Corporate Bond Market Transparency: Liquidity Concentration, Informational Efficiency, and Competition*

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Current Draft: April 2006.
Preliminary. Please do not circulate.

* The paper has benefited from the comments of Gordon Fuller and seminar participants at the Securities and Exchange Commission. Amy Edwards and Mike Piwowar are Financial Economists in the Office of Economic Analysis of the SEC. M. Nimalendran is the Bank of America Professor of Finance at the University of Florida. The project was started while Nimal was a Visiting Scholar at the SEC. The Securities and Exchange Commission disclaims responsibility for any private publication or statement of any SEC employee. This study expresses the authors' views and does not necessarily reflect those of the Commission, the Commissioners, or other members of the staff. All errors and omissions are the sole responsibility of the authors.

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Abstract

The recent introduction of price transparency (the ability of market participants to observe last sale information in the trading process) in the U.S. secondary corporate bond market has led to lower transaction costs for investors. Thus far, the existing literature only speculates on which market mechanisms drive this decrease. (See Edwards, Harris, and Piwowar (2006), Bessembinder, Maxwell, and Venkataraman (2006), and Goldstein, Hotchkiss, and Sirri (2006).) The lower transaction costs enabled by transparency could be due to liquidity concentration within the market, an increase in informational efficiency, and/or improvements in competition among dealers. In this paper, we conduct tests of these three non-mutually exclusive hypotheses.

JEL Classification: G10; G20

Keywords: Corporate bonds; fixed income; liquidity; transaction costs; TRACE; price transparency; market microstructure; dealers; liquidity concentration; informational efficiency; competition.

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I. Introduction

The recent introduction of price transparency (the ability of market participants to observe last sale information in the trading process) in the U.S. secondary corporate bond market has led to lower transaction costs for investors. (See Edwards, Harris, and Piwowar (2006), Bessembinder, Maxwell, and Venkataraman (2006), and Goldstein, Hotchkiss, and Sirri (2006).) Thus far, the existing literature only speculates on which market mechanism(s) drive this decrease. Edwards, Harris, and Piwowar (2006) and Bessembinder, Maxwell, and Venkataraman (2006) conjecture that the decrease in transaction costs comes from improved competition. In related studies of the U.S. secondary municipal bond market, Harris and Piwowar (2006) and Green, Hollifield, and Shurhoff (2005) attribute the large transaction costs to a lack of transparency and speculate that transparency would promote more competition in municipal bonds leading to smaller transaction costs. The lower transaction costs enabled by transparency could also be due to improvements in informational efficiency or could be a result of liquidity concentration within the market. In this paper, we propose to conduct tests of these three non-mutually exclusive hypotheses.

Understanding which market mechanisms are affected by transparency will improve our understanding of the roles that information, competition, and liquidity play in price discovery and on transactions costs in the bond market. The findings in this paper may help us better understand why regulators, rather than industry initiatives, often act to achieve various forms of transparency in many markets. They will also help us better understand how transparency improves the functioning of markets. Finally, our findings will get us closer to understanding whether the benefits from transparency are welfare improving or zero-sum.

The policy implications that follow from findings in this paper will extend well beyond the U.S. corporate bond markets. In the European Union, member states are required by Article 65 of the Markets in Financial Instruments Directive (MiFID) to review whether the extensive transparency requirements in the Directive relating to equity markets should be extended to other asset classes, such as bonds.[1] The UK Financial Services Authority (FSA), for example, has recently issued a discussion paper to help them develop their policy on trading transparency in the UK secondary bond markets, and then held a roundtable seminar of industry participants, regulators, and academics to discuss market efficiency, price formation, and best execution issues in the bond market within the context of the MiFID transparency issues.[2] Around the globe, events such as this past summer's "Conference on Developing Bond Markets" sponsored by the Asian Development Bank Institute and the more recent "Seminar On Developing Corporate Bond Markets in Asia" jointly sponsored by Bank of International Settlements and the People's Bank of China highlight the increasing importance at the highest levels of policymaking that Asian countries are placing on well-functioning secondary corporate bond markets.

In this paper, we find that the transparency-induced change in concentration of liquidity across bonds results in more concentration in relatively less liquid bonds. We also find that the percent of customer bond volume reported by low cost dealers is positively associated with price transparency. We interpret this result as evidence that price competition among corporate bond dealers has increased due to transparency.

[1] http://europa.eu.int/eur-lex/pri/en/oj/dat/2004/l_145/l_14520040430en00010044.pdf
[2] "Trading transparency in the UK secondary bond markets", http://www.fsa.gov.uk/pubs/discussion/dp05_05.pdf

We find evidence that transaction costs are negatively related to the amount of liquidity concentration, positively related to the probability of trading with an informed investor. We find weak evidence that transactions cost are negatively related to the percent of customer bond volume reported by low cost dealers. Controlling for all of these factors, we still find that transaction costs are significantly and negatively related to the amount of price transparency.

Overall, these results suggest that contrary to the predictions of many market participants, the benefits of transparency are not accruing to the relatively more liquid bonds at the expense of the more illiquid bonds. Although price competition among dealers has increased slightly due to price transparency, the benefits still do not seem to be accruing to all investors.

This paper proceeds as follows. Section II provides background information on the U.S. corporate bond market. Section III develops our hypotheses. Section IV describes our data and sample selection procedures. Section V describes our tests and measures of transaction costs, informational efficiency, competition, and liquidity concentration. Section VI presents results and discusses the importance of the examination in the context of current regulatory initiatives. Section VII concludes.

II. Background

In the United States, the vast majority of secondary corporate bond transactions occur in over-the-counter dealer markets.[3] Broker-dealers execute most public customer transactions in a principal capacity.[4] Customers who want to trade bonds purchase them from dealers and sell them to dealers. Dealers trade among themselves in the interdealer market to obtain securities desired by customers or to manage their inventories.

[3] A small number of bonds are listed and traded on the New York Stock Exchange (NYSE) Automated Bond System (ABS). Biais and Green (2005) examine why the NYSE lost its corporate bond market share to the OTC market over in the twentieth century.

[4] Hereafter, we collectively refer to brokers and dealers as simply "dealers."

On January 23, 2001, the Securities and Exchange Commission approved the NASD's proposal to establish the Trade Reporting and Compliance Engine ("TRACE") system for reporting and disseminating transaction information on corporate bonds not traded on an exchange. The dissemination of transaction information is the transparency studied here. On July 1, 2002, TRACE was officially launched.

Dealers must report all over-the-counter secondary market transactions in corporate bonds to the NASD's Trade Reporting and Compliance Engine ("TRACE") system within 15 minutes of execution.[5] Currently, transaction information from virtually all of the reported trades is immediately disseminated to the public through the www.NasdBondInfo.com website and through various data vendors. However, there are a few instances in which this is not the case. First, transactions in securities sold to Qualified Institutional Buyers (QIBs) under Rule 144A of the Securities Act of 1933 are subject to the TRACE reporting requirement, but they are never publicly disseminated. This exclusion is motivated by the restrictions on resale that apply to Rule 144A securities. Moreover, the NASD has excluded certain bonds, including bonds classified as "asset-backed", from TRACE reporting and transparency.[6]

NASD expanded TRACE transparency at a deliberate pace, in part because of concerns expressed by some dealers that transparency of last sale information could adversely affect market liquidity, especially in more thinly traded bonds. At its inception on July 1, 2002, TRACE disseminated last-sale information only on investment-grade bonds with an initial issuance size of $1 billion or greater; and on 50 high-yield issues that correspond to the former

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[5] The time allowed for dealers to report trades had gradually declined since the introduction of TRACE from 75 minutes to 15 minutes, as of July 1, 2005.

