for each rating-maturity group. We report standard errors clustered at the bond level in parentheses and the number of observations in brackets. Data are from Academic TRACE and the sample period is 1 July 2002 to 30 June 2015.

	Maturity			
	Short	Medium	Long	All
Safe	14.1	38.3	47.8	26.4
	(0.93)	(1.92)	(2.47)	(1.15)
	[54,842]	[20,459]	[20,632]	[95,933]
AA	18.9	35.5	39.6	26.9
	(0.55)	(1.83)	(1.60)	(0.74)
	[97,019]	[40,224]	[34,992]	[172,235]
A	19.1	34.2	43.3	30.3
	(0.32)	(0.74)	(0.78)	(0.40)
	[276,465]	[161,885]	[187,567]	[625,917]
BBB	25.2	36.9	43.3	35.6
	(0.46)	(0.69)	(0.86)	(0.46)
	[192,586]	[164,093]	[234,458]	[591,137]
BB	40.9	35.6	46.6	40.8
	(1.13)	(1.20)	(2.09)	(0.96)
	[55,049]	[75,890]	[62,313]	[193,252]
B	41.6	43.0	51.7	44.8
	(2.64)	(2.65)	(4.34)	(1.78)
	[32,973]	[36,775]	[24,297]	[94,045]
C	59.0	43.3	112.7	63.1
	(7.47)	(7.92)	(16.22)	(5.31)
	[16,401]	[14,914]	[7,326]	[38,641]
All	23.9	36.5	44.9	34.1
	(0.34)	(0.52)	(0.66)	(0.10)
	[725,335]	[514,240]	[571,585]	[1,811,160]

Table 6: Bid-ask spread estimates: financials vs non-financials

For all bonds in the sample, we calculate daily bid-ask spreads from round-trip intermediation chains, as a percentage of the mid-price and measured in basis points and report the average bid-ask spread across rating and maturity. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). We report standard errors clustered at the bond level in parentheses and the number of observations in brackets. Data are from Academic TRACE and the sample period is 1 July 2002 to 30 June 2015.

	Non-financials			Financials		
	Short	Medium	Long	Short	Medium	Long
Safe	13.2	33.1	44.3	16.9	40.1	53.7
	(1.18)	(3.51)	(4.72)	(1.09)	(3.17)	(3.65)
	[8,438]	[4,963]	[7,317]	[46,404]	[15,496]	[13,315]
AA	12.0	28.5	36.9	20.4	44.0	44.7
	(0.51)	(1.54)	(1.78)	(0.99)	(3.51)	(2.97)
	[36,619]	[17,756]	[20,020]	[60,400]	[22,468]	[14,972]
A	15.1	31.0	44.3	18.1	38.4	48.6
	(0.40)	(0.80)	(0.95)	(0.58)	(1.59)	(1.85)
	[127,644]	[85,390]	[120,665]	[148,821]	[76,495]	[66,902]
BBB	22.5	34.9	43.0	32.3	45.0	51.0
	(0.60)	(0.83)	(0.95)	(1.16)	(2.36)	(2.66)
	[132,740]	[125,654]	[191,056]	[59,846]	[38,439]	[43,402]
BB	33.7	32.7	41.0	54.7	40.0	55.6
	(1.26)	(1.35)	(2.20)	(3.05)	(3.81)	(6.78)
	[39,009]	[65,004]	[54,842]	[16,040]	[10,886]	[7,471]
B	44.0	41.9	51.8	40.9	41.1	33.7
	(3.17)	(3.06)	(5.02)	(5.79)	(8.37)	(8.88)
	[27,285]	[32,100]	[21,662]	[5,688]	[4,675]	[2,635]
C	40.8	36.0	110.7	138.2	101.2	175.9
	(9.26)	(9.08)	(17.90)	(14.35)	(16.36)	(44.87)
	[12,521]	[13,314]	[6,692]	[3,880]	[1,600]	[634]

Table 7: Bid-ask spread estimates for retail-sized transactions

This table presents average bid-spreads for retail-sized transactions i.e. transactions with a trade size less than $100,000. For all bonds in the sample, we calculate daily bid-ask spreads from round-trip intermediation chains, as a percentage of the mid-price and measured in basis points and report the average bid-ask spread across rating and maturity. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). We report standard errors clustered at the bond level in parentheses and the number of observations in brackets. Data are from Academic TRACE and the sample period is 1 July 2002 to 30 June 2015.

