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

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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.

Keywords: Bid-ask spread; Liquidity; Over-the-counter markets; Inventory costs; Corporate bonds

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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 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

[1] Examples of research finding that liquidity impacts bond prices include Bao, Pan, and Wang (2011), Friewald, Jankowitsch, and Subrahmanyam (2011), Dick-Nielsen, Feldhütter, and Lando (2012), and Acharya, Amihud, and Bharath (2013). Recent research that uses transaction costs to measure corporate bond liquidity include Aquilina and Suntheim (2016), Adrian, Fleming, Shachar, and Vogt (2017), Trebbi and Xiao (2017), Bessembinder, Jacobsen, Maxwell, and Venkaraman (2018), and Choi and Huh (2018).

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.

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, Garleanu, and Pedersen (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, Kermani, and Song (2017), and Hollifield, Neklyudov, and Spatt (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, Gorton, and Holmström (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, Gorton, and Holmström (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, Kermani, and Song (2017), and Hollifield, Neklyudov, and Spatt (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, Harris, and Piwowar (2007), Bessembinder, Maxwell, and

Venkaraman (2006), Goldstein, Hotchkiss, and Sirri (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 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]

Table 1 shows summary statistics of our data sample. 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,

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

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, Kermani, and Song (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 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. 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. 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, Harris, and Piwowar (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, Cui, He, and Milbradt (2018)). Empirically, Edwards, Harris, and Piwowar (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, Harris, and Piwowar (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, Amihud, and Bharath (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

[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.

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 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.

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, Garleanu, and Pedersen (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

[4]Feldhütter (2012), He and Milbradt (2014), Vayanos and Weill (2008), Lagos and Rocheteau (2009), Lagos,

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 is 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

Rocheteau, and Weill (2009), Duffie, Garleanu, and Pedersen (2007), Sambalaibat (2018) and many others.

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 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, Kermani, and Song (2017), and Hollifield, Neklyudov, and Spatt (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 7 shows the correlations between our measures. 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).

[5] The prediction of our model is consistent with Dang, Gorton, and Holmström (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, Lester, and Weill (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)).

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 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. 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 8 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 9 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 10 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 10 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 9 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 8 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 11 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 8 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, Hirtle, Morgan, Peristiani, and Santos (2007)).

Table 12 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 8 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, Gorton, and Holmström (2015)).

Table 13 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 central dealers.

Table 14 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.

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

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 in Table 15.

Panel A shows the results for all bonds. 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.

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

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

determinant of 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, O'Hara, and Zhou (2018), and Bessembinder, Jacobsen, Maxwell, and Venkaraman (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, Garleanu, and Pedersen (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 16 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 bond, suggesting that asymmetric information, at least for investment grade bonds, is not important for determining bid-ask spreads.

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

$$DC_{j,t} = \sum_{i=1}^{N} s_i^2. \tag{3}$$

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

$$\frac{\text{dealer sell price } - \text{dealer buy price}}{\text{mid-price}} \tag{4}$$

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

$$\frac{1}{2}(K_A - C_0) + \frac{1}{2}(C_0 - K_B) \tag{5}$$

while the expected revenue if the investor is informed is

$$\frac{1}{2}(K_A - C_u) + \frac{1}{2}(C_d - K_B) \tag{6}$$

The dealer revenue in equation (6) 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

$$(1-p)\left(\frac{1}{2}(K_A - C_0) + \frac{1}{2}(C_0 - K_B)\right) + p\left(\frac{1}{2}(K_A - C_u) + \frac{1}{2}(C_d - K_B)\right) = 0 \tag{7}$$

and simplifying the expression yields

$$K_A - K_B = p(C_u - C_d). \tag{8}$$

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 (8) holds for both dealers and the ratio between the bid-ask spread in the equity and the debt market is

$$\frac{K_A^E - K_B^E}{K_A^D - K_B^D} = \frac{E_u - E_d}{D_u - D_d} \tag{9}$$

while the ratio between the relative bid-ask spreads is

$$\frac{(K_A^E - K_B^E)/E_0}{(K_A^D - K_B^D)/D_0} = \frac{(E_u - E_d)/E_0}{(D_u - D_d)/D_0}. \tag{10}$$

Equation (10) 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

$$\frac{(K_A^E - K_B^E)/E_0}{(K_A^D - K_B^D)/D_0} \to \frac{N(d_1)/C(V_0)}{\big(1 - N(d_1)\big)/(D - P(V_0))} \tag{11}$$

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

$$d_1 = \frac{1}{\sigma\sqrt{T}}\left(\log(V_0/d) + (r_t - \delta_t - \frac{1}{2}\sigma^2)T\right) \tag{12}$$

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

$$\sigma_t = R(L_t)(1 - L_t)\sigma_{E,t} \tag{13}$$

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 (11) 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.

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: 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 8: Summary statistics for empirical measures

This table shows the average value of empirical measures and the number of observations in brackets. Bond volatility and equity volatility are annualized volatilities measured in percent, chain time is measured in days, dealer concentration is measured in percent, while equity bid-ask spread is calculated as a percentage of the mid-price and measured 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 9: 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 10: 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 11: 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 12: 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 13: 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 14: 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 15: Predicted bid-ask spreads - panel regression

This table presents coefficient estimates using actual bid-ask spreads 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 16: 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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