[6] NASD Rule 6210(a) excludes debt issued by government-sponsored entities, mortgage- or asset backed securities, collateralized mortgage obligations, and money market instruments from the definition of the term "TRACE-eligible security."

"FIPS 50." This initial set of about 600 TRACE-disseminated bonds represented a small segment of the market.

On March 3, 2003, TRACE added dissemination of investment-grade bonds rated A3 or higher by Moody's, and A- or higher by Standard and Poor's, with an initial issuance of $100 million or greater. This constituted over 4,000 TRACE-eligible securities and roughly 75% of the then-current average daily trading volume in investment-grade securities. On April 14, 2003, TRACE began disseminating prices for an additional 120 bonds rated Baa / BBB (the lowest investment-grade category) with an initial issuance size of less than $1 billion.

On October 1, 2004, TRACE began disseminating all remaining TRACE-eligible bonds, except Rule 144A bonds, and the two groups of bonds described above, that were designated for dissemination delays effective February 7, 2005. This represented the first time TRACE disseminated non-investment grade bonds other than the 50 bonds that correspond to the former "FIPS 50."[7] These delays were removed in January 2006.

III. Hypotheses

We have identified three economic hypotheses that could explain how the implementation of price transparency in the U.S. corporate bond market resulted in lower transaction costs for investors.

A. Liquidity Concentration

Under our liquidity concentration hypothesis, transparency decreases transaction costs on average because transparency allows investors to migrate toward more liquid securities. When choosing bonds to invest in, a rational investor will choose to invest in a relatively more liquid

[7] At various times, the NASD altered transparency for small groups of bonds as a result of revising the list of 50 transparent high-yield bonds (the TRACE 50, formerly the FIPS 50). This involved some transparent bonds becoming opaque and some opaque bonds becoming transparent. See Alexander, Edwards, and Ferri (2000) for a discussion of the criteria for the FIPS 50.

bond when faced with a decision between two substitutes that differ only in the level of liquidity. Transparency not only allows investors and dealers to view transaction prices but also allows them to judge the relative liquidity of the bonds. Therefore, we can naturally expect to observe more trading in the relatively liquid bonds and less trading in the relatively illiquid bonds.

An acceptance of this hypothesis would imply that the prior transaction cost results are a consequence over-weighting the more liquid bonds in the averages and of the inability to measure transaction costs of more inactive bonds. Indeed, Goldstein, Hotchkiss, and Sirri (2006) are unable to detect a change in transaction costs for relatively illiquid bonds while they find a decline for more liquid bonds. Such a finding might weaken arguments that post-trade transparency from TRACE was welfare improving and strengthen arguments that price transparency resulted in a zero-sum transfer of benefits.

A rejection of this hypothesis would be consistent with an improvement in liquidity for all bonds. This would be inconsistent with the arguments brought up by the industry against creating post-trade transparency in other countries.

B. Informational Efficiency

Performance and informational efficiency of markets is an important issue that has been the subject of a substantial amount of theoretical and empirical research in financial economics. (See, for example, "Market Microstructure Theory," by Maureen O'Hara, 1997). One of the important issues that affect market performance is transparency. Several theoretical studies have examined the effect of transparency on market performance and informational efficiency. Pagano and Roell (1996) use a Kyle (1985) type framework to examine the effect of transparency on profits to informed and uninformed traders. They show that the expected trading costs for the uninformed traders are lower in the transparent market relative to a dealer market. This is because trade information available in the transparent market allows greater exposure of informed traders. Under the informational efficiency hypothesis, we posit that transparency improves informational efficiency by reducing the informational advantage that informed traders' possess.

C. Competition

One possible consequence of transparency is that it alters the competitive environment. Transparency allows investors to observe the prices that others are paying or receiving. Armed with this information, investors can demand better prices from their current dealers and/or move their trades to lower cost dealers.

Therefore, this hypothesis questions whether transparency results in customer orders flowing to the low cost dealers. If it does, then we should observe low cost dealers attracting more order flow in relatively transparent bonds compared to relatively opaque bonds. And, of course, we should expect to see dealers adjusting their prices to attract/maintain customer order flow. If we do not observe order flow going to the low cost dealers, then the conjectures regarding the effect of transparency on dealer competition may be overstated. Alternatively, such a result could imply that post-trade transparency is not sufficient to lower investors' search costs.

IV. Data

We obtain data on every corporate bond trade reported to TRACE for January 2003 through July 2005 from the NASD.[8] The TRACE data consist of all over-the-counter (OTC) transactions in all corporate bonds, and therefore, provides the most comprehensive source of

[8] As previously mentioned, the TRACE system began on July 1, 2002. Our analysis uses 2003 data to allow market participants to familiarize themselves with the system.

transaction data for corporate bond transactions in the United States.[9] Data items include the price, time, and size of the transaction as well as the side (or sides for interdealer transactions) on which the dealer participated. We also have issuer and issue information provided by TRACE master files in the form of several snapshots taken during the sample period.

We filter out duplicate reports of interdealer trades, trades that subsequently were corrected, trades for which we suspect the data were incorrectly reported, and trade reports for which data are missing. Table 1 Panel A shows how we arrive at our final sample. Our initial sample of 24,037 consists of filtered transaction data in those bonds for which we have enough transactions to estimate transaction costs using the regression model outlined in Edwards, Harris, and Piwowar (2006). The final sample of 7,422 consists of the initial sample less the bonds for which we cannot estimate measures for each of our hypotheses. We describe these measures in the next section.

Panel B shows that while most of our sample appear in the BBB to A range, the bonds are distributed across various levels of credit risk. Average volume statistics for our sample bonds are given in Panel C. The average bond has about $250 Thousand in total each day and $3.5 Thousand in retail-size volume. The typical sample bond trades 3.7 times per day with 1.7 trades being of retail-size. These figures are much higher than those reported in Edwards, Harris, and Piwowar(2006), because our measure of information efficiency requires at least 30 total trading days thus removing the less active bonds from our sample.

As given in Panel C of Table 1, the level of transparency varies across our sample. During our sample period, the transparency of the corporate bond market changed several times.

[9] The only trades omitted from TRACE are those that occur on exchanges, of which the vast majority occur on in the NYSE's Automated Bond System (ABS). Over 98% of all ABS trades are retail-sized trades (Edwards, 2006). Edwards, Harris, and Piwowar (2006) report that fewer than five percent of all bonds are listed on the NYSE and Edwards (2006) shows that the NYSE conducts about 19% of the trades in listed bonds.

At the end of our sample period, all active bonds except Rule 144a bonds, which we exclude, are transparent, while only a few were transparent at the start of our sample period. The average bond was transparent for about 45% of its trades during the sample period. The variance of 37% tells us that this statistic varies widely across the sample.