	Maturity			
	Short	Medium	Long	All
Safe	76.5	151.7	224.7	137.0
	(2.38)	(5.16)	(5.78)	(3.71)
	[76,104]	[47,445]	[44,584]	[168,133]
AA	81.9	132.0	210.4	113.1
	(1.98)	(5.46)	(9.63)	(3.23)
	[123,172]	[53,935]	[29,030]	[206,137]
A	82.2	134.4	219.8	129.3
	(1.15)	(2.13)	(3.98)	(1.93)
	[361,684]	[227,036]	[175,531]	[764,251]
BBB	116.3	164.2	237.9	160.8
	(1.41)	(2.46)	(4.17)	(1.93)
	[281,643]	[168,144]	[154,952]	[604,739]
BB	181.7	202.0	280.1	209.0
	(2.38)	(4.95)	(7.60)	(3.13)
	[108,945]	[48,572]	[46,627]	[204,144]
B	227.1	250.2	318.8	255.2
	(6.24)	(10.16)	(11.05)	(5.41)
	[38,772]	[21,464]	[18,878]	[79,114]
C	369.9	369.2	454.5	388.4
	(12.55)	(20.04)	(24.67)	(9.84)
	[24,314]	[9,165]	[9,463]	[42,942]
All	114.3	158.1	240.0	155.6
	(1.22)	(1.78)	(2.86)	(2.05)
	[1,014,634]	[575,761]	[479,065]	[2,069,460]

Table 8: Correlations between empirical measures

This table shows the correlations between measures of inventory, asymmetric information, search costs, dealer network, and dealer concentration. The measures are defined in Section 4. We combine data from Academic TRACE, Mergent FISD, COMPUSTAT, and CRSP. We report standard errors in parentheses and the convention for p-values is: * when $p < 0.05$, and ** when $p < 0.01$. The sample period covers 1 August 2004 to 30 June 2015.

	BV	AI	CT	DN	DC
Bond volatility (BV)	1				
Asymmetric information (AI)	0.315**	1			
	(0.001)				
Chain time (CT)	0.050**	−0.005**	1		
	(0.001)	(0.001)			
Dealer network (DN)	0.08**	0.028**	0.131**	1	
	(0.001)	(0.001)	(0.001)		
Dealer concentration (DC)	−0.025**	−0.016**	−0.091**	−0.039**	1
	(0.001)	(0.001)	(0.001)	(0.001)	

Table 9: Summary statistics for empirical measures

This table shows the average value of empirical measures and the number of observations in brackets. Bond and equity volatility are annualized volatilities measured in percent, chain time is in days, dealer concentration is in percent, while equity bid-ask spread is relative to the mid-price and in basis points.