Table 2 Panel A gives the aggregate trading and dealer activity in our sample bonds. The average bond had trades reported by 91 different dealers throughout the sample period. At most, 720 dealers trade the same bond while as little as three dealers trade another. The number of trades in a sample bond varies greatly from 50 to 93,353. Likewise, the number of customer transactions varies from 46 to 65,914.

Panel B of Table 2 provides statistics on the number of bonds typically traded by the dealers. A total of 1,895 different dealers traded sample bonds. Some dealers trade only one bond, while others traded hundreds of bonds. Some dealers trade primarily with other dealers, while others trade primarily with customers. The average dealer conducts 6,798 trades (4,603 customer trades) in 356 bonds.

V. Measures

A. Transaction Costs and Methods

We estimate transaction costs using the econometric model developed in Harris and Piwowar (2006) and enhanced to apply to corporate bonds in Edwards, Harris, and Piwowar (2006). The model allows relative transaction costs (cost as a fraction of price) to vary over different trade sizes.

We first estimate the following equation for each bond.

$$
\begin{aligned}
& r_{ts}^{P} - Days_{ts}\left(5\% - CouponRate\right) = \\
& \qquad c_0\left(Q_t - Q_s\right) + c_1\left(Q_t \frac{1}{S_t} - Q_s \frac{1}{S_s}\right) + c_2\left(Q_t \log S_t - Q_s \log S_s\right) \\
& \qquad + c_3\left(Q_t S_t - Q_s S_s\right) + c_4\left(Q_t S_t^2 - Q_s S_s^2\right) \\
& \qquad + \beta_1 AveIndexRet_{ts} + \beta_2 DurationDif_{ts} + \beta_3 CreditDif_{ts} + \eta_{ts}
\end{aligned} \tag{1}
$$

where r_{ts}^{P} is continuously compounded observed bond price return between trades *t* and *s* and $Days_{ts}$ counts the number of calendar days between trades *t* and *s*. The left hand side expresses the continuously compounded bond return as the equivalent rate on a notional five percent coupon bond.

On the right hand side, Q_t indicates with a value of 1, –1, or 0 whether the customer was a buyer, a seller, or not present (interdealer trade). S_t is the dollar size of the trade. The final three terms decompose the common factors of the unobserved bond return into an average bond index return, differences between index returns for long and short term bonds and for high and low quality bonds.

The estimated transaction cost for a given trade size in a given bond is then:

$$
\hat{c}\left(S\right) = \hat{c}_0 + \hat{c}_1 \frac{1}{S} + \hat{c}_2 \log S + \hat{c}_3 S + \hat{c}_4 S^2 . \tag{2}
$$

B. Liquidity Concentration

Unlike the other measures described below, the literature cannot help us construct a measure for liquidity concentration. Therefore, we derive our own. Our liquidity concentration measure examines (a) whether a given bond is relatively more liquid or less liquid than its close substitutes, and (b) whether that bond is capturing more of the market share of trades among bonds that are close substitutes. We focus on close substitutes because corporate bond investors do not choose specific bonds as much as they select an interest rate risk and credit risk exposure.

Our first step, therefore, in designing our measure is to create a set of bonds that are substitutes for each sample bond. We focus primarily on the level of interest rate risk and credit risk in selecting substitutes. Further, because investment grade bond prices are more sensitive to interest rate changes and less sensitive to firm-specific changes, we treat investment grade bonds differently than non-investment grade bonds. Our approach is to match each bond with every other bond and then delete the matches that would not be close substitutes. We allow the bonds that do not end up in our final sample to be close substitutes for our sample bonds. A bond cannot be a close substitute of another if one matures before the other is issued. Therefore, we require that both bonds have at least one month in common. Next we require close substitutes to have about same credit rating because an A-rated bond is unlikely to be a good substitute for an AA-rated bond.

For each investment grade match remaining, we keep those with the same duration, same callability, and same coupon style, and with a similar outstanding size. The duration is measured by the modified duration to maturity. For callability, we look simply at whether both bonds are callable or both non-callable. We do not allow a floating coupon bond to be a close substitute for a fixed coupon bond. Because a very small bond is unlikely to be a good substitute for a very large bond, we require that the bonds are either both large-sized (> $500 million outstanding), both medium-sized ($100 million to $500 million), or both small-sized issues (<$100 million).

The close substitutes for non-investment grade bonds are determined more by firm or industry specific factors that affect the certainty that the issuer will make future cash flows. For these bonds, we require that close substitutes have the same two-digit SIC code or come from the same parent company. We also require that both have sinking provisions or both do not have sinking provisions. Likewise, both bonds either have put provisions or both do not.

After applying these requirements for substitutes, we are unable to find any substitutes for 87 bonds. Table 3 shows that the average sample bond has about 61 close substitutes. We estimate the average transaction cost for the close substitutes of each bond. We define a bond as relatively liquid compared to its substitutes if the cost to trade that bond is less than the cost to trade its close substitutes. Because our transaction cost measure varies by trade size, we measure liquidity using a trade size of 100 bonds. This size represents a large retail trade or a small institutional trade. As shown in Table 3, slightly less than half of our sample bonds are liquid relative to their substitutes and slightly more than half are illiquid. The relatively liquid bonds have about the same number of substitutes as the relatively illiquid.

Because we chose a specific trade size for the transaction cost comparison, Table 3 examines how the costs of the relatively liquid bonds compare to the relatively illiquid bonds over various trade sizes. As expected, the relatively illiquid bonds are more expensive to trade at the compared size of 100 bonds. The illiquid bonds are also more expensive to trade at most other trade sizes, except for the very large trade sizes.

We also aggregate the volume executed over our sample period across the close substitutes for each bond. We then estimate the portion of trades and volume executed in each sample bond relative to its substitutes. Surprisingly, Table 3 shows that the relatively illiquid bonds trade more than the relatively liquid bonds. The liquid bonds capture 5.6% of the volume relative to its substitutes while the illiquid bonds capture 6.7% of the volume. Because these percentages are dependent on the number of substitutes, we compare them to what we would expect if volume is evenly distributed across substitutes. For both the liquid and illiquid bonds, we find that volume is higher than expected. This result is most likely because our substitutes can come from the set of bonds with too few observations to be included in our final sample.

Even when compared to this expected volume, the illiquid bonds appear to trade more than the liquid bonds.

C. Informational Efficiency

Researchers in market microstructure have developed several measures for adverse selection costs in the equity market. These measure fall into three broad categories: (1) covariance based measures that require both pre-trade and post-trade transparency,[10] (2) price impact measures such as Kyle lambda, which requires transaction prices, volume, and trade direction (buy/sell), and (3) Probability of Informed trade (PIN) measure proposed by Easley, Kiefer, O'Hara, and Paperman (1996) (hereafter, EKOP) and Easley, Kiefer, and O'Hara (1997), which requires only the total number of buys and sells in a set period such as a day. We use the PIN measure to proxy for informational efficiency (or adverse selection costs) for several reasons. First, the covariance based measure requires quotes as well as trade transparency and under the current TRACE system we only have post trade transparency. Second, the Kyle lambda type measure requires active trading in the underlying security to obtain reasonable estimates. In the case of bonds, trading activity may not be very active to obtain good estimates. The parameters of the model underlying the PIN measure can be estimated using only the number of buys and sells in a particular period such as a day. We will estimate PIN exactly as described in EKOP.

The EKOP model is a mixed discrete-and-continuous time, sequential trade model of market making. It explicitly models the arrival rates of traders to the market in a continuous time framework that allows empirical estimation of the model's parameters. Individuals trade a single risky asset and money with a market maker over d=1,2, … , D trading days. Within any trading day, time is continuous. The market maker stands ready to buy or sell one unit of the asset at his posted bid and ask prices at any time. He is competitive and risk neutral so the bid and ask prices (if they were advertised) are the expected value of the asset conditional on his information at the time of trade.

Figure 1 illustrates the intuition of the model. Prior to the beginning of any trading day, nature determines whether an information event relevant to the value of the asset will occur. Information events are independently distributed and occur with probability α. These events are good news (signals) with probability $1-\delta$, or bad news (signals) with probability δ. After the end of trading on any day, and before nature moves on again, the full information value of the asset is realized. Trade arises from both informed traders (those who have the access to the signal) and uninformed traders.[11] On any day, arrivals of uninformed buyers and uninformed sellers are determined by independent Poisson processes. Uninformed buyers and uninformed sellers each arrive at rate ε where this rate is defined per minute of the trading day.[12]

Only on days for which information events have occurred, informed traders arrive together with uninformed traders. Assume that informed traders are risk neutral and competitive also. If an informed trader observes a good signal, to maximize the profit, he will only buy the stock and conversely, he will only sell if the signal is bad. Assume that the arrival of news comes to one trader at a time, and his subsequent arrival at the market also follows a Poisson process. The arrival rate for this process is μ. All of these arrival processes are assumed to be independent. Given this process, the prevalence of informed traders can then be estimated by comparing the number of buy and sell orders observed on a given day. The estimation of the parameters is based on the likelihood function given in EKOP and the MLE method.

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[10] See George, Kaul, and Nimalendran (1991), Huang and Stoll (1997).
[11] Uninformed traders are liquidity traders in this article.
[12] EKOP mention that they tried allowing uninformed buyers and uninformed sellers to arrive at different rates but empirical work showed that these two rates are not significantly different from each other.

Table 4 gives descriptive statistics on our PIN measure, as well as the arrival rate of informed and uninformed investors. As a ratio, PIN can vary from 0 to 1. In fact, the minimum value for PIN is 0, but the maximum is 0.86 so the PIN does not seem constrained by its bounds. The average PIN is 0.26. Panel B shows how these measures vary with credit quality. While the PIN is highest for bonds that default during our sample period, there is surprisingly little variation from the highest rated bonds to speculative bonds. A closer examination shows that the arrival rate of informed investors increases slightly for lower credit quality bonds. Preliminarily, PIN seems to be somewhat correlated with the transparency level of the bond. The more transparent bonds have only a slightly lower PIN, but have a much higher arrival rate of informed and uninformed investors. Preliminary evidence also shows that PIN is positively correlated with transaction costs at every transaction cost level.

D. Competition

The industrial organization literature on competition is quite extensive, but researchers still disagree on which measures are most appropriate. One class of measures is concentration indices, which summarize the distribution of market shares among firms. The *m*-firm concentration ratio adds up the *m* highest shares in the industry. In our context, an *m*-firm concentration ratio would add up the *m* highest (say, Top 5 or Top 10) dealer market shares according to some measure of bond trading activity, such as total number of trades, total customer volume, etc.

The Herfindahl index adds up the squares of the market shares. Under the Horizontal Merger Guidelines issued by the U.S. Department of Justice and the Federal Trade Commission, markets with a Herfindahl index below 1,000 are considered to be unconcentrated, market with a

Herfindahl index between 1,000 and 1,800 are considered to be moderately concentrated, and those with a Herfindahl index greater than 1,800 points are considered to be concentrated.[13]

Schultz (2003) finds that the Herfindahl index is a better measure of competition in the U.S. equity market than the number of broker-dealers because the latter tends to overstate the degree of competition.[14] Using stock market transaction data from May 1995 through February 1998, Schultz (2003) finds that the median (mean) Herfindahl index computed on a monthly basis reams fairly constant at about 2,400-2,500 (3,000-3,100). The first and third quartiles are usually around 1,500 and 4,000. The average number of market makers exceeds ten, but a Herfindahl index of 2,500 would occur if four market makers split all the volume equally.

Table 5 shows that the median (mean) Herfindahl index in our sample is about 900 (1,300). The first and third quartiles are about 600 and 1,500. Comparing these numbers to Schultz (2003) makes the bond market appear less concentrated than the equity markets. Table 2 shows that the median (mean) number of dealers per bond is 72 (91). But, a Herfindahl index of 1,000 would occur if ten dealers split all the volume equally. Therefore, despite the large number of dealers trading individual bonds, the trading appears fairly concentrated in a few dealers.

In unreported results, we examine whether the dealer concentration is stable over our sample period. We find that the total number of dealers reporting TRACE transactions each month is fairly stable over the sample period at about 1,100 dealers. Monthly rankings of dealers based on market share (based on the number of transactions or dollar volume) yield some interesting patterns. Overall, the monthly dealer rankings are very stable. For example, nine of the ten dealers with the largest market share in January 2003 are still in the top ten in December

[13] http://www.usdoj.gov/atr/public/guidelines/horiz_book/hmg1.html
[14] See also Chung, Chuwonganant, and McCormick (2004).

2004. However, if we segment dealers by retail-size (<=$100,000) transactions and institutional-size (>$100,000) transactions, we find that the retail rankings are less stable. Only seven of the ten dealers with the largest retail-size market share in January 2003 are still in the top ten in December 2004. Furthermore, the monthly Herfindahl index for the retail-size segment exhibits a 19% decrease, while the monthly Herfindahl index for the institutional-size segment exhibits only a 3% decrease. Thus, on an aggregate basis, there are some changes, at least in the retail-size segment, in the dealer landscape and competition in the market.

Concentration indices are useful because they give an easily computable and interpretable indication of the competitiveness of an industry. However, they have no systematic relationship with economic variables of interest for assessing changes in cost, demand, or policy.[15] Furthermore, they are endogenous, so they do not allow simple observations of correlation to be interpreted in a causal way. Accordingly, the concentration measures such as Herfindahl do not help us understand why transparency should lead to lower transaction costs.

For our purposes, we are interested in measuring the competition that would result in lower overall transaction costs from transparency. Therefore, we focus on price competition and use the fundamental economics of our hypothesis to select the most appropriate measure. For example, transparency lowers the search costs associated with distinguishing the low cost dealers from the high cost dealers. Therefore, we would expect transparency to result in investors switching from high cost dealers to low cost dealers.

Therefore, our measure will first separate these two dealer types. We differentiate the low cost dealers from the high cost dealers using residuals from equation (1). The residuals measure how an individual dealer's costs compare to the mean cost in a given bond. Because

[15] See, for example, Tirole (1988), Farrell and Shapiro (1990), and the Mulherin (1996) comments on McInish and Wood (1996).

equation (1) is estimated for each bond, we can aggregate a dealer's residuals over every bond. We then estimate whether the dealer is a low cost dealer by estimating whether its average residual is statistically less than zero using a t-test.[16] Likewise, a high cost dealer is one whose average residual is statistically greater than zero.