	Bond volatility				Chain time				Dealer concentration			
	Short	Medium	Long	All	Short	Medium	Long	All	Short	Medium	Long	All
Safe	3.0	6.2	12.3	5.3	7.5	9.1	9.4	8.2	30.0	26.5	24.4	28.1
	[33,913]	[10,744]	[9,680]	[54,337]	[54,842]	[20,459]	[20,632]	[95,933]	[53,011]	[18,966]	[19,011]	[90,988]
AA	3.7	8.4	10.6	5.5	6.8	8.5	7.8	7.4	31.3	29.7	31.0	30.9
	[67,810]	[16,624]	[13,606]	[98,040]	[97,019]	[40,224]	[34,992]	[172,235]	[94,444]	[36,511]	[31,494]	[162,449]
A	3.7	7.9	12.5	6.7	6.8	8.6	8.3	7.7	34.7	32.5	32.5	33.5
	[192,788]	[83,137]	[79,593]	[355,518]	[276,465]	[161,885]	[187,567]	[625,917]	[269,616]	[150,520]	[171,268]	[591,404]
BBB	5.1	8.6	12.9	8.5	6.4	7.3	7.7	7.2	39.4	36.3	32.2	35.8
	[118,634]	[87,127]	[91,958]	[297,719]	[192,586]	[164,093]	[234,458]	[591,137]	[187,288]	[154,329]	[213,621]	[555,238]
BB	8.9	11.2	14.9	11.3	5.7	7.7	7.7	7.1	37.7	30.2	30.7	32.6
	[35,698]	[38,712]	[26,174]	[100,584]	[55,049]	[75,890]	[62,313]	[193,252]	[53,633]	[71,518]	[57,530]	[182,681]
B	10.9	14.5	16.8	13.6	6.1	7.6	7.7	7.1	35.6	29.0	32.9	32.4
	[20,596]	[18,725]	[12,532]	[51,853]	[32,973]	[36,775]	[24,297]	[94,045]	[32,046]	[34,718]	[22,836]	[89,600]
C	25.2	25.4	23.9	25.1	6.1	7.8	6.2	6.8	33.6	27.4	37.3	31.9
	[10,817]	[8,725]	[4,485]	[24,027]	[16,401]	[14,914]	[7,326]	[38,641]	[15,986]	[14,381]	[7,017]	[37,384]
All	5.2	9.6	13.2	8.3	6.6	7.9	8.0	7.4	35.4	32.5	31.9	33.5
	[480,256]	[263,794]	[238,028]	[982,078]	[725,335]	[514,240]	[571,585]	[1,811,160]	[706,024]	[480,943]	[522,777]	[1,709,744]
	Equity volatility				Equity bid-ask spread							
Safe	31.4	29.0	28.0	30.0	7.3	6.7	6.1	6.9				
	[35,546]	[14,706]	[15,736]	[65,988]	[35,546]	[14,706]	[15,736]	[65,988]				
AA	37.0	34.6	30.5	35.2	7.6	7.8	6.7	7.5				
	[54,630]	[21,399]	[17,436]	[93,465]	[54,630]	[21,399]	[17,436]	[93,465]				
A	35.7	36.7	34.3	35.5	6.8	7.5	7.6	7.2				
	[172,423]	[100,789]	[115,512]	[388,724]	[172,423]	[100,789]	[115,512]	[388,724]				
BBB	35.3	36.7	36.5	36.1	10.7	10.4	10.8	10.7				
	[101,700]	[80,486]	[107,523]	[289,709]	[101,700]	[80,486]	[107,523]	[289,709]				
BB	44.7	44.0	41.8	43.5	16.7	16.8	14.5	16.0				
	[26,815]	[33,617]	[28,605]	[89,037]	[26,815]	[33,617]	[28,605]	[89,037]				
B	51.2	49.7	56.2	52.0	30.4	21.2	26.7	26.0				
	[15,483]	[16,329]	[11,895]	[43,707]	[15,483]	[16,329]	[11,895]	[43,707]				
C	59.3	61.4	66.0	61.8	46.9	37.3	47.3	43.4				
	[5,851]	[5,856]	[4,187]	[15,894]	[5,851]	[5,856]	[4,187]	[15,894]				
All	36.9	38.3	36.5	37.2	10.0	10.9	10.6	10.4				
	[412,448]	[273,182]	[300,894]	[986,524]	[412,448]	[273,182]	[300,894]	[986,524]				

Table 10: Estimated relation between bid-ask spreads and empirical measures

For our measures of inventory costs (bond return volatility), search costs (chain time), and bargaining (dealer concentration) we calculate predicted bid-ask spreads as follows. We run the regression $BA_{it} = \beta_0 + \beta_1 p_{it} + \epsilon_{it}$ where BA_{it} is the bid-ask spread of bond i on day t and p_{it} the corresponding proxy and then calculate a predicted spread as $\hat{BA}_{it} = \hat{\beta}_0 + \hat{\beta}_1 p_{it}$. This table presents summary statistics from the regression. We combine data from Academic TRACE and Mergent FISD. The sample period covers 1 August 2004 to 30 June 2015 for inventory, 1 July 2002 to 30 June 2015 for search costs, and 1 August 2002 to 30 June 2015 for dealer concentration. Standard errors are clustered at the bond level with t-statistics in parenthesis. The convention for p-values is: * when $p < 0.05$ and ** when $p < 0.01$.

	Bond volatility	Chain time	Dealer concentration
$\hat{\beta}_0$	9.067**	29.181**	27.305**
	(15.65)	(109.13)	(46.34)
$\hat{\beta}_1$	278.124**	0.658**	20.937**
	(27.98)	(22.41)	(19.60)
N	982,078	1,811,160	1,709,744
Adj. R^2	0.024	0.002	0.001

Table 11: Dealer inventory - predicted bid-ask spreads

This table shows average predicted bid-ask spreads from inventory models measured in basis points as a function of bond rating and maturity. For an actual bid-ask spread for bond i on day t, BA_{it}, we calculate a predicted bid-ask spread by estimating the regression

$$BA_{it} = \beta_0 + \beta_1 \sigma_{it-1} + \epsilon_{it}$$

where σ_{it-1} is the volatility of bond i at the end of the previous month, and calculate a predicted bid-ask spread as $\hat{BA}_{it} = \hat{\beta}_0 + \hat{\beta}_1 \sigma_{it-1}$. We report the average difference between actual and predicted bid-ask spreads in brackets. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). Data are from Academic TRACE, Mergent FISD, and WRDS Bond Returns. The sample period covers 1 August 2004 to 30 June 2015.

	Maturity			
	Short	Medium	Long	All
Safe	17.4	26.2	43.3	23.7
	[-0.42]	[15.33]	[10.98]	[4.73]
AA	19.3	32.3	38.7	24.2
	[-2.06]	[19.35]	[7.30]	[2.87]
A	19.4	31.0	43.8	27.6
	[-4.04]	[6.34]	[8.30]	[1.15]
BBB	23.2	33.1	45.0	32.8
	[-1.69]	[3.96]	[5.01]	[2.03]
BB	33.8	40.1	50.6	40.6
	[-0.35]	[-8.70]	[3.73]	[-2.50]
B	39.5	49.3	55.9	47.0
	[-10.23]	[-12.97]	[-12.05]	[-11.66]
C	79.3	79.8	75.5	78.8
	[-36.86]	[-41.82]	[14.91]	[-29.00]
All	23.5	35.8	45.9	32.2
	[-3.65]	[1.57]	[5.63]	[0.00]

Table 12: Search costs - predicted bid-ask spreads

This table shows average predicted bid-ask spreads implied by search costs measured in basis points as a function of bond rating and maturity. For an actual bid-ask spread for bond i on day t, BA_{it}, we calculate a predicted bid-ask spread by estimating the regression

$$BA_{it} = \beta_0 + \beta_1 TIME_{it} + \epsilon_{it}$$

where $TIME_{it}$ is the time it takes to complete the round-trip chain for bond i that starts on day t, and calculate a predicted bid-ask spread as $\hat{BA}_{it} = \hat{\beta}_0 + \hat{\beta}_1 TIME_{it}$. We report the average difference between actual and predicted bid-ask spreads in brackets. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). Data are from Academic TRACE and Mergent FISD. The sample period covers 1 July 2002 to 30 June 2015.

	Maturity			
	Short	Medium	Long	All
Safe	34.1	35.1	35.3	34.6
	[-17.77]	[3.23]	[15.07]	[-6.23]
AA	33.7	34.8	34.3	34.1
	[-16.39]	[2.37]	[5.90]	[-7.48]
A	33.7	34.8	34.7	34.3
	[-16.98]	[-0.30]	[11.17]	[-4.23]
BBB	33.4	34.0	34.3	33.9
	[-7.85]	[3.35]	[10.18]	[2.41]
BB	33.0	34.2	34.2	33.9
	[6.86]	[-0.50]	[8.53]	[4.51]
B	33.2	34.2	34.2	33.8
	[10.30]	[7.56]	[15.56]	[10.59]
C	33.2	34.3	33.3	33.7
	[30.61]	[8.66]	[83.01]	[32.07]
All	33.6	34.4	34.4	34.1
	[-10.41]	[2.01]	[11.40]	[0.00]