Panel B of Table 5 shows the distribution of high and low cost dealers in our sample bonds. Because we require a statistical test, a large portion of our sample dealers are neither high-cost nor low-cost. The measure identifies a significant proportion of low cost and high cost dealers. Slightly more dealers are identified as high cost dealers than low cost dealers, but a little over 50% of dealers are neither low cost nor high cost. The aggregate trading activity is dominated by high and low cost dealers. High cost dealers are more active than low cost dealers, especially when focusing on customer transactions.

For our test statistic, we are concerned not with the aggregate activity of the low cost dealers but with the activity in individual bonds. Table 5 Panel C reports the distribution of the trading activity of high and low cost dealers. Low cost dealers account for an average of 34% to 40% of trading but can account for none or almost all of the trading activity in particular bonds. Likewise, high cost dealers can account for all or none of the activity in particular bonds, but account for an average of 50% to 60% of trading. The average bond has more activity from high cost dealers than low cost dealers.

VI. Results

Because transaction costs are measured separately for each bond, our test is a cross-sectional one. Further, we need to be careful in our test design so that we attribute transparency to a change in our economic effects from our hypotheses and that the changes in the economic

[16] For comparison purposes, we also defined high and low cost bonds using two different nonparametric tests instead of t-tests. Results obtained from these two alternative definitions are qualitatively and quantitatively similar to those

effects altered transaction costs. Therefore, we will use a multiple equation system such as the following:

$$\begin{aligned}
&LiquidityConcetration = x'\beta_1 && + \varepsilon_1, \\
&PIN = x'\beta_2 + \gamma_{12} LiquidityConcentration && + \varepsilon_2, \\
&DealerCompetition = x'\beta_3 + \gamma_{13} LiquidityConcentration + \gamma_{23} PIN && + \varepsilon_3, \\
&TransactionCosts = x'\beta_4 + \gamma_{14} LiquidityConcetration + \gamma_{24} PIN + \gamma_{34} DealerCompetition && + \varepsilon_4
\end{aligned} \quad (3)$$

$where: x$ includes $Transparency$ and other variables

This system is a triangular system as described in Figure 2. Furthermore, this fully recursive triangular model can be consistently estimated using equation-by-equation ordinary least squares. The first part of the system of equations examines whether transparency is associated with a change in liquidity concentration, measured as the market share of a given bond relative to its substitutes if it is liquid relative to its substitutes and zero if it is illiquid relative to its substitutes. A positive coefficient on transparency would be consistent with an increase in liquidity concentration. The second part of the system examines whether transparency is associated with an increase in information efficiency, as measured by PIN. A negative coefficient on transparency is consistent with an increase in information efficiency. This system also examines whether the level of liquidity concentration is associated with better information efficiency.

The third part of the system in (3) examines whether transparency is associated with an increase in price competition, as measured by the market share of low cost dealers. A positive coefficient on the transparency variable supports this hypothesis. This equation also examines whether the market share of low cost dealers is associated with liquidity concentration and/or information efficiency. The final equation examines how transaction costs are associated with

obtained from the reported results.

transparency, information efficiency, competition, and liquidity concentration. This equation would confirm whether any of the three hypotheses can explain the decline in transaction costs with transparency.

Table 6 provides the results of these tests. The first twelve independent variables control for various transaction cost determinants. The next two, whether a bond is listed on ABS and the fraction of trades that are TRACE-transparent, measure the level of transparency. The final three independent variables are the first three dependent variables in the system of equations. These are the variables that test our hypotheses.

The TRACE-transparent coefficient in the liquidity concentration regression is negative and significant, suggesting that transparency leads to less liquidity concentration. Although the transaction cost regression shows that more liquidity concentration is associated with lower transaction costs, the results in the liquidity concentration regression are not consistent with the hypothesis that transparency leads to lower transaction costs because of increased liquidity concentration.

The PIN regression suggests that PIN is not associated with TRACE-transparency. The transaction cost regression confirms that adverse selection is indeed related to transaction costs. However, because transparency does not affect PIN, we must reject the hypothesis that transparency leads to lower transaction costs because of improved information efficiency.

Our last hypothesis examines whether improved competition can explain the lower transaction costs. The coefficient on the TRACE-transparency variable in the competition regression is positive and significant. The evidence of an increase in the market share of low cost dealers is consistent with transparency improving price competition. However, the transaction cost regression shows that transaction costs are not related to the percentage of customer volume reported by low cost dealers. Therefore, we also reject our third hypothesis that transparency reduces transaction costs because of improved price competition.

Overall, we reject all three of our hypotheses to explain the effect of transparency on transaction costs. While our measure of price competition is affected by transparency, it does not influence transaction costs. Conversely, our measures of information efficiency and liquidity concentration are important to transaction costs but are unaffected by transparency. Finally, the coefficient on TRACE-transparency in the transaction costs regression is negative and significant despite the inclusion of variables measuring each of the three hypotheses. This coefficient further suggests that our measures are not fully explaining why transparency leads to lower transaction costs.

VII. Conclusions

The recent introduction of price transparency in the U.S. secondary corporate bond market has led to lower transaction costs for investors. The existing literature (Edwards, Harris, and Piwowar (2006), Bessembinder, Maxwell, and Venkataraman (2006), and Goldstein, Hotchkiss, and Sirri (2006)) provides unambiguous empirical support for this fact, but it only speculates on which market mechanisms drive this decrease.

We hypothesize that the lower transaction costs enabled by transparency could be due to improvements in competition among dealers, an increase in informational efficiency, and/or liquidity concentration within the market. We conduct tests of these three non-mutually exclusive hypotheses.

We find that the transparency-induced change in concentration of liquidity across bonds results in more concentration in relatively more illiquid bonds. We also find that the percent of customer bond volume reported by low cost dealers is positively associated with price transparency. We interpret this result as evidence that price competition among corporate bond dealers has increased due to transparency.

We find evidence that transaction costs are negatively related to the amount of liquidity concentration, positively related to the probability of trading with an informed investor. We find weak evidence that transactions cost are negatively related to the percent of customer bond volume reported by low cost dealers. Overall, these results suggest that contrary to the predictions of many market participants, the benefits of transparency are not accruing to the relatively more liquid bonds at the expense of the more illiquid bonds. Although price competition among dealers has increased slightly due to price transparency, the benefits still do not seem to be accruing to all investors.

The results of our analysis deepen our understanding of how markets work and how information, competition, and liquidity interact with transparency to determine transactions costs in the bond markets. We acknowledge that this paper is only a first-step. We note that our analysis leaves room for additional explanations. Controlling for all of the explanations hypothesized in this paper, we still find that transaction costs are significantly and negatively related to the amount of price transparency.

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Table 1: Sample Composition and Aggregate Descriptive Statistics

This table describes the effects of the various filters used to construct our final sample. Transaction data are taken from the complete January 2003 through July 2005 TRACE transaction dataset. Security characteristic data are taken from twenty four snapshots of the TRACE master file supplied by the NASD for same period. We start with a sample consisting of bonds that have enough observations to identify the transaction cost regression model. We then remove the bonds for which we cannot identify measures for our three hypotheses.

Panel A: Sample Selection

	Bonds
Sample of bonds with transaction cost estimates	24,037
Subtotal after removing issues for which we could not estimate PIN (also no 144a, at least 30 days of customer trades)	7,509
Subtotal after removing issues with no substitutes	7,422
Final sample used in regressions	7,422

Panel B: Sample Composition

	Number of Bonds	**Number of Trades**	**Trading Volume ($ billions)**
By Credit Rating			
Superior (AA and up)	638	1,101,671	619.5
Other investment grade (BBB-A)	4,111	7,238,622	4,861.2
Speculative (below BBB)	2,299	4,068,304	2,824.7
Not Rated	95	88,549	64.3
Defaulted	279	376,233	230.1

Panel C: Descriptive Statistics – Averages across bond issues

Variable	Mean	Median	Variance
Volume			
Average daily bond volume ($ par)	255,235.6	96,663.9	57,6784.3
Average daily retail size bond volume	3,551.6	1,794.9	7,438.8
Average daily number of trades	3.7	1.9	6.6
Average daily number of retail size trades	1.7	0.9	3.5
Transparency			
Percent of trades transparent	45.3	32.6	37.0
ABS listed	3.8	0.0	19.0

Table 2: Descriptive Statistics of Trading Activity

This table provides descriptive information related to trading activity across bonds and dealers. Total number of trades, total dollar volume, and total bond volume include customer and interdealer transactions. Number of customer trades, customer dollar volume, and customer bond volume exclude interdealer trades. Dollar volume is expressed in thousands. Bond volume is expressed in the number of $1,000 par value bonds.

Panel A: Breakdown of Trading Activity Across All Bonds

	N	Min	25th Pctl	Median	Mean	75th Pctl	Max
Number of dealers per bond	7,422	3	46	72	91	114	720
Total number of trades	7,422	50	368	699	1,734	1,519	93,353
Total dollar volume ($ thousands)	7,422	390	44,775	337,807	1,158,573	1,088,356	100,152,965
Total bond volume (number of $1,000 par value bonds)	7,422	387	45,926	343,380	1,146,905	1,081,961	99,178,277
Number of customer trades	7,422	46	276	507	1,174	1,059	65,914
Customer dollar volume ($ thousands)	7,422	353	27,950	278,950	814,152	834,442	60,026,336
Customer bond volume (number of $1,000 par value bonds)	7,422	350	28,899	284,320	807,768	827,243	59,740,498

Panel B: Breakdown of Trading Activity Across All Dealers

	N	Min	25th Pctl	Median	Mean	75th Pctl	Max
Number of bonds traded	1,895	1	9	48	356	224	6,688
Total number of trades	1,895	1	19	133	6,798	903	950,764
Total dollar volume ($ thousands)	1,895	1	866	8,451	4,541,973	90,926	621,423,790
Total bond volume (number of $1,000 par value bonds)	1,895	1	914	8,690	4,496,232	98,266	611,508,430
Number of customer trades	1,895	0	10	78	4,603	541	886,014
Customer dollar volume ($ thousands)	1,895	0	434	4,400	3,191,734	41,815	515,424,009
Customer bond volume (number of $1,000 par value bonds)	1,895	0	450	4,704	3,166,705	46,701	508,412,796

Table 3: Descriptive Statistics for Liquidity Concentration

This table provides descriptive information related to our measure of liquidity concentration. The number of substitutes refers to the average number of bonds that have the same credit risk and interest rate risk as a given bond. For investment grade bonds, substitutes have similar rating, duration, size, and call provisions. For high-yield bonds, substitutes are from the same issuer or industry and have similar sinking fund and put provisions. The % of bond volume and trade volume refer to the volume of a given bond relative to its set of substitutes. Net bond volume and trade volume compare a given bond's volume to its expected volume if it were evenly distributed across substitutes. Transaction costs are measured for various trade sizes as given by equation (2). The Relatively Liquid bonds are bonds that have lower transaction costs for the 100 bond trade size than the average of its substitutes. Means and [medians] are reported along with the results of two sample t-tests and rank sum tests. ** and * indicate that the mean or median of the statistic of the illiquid bonds differs from the liquid bonds.

	All	Relatively Liquid	Relatively Illiquid
Number of Issues	7,422	3,584	3,845
Number of Substitutes	61.45 [43.00]	61.43 [42.00]	60.47 [44.00]
% of Bond Volume	6.15 [2.26]	5.57 [2.08]	6.69 ** [2.45]**
% of Trade Volume	7.31 [2.74]	5.47 [2.00]	9.03 ** [3.66]**
Net Bond Volume	1.59 [0.10]	1.09 [-0.08]	2.05 ** [0.28]**
Net Trade Volume	2.75 [0.54]	0.98 [-0.05]	4.40 ** [1.27]**
Transaction Costs (bps)			
5 bonds	71.75 [54.76]	49.29 [38.02]	87.97 ** [73.35]**
10 bonds	68.59 [52.11]	46.32 [35.12]	84.86 ** [71.44]**
20 bonds	59.83 [44.95]	38.26 [29.15]	75.72 ** [62.86]**
50 bonds	43.85 [31.32]	27.07 [22.01]	58.24 ** [47.27]**
100 bonds	32.63 [22.66]	20.24 [16.67]	45.32 ** [34.45]**
200 bonds	23.63 [16.44]	14.86 [12.30]	34.01 ** [24.99]**
500 bonds	14.25 [9.86]	9.35 [7.35]	20.69 ** [14.55]**
1,000 bonds	8.83 [5.45]	6.42 [4.03]	12.13 ** [8.33]**
2,000 bonds	5.11 [2.74]	4.55 [2.18]	5.93 ** [3.89]
5,000 bonds	2.65 [0.85]	2.80 [1.08]	2.41 [0.33]
10,000 bonds	4.40 [1.62]	3.38 [1.30]	5.85 ** [2.69]

Table 4: Descriptive Statistics on Informational Efficiency

This table presents descriptive statistics on our measure of informational efficiency. PIN is the probability of informed trading, as calculated according to Easley, Kiefer, and O'Hara (1997). Informed is the arrival rate of informed traders. Uninformed is the arrival rate of uninformed (liquidity) traders.

Panel A: Full Sample

	N	Min	25th Pctl	Median	Mean	75th Pctl	Max
Full Sample							
PIN	7,422	0.00	0.18	0.24	0.26	0.32	0.86
Informed	7,422	0.00	0.12	0.22	0.65	0.48	56.00
Uninformed	7,422	0.08	0.40	0.72	1.59	1.50	73.40

Panel B: Breakdown by Credit Quality

	N	Min	25th Pctl	Median	Mean	75th Pctl	Max
Superior							
PIN	638	0.00	0.17	0.23	0.26	0.32	0.83
Informed	638	0.00	0.11	0.22	0.64	0.43	14.54
Uninformed	638	0.08	0.36	0.72	1.59	1.44	29.00
Other Investment Grade							
PIN	4,111	0.00	0.17	0.24	0.25	0.31	0.86
Informed	4,111	0.00	0.12	0.22	0.62	0.44	56.00
Uninformed	4,111	0.10	0.41	0.71	1.65	1.46	73.40
Speculative							
PIN	2,299	0.00	0.18	0.24	0.26	0.33	0.85
Informed	2,299	0.00	0.12	0.24	0.72	0.59	50.58
Uninformed	2,299	0.09	0.40	0.80	1.58	1.64	54.47
Missing							
PIN	95	0.00	0.19	0.27	0.29	0.36	0.83
Informed	95	0.00	0.09	0.16	0.67	0.38	17.43
Uninformed	95	0.09	0.29	0.45	0.99	0.98	12.72
Defaulted							
PIN	279	0.00	0.26	0.33	0.33	0.40	0.67
Informed	279	0.00	0.14	0.30	0.55	0.63	6.02
Uninformed	279	0.10	0.31	0.57	1.10	1.21	15.69