Table 13: Bargaining - predicted bid-ask spreads

This table shows average predicted bid-ask spreads implied by dealer bargaining power measured in basis points as a function of bond rating and maturity. For an actual bid-ask spread for bond i on day t, BA_{it}, we calculate a predicted bid-ask spread by estimating the regression

$$BA_{it} = \beta_0 + \beta_1 DC_{it} + \epsilon_{it}$$

where DC_{it} is the dealer concentration for bond i at day t, and calculate a predicted bid-ask spread as $\hat{BA}_{it} = \hat{\beta}_0 + \hat{\beta}_1 DC_{it}$. We report the average difference between actual and predicted bid-ask spreads in brackets. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). Data are from Academic TRACE and Mergent FISD. The sample period covers 1 August 2002 to 30 June 2015.

	Maturity			
	Short	Medium	Long	All
Safe	33.6	32.9	32.4	33.2
	[-17.45]	[6.28]	[20.09]	[-4.66]
AA	33.9	33.5	33.8	33.8
	[-16.82]	[4.75]	[7.57]	[-7.24]
A	34.6	34.1	34.1	34.3
	[-18.06]	[0.84]	[12.92]	[-4.28]
BBB	35.6	34.9	34.0	34.8
	[-10.32]	[2.79]	[11.83]	[1.84]
BB	35.2	33.6	33.7	34.1
	[4.62]	[0.38]	[11.18]	[5.02]
B	34.8	33.4	34.2	34.1
	[8.64]	[9.26]	[16.21]	[10.81]
C	34.3	33.0	35.1	34.0
	[30.07]	[10.82]	[83.43]	[32.68]
All	34.7	34.1	34.0	34.3
	[-11.77]	[2.81]	[13.31]	[0.00]

Table 14: Asymmetric information - predicted bid-ask spreads

This table shows daily predicted bid-ask spreads from our asymmetric information model measured in basis points as a function of bond rating and maturity. We report the average difference between actual and predicted bid-ask spreads in brackets. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). Data are from Mergent FISD, COMPUSTAT, and CRSP. The sample period covers 1 July 2002 to 30 June 2015.

	Maturity			
	Short	Medium	Long	All
Safe	0.1	0.1	0.2	0.1
	[19.49]	[41.59]	[53.81]	[32.60]
AA	0.0	0.1	0.1	0.1
	[19.00]	[44.22]	[45.98]	[29.81]
A	0.0	0.1	0.3	0.1
	[17.76]	[38.46]	[48.43]	[32.24]
BBB	0.2	0.4	0.8	0.5
	[26.05]	[41.06]	[48.83]	[38.67]
BB	0.7	1.4	1.9	1.3
	[38.99]	[37.15]	[44.70]	[40.13]
B	2.7	3.1	6.2	3.8
	[44.01]	[38.07]	[52.39]	[44.07]
C	5.1	7.3	11.1	7.5
	[74.41]	[29.67]	[107.46]	[66.63]
All	0.3	0.7	1.0	0.6
	[23.29]	[39.48]	[49.34]	[35.71]

Table 15: Dealer network - predicted bid-ask spreads

This table shows daily predicted bid-ask spreads implied by the dealer network measured in basis points as a function of bond rating and maturity. We report the average difference between actual and predicted bid-ask spreads in brackets. 'Safe' includes AAA and AA+ rated bonds, 'AA' includes bonds rated AA or AA-, 'C' includes C, CC, and CCC rated bonds, while the remaining categories follow standard conventions. Maturities are 0-4 years (short), 4-8 years (medium), and >8 years (long). Data are from Academic TRACE and Mergent FISD. The sample period covers 1 July 2002 to 30 June 2015.

	Maturity			
	Short	Medium	Long	All
Safe	37.0	40.7	36.4	37.6
	[-20.61]	[-2.36]	[14.05]	[-9.26]
AA	36.5	36.3	29.3	35.0
	[-19.23]	[0.85]	[10.89]	[-8.42]
A	34.8	34.9	31.1	33.7
	[-18.09]	[-0.42]	[14.70]	[-3.69]
BBB	36.5	33.9	31.9	33.9
	[-10.96]	[3.45]	[12.57]	[2.37]
BB	39.1	32.4	35.1	35.1
	[0.73]	[1.38]	[7.71]	[3.23]
B	38.0	33.9	35.0	35.6
	[5.46]	[7.90]	[14.83]	[8.83]
C	44.3	35.1	42.2	40.4
	[19.53]	[7.83]	[74.12]	[25.36]
All	36.3	34.5	32.3	34.5
	[-13.19]	[1.94]	[13.57]	[-0.45]