Panel C: Breakdown by Transparency Level

	N	Min	25th Pctl	Median	Mean	75th Pctl	Max
Less than 33%							
PIN	3,747	0.00	0.19	0.26	0.27	0.33	0.86
Informed	3,747	0.00	0.11	0.19	0.44	0.37	19.65
Uninformed	3,747	0.08	0.34	0.56	1.04	1.05	33.81
33% - 67%							
PIN	1,153	0.00	0.18	0.24	0.26	0.31	0.85
Informed	1,153	0.00	0.13	0.23	0.52	0.45	17.43
Uninformed	1,153	0.10	0.44	0.78	1.36	1.41	35.12
Greater than 67%							
PIN	2,522	0.00	0.16	0.23	0.25	0.31	0.84
Informed	2,522	0.00	0.15	0.30	1.03	0.76	56.00
Uninformed	2,522	0.10	0.55	1.10	2.52	2.61	73.40

Table 5: Descriptive Statistics for Dealer Competition

This table provides descriptive information related to our measure of dealer competition. The Herfindahl index adds up the squares of the market shares. Low cost (high cost) dealers are identified by pooling all trades and testing whether a dealer's transaction costs are statistically significantly lower (higher) than the average, at the 10% level.

Panel A: Breakdown of Herfindahl Across All Bonds

	N	Min	25th Pctl	Median	Mean	75th Pctl	Max
Trades	7,422	164.8	423.4	592.3	1,003.2	986.9	9,060.3
Dollar volume ($ thousands)	7,422	212.2	624.8	910.8	1,314.0	1,519.8	9,271.7
Bond volume (number of $1,000 par value bonds)	7,422	211.9	623.6	907.7	1,310.2	1,509.4	9,256.7
Customer trades	7,422	188.1	567.1	803.7	1,274.5	1,327.7	9,567.7
Customer dollar volume ($ thousands)	7,422	231.1	818.3	1,171.3	1,596.5	1,850.9	9,736.1
Customer bond volume (number of $1,000 par value bonds)	7,422	229.0	817.7	1,170.8	1,592.5	1,847.6	9,728.9

Panel B: Distribution of Aggregate Trading Activity Across Low Cost vs. High Cost Dealers

	Low Cost Dealers		In Between		High Cost Dealers	
	Count	Percent	Count	Percent	Count	Percent
Distribution of dealers	433	22.9	1,010	53.3	452	23.8
Distribution of trading activity						
Total number of trades	5,623,199	43.7	1,209,086	9.4	6,049,550	47.0
Total dollar volume ($ thousands)	3,507,384	40.2	584,968	6.7	4,630,999	53.1
Total bond volume (number of $1,000 par value bonds)	3,137,916	36.5	726,598	8.4	4,742,525	55.1
Number of customer trades	2,053,769	34.0	205,065	3.4	3,789,502	62.7
Customer dollar volume ($ thousands)	3,073	36.1	729	8.6	4,718	55.4
Customer bond volume (number of $1,000 par value bonds)	2,019	33.6	213	3.6	3,769	62.8

Table 5: Descriptive Statistics for Dealer Competition (continued)

This table provides descriptive information related to our measure of dealer competition. The Herfindahl index adds up the squares of the market shares. Low cost (high cost) dealers are identified by pooling all trades and testing whether a dealer's transaction costs are statistically significantly lower (higher) than the average, at the 10% level.

Panel C: Distribution of Trading Activity by Low Cost and High Cost Dealers Across Bonds

Percent of Trading Activity	N	Min	25^{th} Pctl	Median	Mean	75^{th} Pctl	Max
Low cost dealers							
Total number of trades	7,422	0.0	30.3	41.5	39.9	50.1	99.0
Total dollar volume ($ thousands)	7,422	0.0	27.3	39.6	38.0	49.2	99.4
Total bond volume (number of $1,000 par value bonds)	7,422	0.0	25.2	35.0	35.0	44.4	99.9
Number of customer trades	7,422	0.0	22.6	33.4	34.0	44.4	99.9
Customer dollar volume ($ thousands)	7,422	0.0	25.2	35.0	35.0	44.4	99.9
Customer bond volume (number of $1,000 par value bonds)	7,422	0.0	22.6	33.4	34.0	44.4	99.9
High cost dealers							
Total number of trades	7,422	0.0	40.7	48.5	50.7	59.2	97.8
Total dollar volume ($ thousands)	7,422	0.0	43.6	53.2	54.9	65.3	100.0
Total bond volume (number of $1,000 par value bonds)	7,422	0.0	45.0	55.1	55.5	66.0	99.5
Number of customer trades	7,422	0.0	47.3	60.4	59.3	72.3	100.0
Customer dollar volume ($ thousands)	7,422	0.0	45.0	55.1	55.5	65.9	99.6
Customer bond volume (number of $1,000 par value bonds)	7,422	0.0	47.3	60.4	59.3	72.3	100.0

Table 6: Regression Analysis

This table presents results of a triangular regression analyses. For relatively liquid bonds, Liquidity Concentration measures the % of bond volume of a given bond relative to its set of substitutes minus its expected volume if volume were evenly distributed across substitutes. Liquidity concentration is equal to zero for bonds that are not relatively liquid. The Relatively Liquid bonds are bonds that have lower transaction costs for the 100 bond trade size than the average of its substitutes. PIN is the probability of informed trading, as calculated according to Easley, Kiefer, and O'Hara (1997). Low cost (high cost) dealers are identified by pooling all trades and testing whether a dealer's transaction costs are statistically significantly lower (higher) than the average, at the 10% level. Transaction costs are measured for a trade size of 20 bonds as given by equation (2).

	Dependent Variable							
	Liquidity Concentration		PIN		Percent of customer bond volume reported by low cost dealers		Transaction Costs (bps)	
Independent Variable	Coeff.*	*t-stat*	Coeff.*	*t-stat*	Coeff.	*t-stat*	Coeff.	*t-stat*
Intercept	0.46	*1.34*	29.92	*36.27*	43.35	*36.36*	-57.75	*-24.76*
Credit rating is BBB	-0.54	*-3.32*	0.23	*0.59*	1.99	*3.82*	14.00	*15.70*
Credit rating is B or BB	-0.18	*-0.95*	3.13	*6.82*	0.33	*0.53*	31.24	*22.78*
Credit rating is C and below	0.30	*1.15*	7.79	*12.44*	-3.61	*-4.29*	45.16	*20.84*
Coupon Rate	-0.11	*-3.17*	-0.93	*-10.85*	-0.16	*-1.38*	3.60	*14.28*
Bond is in default	-0.29	*-0.57*	6.23	*5.08*	-1.65	*-1.01*	73.96	*9.16*
Years since issuance (sq. root)	-0.26	*-3.35*	-0.47	*-2.54*	-2.17	*-8.78*	6.91	*11.73*
Years to maturity (sq. root)	0.00	*0.01*	0.70	*6.41*	-1.86	*-12.69*	23.68	*68.39*
Bond is soon to be called	1.48	*1.45*	29.55	*12.13*	6.01	*1.84*	-72.43	*-5.12*
Bond has a sinking fund	2.34	*3.96*	0.70	*0.50*	-0.68	*-0.36*	-23.70	*-1.46*
Issue Size (sq. root of millions)	0.08	*11.41*	-0.11	*-6.25*	-0.20	*-8.54*	0.15	*4.99*
Total other issues by same issuer (sq. root of millions)	0.00	*4.77*	0.01	*4.39*	0.02	*11.03*	0.07	*21.97*
Issue listed on NYSE ABS	-0.39	*-1.27*	1.93	*2.64*	1.61	*1.65*	-9.32	*-5.30*
TRACE-transparent (fraction of trades reported to public)	-0.60	*-2.61*	0.28	*0.51*	1.55	*2.13*	-8.48	*-5.60*
Liquidity Concentration			2.61	*0.94*	-3.76	*-1.02*	-66.25	*-10.56*
PIN					0.12	*0.08*	65.97	*28.88*
Percent of customer bond volume reported by low cost dealers							-0.03	*-1.07*
Adjusted R^2	0.03		0.07		0.10		0.61	
Sample Size	7,422		7,422		7,422		7,422	