Table 16: Predicted bid-ask spreads - panel regression

This table presents coefficient estimates using actual bid-ask spreads from institutional-sized transactions (trade sizes greater than or equal to \$100,000) measured in basis points as the dependent variable. We combine data from Academic TRACE, Mergent FISD, WRDS Bond Returns, COMPUSTAT, and CRSP. The sample period covers 1 August 2004 to 30 June 2015. Standard errors are clustered at the bond level with t–statistics in parenthesis. The convention for p-values is: * when $p < 0.05$ and ** when $p < 0.01$.

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: All Bonds						
Bond volatility	309.452**					269.186**
	(25.36)					(25.90)
Asymmetric information		5.801**				1.530**
		(7.23)				(2.83)
Chain time			0.701**			0.298**
			(13.77)			(6.47)
Dealer network				0.807**		0.734**
				(41.35)		(44.33)
Dealer concentration					10.378**	19.088**
					(4.87)	(10.21)
N	616,887	616,887	616,887	616,887	616,887	616,887
Adj. R^2	0.030	0.005	0.002	0.035	0.000	0.060
Panel B: Investment Grade						
Bond volatility	367.494**					293.469**
	(36.28)					(31.50)
Asymmetric information		30.172**				14.925**
		(7.82)				(6.90)
Chain time			0.777**			0.346**
			(21.31)			(12.20)
Dealer network				0.730**		0.637**
				(40.09)		(49.03)
Dealer concentration					5.461**	11.851**
					(2.87)	(9.52)
N	520,680	520,680	520,680	520,680	520,680	520,680
Adj. R^2	0.061	0.026	0.005	0.050	0.000	0.107
Panel C: Speculative Grade						
Bond volatility	229.035**					186.636**
	(7.87)					(7.09)
Asymmetric information		3.122**				1.619**
		(5.28)				(3.12)
Chain time			0.341			-0.083
			(1.37)			(-0.35)
Dealer network				1.175**		1.138**
				(18.55)		(18.58)
Dealer concentration					39.984**	51.784**
					(4.77)	(6.91)
N	96,207	96,207	96,207	96,207	96,207	96,207
Adj. R^2	0.007	0.002	0.000	0.024	0.001	0.031

Table 17: Predicted bid-ask spreads - panel regression for retail-sized transactions

This table presents coefficient estimates using actual bid-ask spreads from retail-sized transactions (trade sizes less than \$100,000) measured in basis points as the dependent variable. We combine data from Academic TRACE, Mergent FISD, WRDS Bond Returns, COMPUSTAT, and CRSP. The sample period covers 1 August 2004 to 30 June 2015. Standard errors are clustered at the bond level with t–statistics in parenthesis. The convention for p-values is: * when $p < 0.05$ and ** when $p < 0.01$.

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: All Bonds						
Bond volatility	984.918**					652.121**
	(37.64)					(30.48)
Asymmetric information		44.204**				22.835**
		(8.06)				(8.14)
Chain time			-0.173**			-0.505**
			(-2.67)			(-10.60)
Dealer network				0.964**		0.719**
				(74.42)		(80.44)
Dealer concentration					130.806**	54.130**
					(12.41)	(8.44)
N	851,858	851,858	851,858	851,858	851,858	851,858
Adj. R^2	0.156	0.063	0.000	0.150	0.007	0.251
Panel B: Investment Grade						
Bond volatility	924.276**					613.422**
	(35.27)					(28.11)
Asymmetric information		82.270**				34.955**
		(14.41)				(11.63)
Chain time			-0.346**			-0.590**
			(-5.86)			(-15.37)
Dealer network				0.879**		0.668**
				(68.61)		(72.67)
Dealer concentration					141.405**	66.114**
					(12.55)	(10.11)
N	732,280	732,280	732,280	732,280	732,280	732,280
Adj. R^2	0.191	0.075	0.000	0.195	0.013	0.314
Panel C: Speculative Grade						
Bond volatility	924.177**					656.805**
	(15.96)					(13.96)
Asymmetric information		27.347**				18.952**
		(7.16)				(6.84)
Chain time			1.308**			0.128
			(4.52)			(0.49)
Dealer network				1.039**		0.889**
				(38.42)		(40.66)
Dealer concentration					-60.138*	5.481
					(-2.48)	(0.32)
N	119,578	119,578	119,578	119,578	119,578	119,578
Adj. R^2	0.063	0.040	0.001	0.061	0.001	0.125