*Coefficient estimates multiplied by 100.

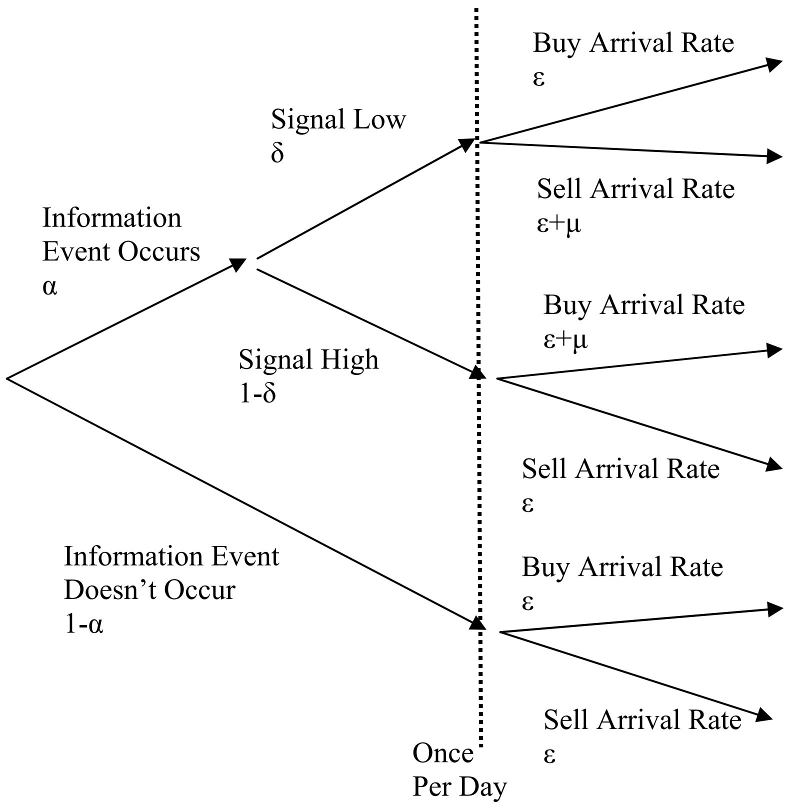
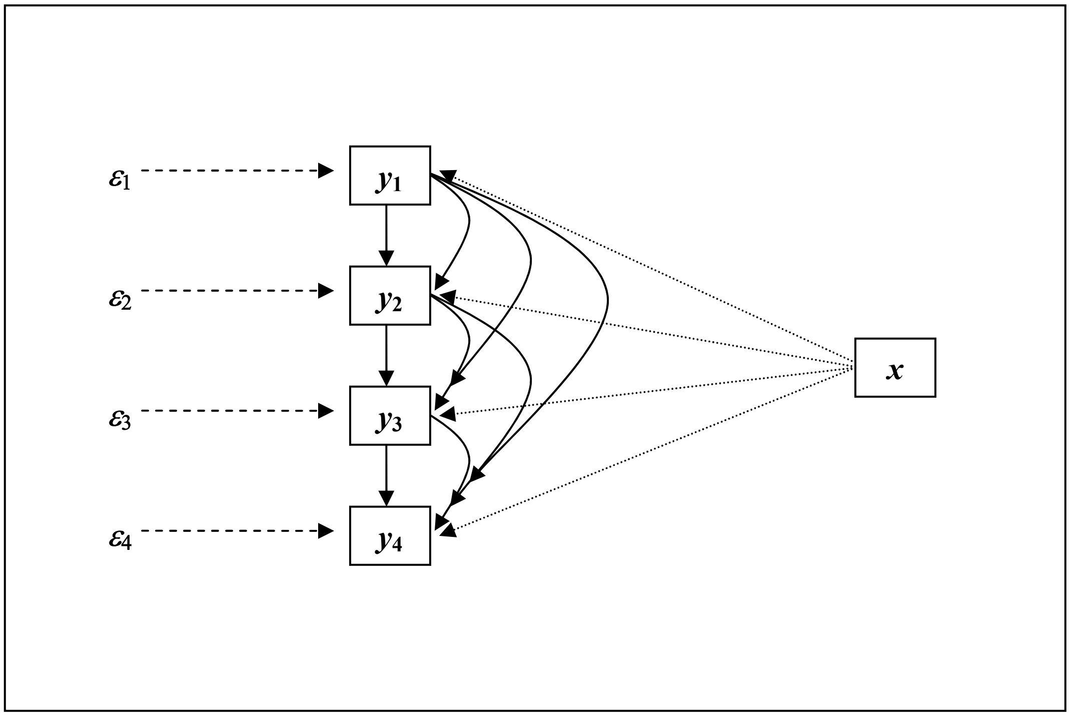


Figure 1. Tree diagram of the trading process.

This diagram gives the structure of the trading process. The α term is the probability of an information event occurs. The $(1-\delta)$ term is the probability that the news is a 'good" news and δ is the probability that is "bad" news. We set δ=.5 based on prior estimates. The ε and μ terms are the arrival rates for uninformed and informed traders, respectively.



Panel A. Schematic representation.

	y_1	y_2	y_3	y_3
Equation 1	1	0	0	0
Equation 2	β_{21}	1	0	0
Equation 3	β_{31}	β_{32}	1	0
Equation 4	β_{41}	β_{42}	β_{43}	1

Panel B. Matrix representation.

Figure 2. Recursive system.

This figure depicts the recursive system estimated in Equation 3:

$$
\begin{aligned}
y_1 &= x'\beta_1 && + \varepsilon_1, \\
y_2 &= x'\beta_2 + \gamma_{12} y_1 && + \varepsilon_2, \\
y_3 &= x'\beta_3 + \gamma_{13} y_1 + \gamma_{23} y_2 && + \varepsilon_3, \\
y_4 &= x'\beta_4 + \gamma_{14} y_1 + \gamma_{24} y_2 + \gamma_{34} y_3 && + \varepsilon_4
\end{aligned}
$$

Panel A depicts the schematic representation. Panel B depicts the matrix representation.