Table 18: Bid-ask spread estimates: matched vs. unmatched chains

For all bonds in the sample, we separate round-trip intermediation chains into those completed within one minute (matched) and those with completion times more than one minute (unmatched). We then calculate daily bid-ask spreads from round-trip intermediations for the two groups separately, as a percentage of the mid-price and measured in basis points and report the average bid-ask spread across rating and maturity. The Safe rating bucket includes AAA and AA+ rated bonds and the AA rating bucket includes bonds rated AA or AA-. The Short, Medium, and Long maturity buckets denote 0-4 years, 4-8 years, and >8 years. We report standard errors clustered at the bond level in parentheses and the number of observations in squared brackets. We combine data from Academic TRACE with Mergent FISD and the sample period covers 1 July 2002 to 30 June 2015.

	Matched				Unmatched			
	Short	Medium	Long	All	Short	Medium	Long	All
Safe	4.0	8.4	9.2	5.9	18.6	42.1	54.8	31.8
	(0.22)	(0.82)	(1.09)	(0.30)	(1.10)	(2.69)	(3.05)	(1.28)
	[10,166]	[3,072]	[3,519]	[16,757]	[47,845]	[18,653]	[18,979]	[85,477]
AA	4.0	6.0	5.9	4.8	19.8	42.2	47.1	30.6
	(0.17)	(0.44)	(0.52)	(0.19)	(0.77)	(2.41)	(1.81)	(0.93)
	[19,192]	[6,960]	[7,367]	[33,519]	[83,489]	[35,373]	[29,853]	[148,715]
A	4.8	7.3	9.7	6.8	18.9	38.6	51.0	33.8
	(0.13)	(0.27)	(0.40)	(0.15)	(0.41)	(0.98)	(0.98)	(0.50)
	[50,527]	[25,730]	[31,043]	[107,300]	[239,364]	[143,634]	[166,868]	[549,866]
BBB	9.4	11.4	11.0	10.6	29.1	42.8	50.3	41.4
	(0.30)	(0.45)	(0.42)	(0.25)	(0.63)	(0.97)	(1.01)	(0.55)
	[38,681]	[34,438]	[47,988]	[121,107]	[163,629]	[139,782]	[204,334]	[507,745]
BB	15.3	14.9	18.4	16.1	47.3	38.2	48.0	44.0
	(0.57)	(0.61)	(0.86)	(0.42)	(1.56)	(1.57)	(2.46)	(1.17)
	[14,521]	[18,313]	[13,888]	[46,722]	[43,916]	[63,125]	[53,389]	[160,430]
B	22.0	22.5	30.0	24.1	50.2	46.9	53.3	49.7
	(1.01)	(1.41)	(1.91)	(0.83)	(3.81)	(3.62)	(5.72)	(2.46)
	[9,230]	[9,103]	[5,523]	[23,856]	[26,237]	[30,850]	[20,859]	[77,946]
C	39.6	47.3	59.2	46.1	69.7	42.1	129.4	69.7
	(2.32)	(3.54)	(4.83)	(1.98)	(11.16)	(10.29)	(21.97)	(7.42)
	[4,711]	[3,363]	[2,007]	[10,081]	[13,321]	[12,994]	[6,034]	[32,349]
All	9.1	12.7	13.0	11.3	26.1	41.0	51.4	38.4
	(0.20)	(0.33)	(0.35)	(0.03)	(0.44)	(0.70)	(0.80)	(0.15)
	[147,028]	[100,979]	[111,335]	[359,342]	[617,801]	[444,411]	[500,316]	[1,562,528]

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