Market Transparency and Institutional Trading Costs

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Abstract

We estimate trade execution costs for a sample of institutional (insurance company) trades in corporate bonds before and after the initiation of public transaction reporting for some bonds through the TRACE system in July 2002. The results indicate a remarkable 50% reduction in trade execution costs for bonds eligible for TRACE transaction reporting, and also suggest the presence of a "liquidity externality" that results in a 20% reduction in execution costs for bonds not eligible for TRACE reporting. Larger trading cost reductions are estimated for less liquid and lower-rated bonds, and for larger trades. The key results are robust to allowances for changes in variables, such as interest rate volatility and trading activity, which might also affect execution costs. We also find decreased market shares for large dealers and a smaller cost advantage to large dealers post-TRACE, suggesting that the corporate bond market has become more competitive after TRACE implementation. The point estimates equate to annual trading cost reductions of roughly $1.2 billion per year for the entire corporate bond market, reinforcing that market design can have first-order effects, even for relatively sophisticated institutional customers.

1. Introduction

Security markets vary greatly in their transparency, i.e. in the amount of information regarding market conditions made public on a timely basis. Equity markets generally disseminate continuous pre-trade information, such as best quotations and, in some cases, descriptions of unexecuted limit orders, and also report immediately prices and sizes of completed trades. Most futures markets report trades, but do not disseminate pre-trade information. Foreign exchange markets disseminate only non-binding "indicative" quotations to the public, and do not report transactions at all. Corporate bond markets were traditionally similarly opaque, with quotations available only to a few market professionals, and no public transaction reporting.

Market transparency has been the subject of a handful of studies, but neither the theoretical predictions nor the empirical evidence is conclusive as to whether market quality is enhanced by increased transparency. This study contributes to the understanding of the role of market transparency by examining institutional trading costs in corporate bonds when the National Association of Securities Dealers (NASD) began to publicly report transactions in approximately 500 corporate bond issues through its Trade Reporting and Compliance Engine (TRACE) on July 1, 2002. The initiation of TRACE transaction reporting provides a potentially powerful experiment for assessing whether transparency is important to market quality, because the corporate bond markets were quite opaque prior to TRACE. In contrast, the previous empirical work on transparency focused on relatively small changes in the already quite transparent equity markets.

Improved transparency has potential to reduce trade execution costs for corporate bonds, for at least three reasons. First, transparency can reduce market maker rents. Pagano and Roell (1996) emphasize that opaque markets tend to benefit relatively well informed dealers in their negotiations with customers. Also, transactions reported through the TRACE system can be monitored by self-regulatory agencies and by the United States Securities and Exchange Commission (SEC). The potential role of increased transparency in improving customers' ability to control and evaluate trade execution costs has been emphasized by Annette Nazareth, Director of the Division of Market Regulation of the SEC:[1]

> "For investors as well as regulators, the difficulty lies in establishing the prevailing market price for a bond. This generally is the base line that is used to assess whether a mark-up (trade execution cost) is reasonable….. Improved transparency will enable investors to better determine the fair price of a bond. This will make them better able to protect themselves against unfair pricing….."

In addition to potential reductions in market-maker rents, improved transparency may decrease market making costs. Naik, Neuberger, and Viswanathan (1999) develop a model implying that improved transparency in a dealer market can improve inventory risk sharing, thereby decreasing inventory carrying costs.

Among the more important recent studies of bond markets, Green, Hollifield, and Schurhoff (2004) and Harris and Piwowar (2004) each examine trades completed in municipal bonds. Though methods of estimating trade execution costs differ across studies, each study reports that small trades pay much larger percentage costs than large trades, and each set of authors conjectures that this may occur because unsophisticated small investors cannot readily evaluate the trading costs they pay in the opaque market for municipal bonds. However, neither study provides direct evidence on the relation between market transparency and trading costs.

This study provides direct evidence on the issue by analyzing trade execution costs for institutional (insurance company) transactions in corporate bonds before and after the introduction of transaction reporting for corporate bonds through TRACE. The results indicate reductions in one-way trading costs for corporate bonds subject to TRACE transaction reporting that average six to seven basis points. These estimated reductions in trading costs average 50% of pre-TRACE trading costs, and equate to approximately $2000 per trade in the present sample of insurance company transactions. Extrapolating beyond the sample employed, we estimate market-wide trading cost reductions of roughly $1.2 billion per year after the initiation of TRACE transaction reporting. The key empirical results are robust to the

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[1] The remarks are excerpted from testimony Ms. Nazareth provided before the United States Senate Committee of Banking, Housing, and Urban Affairs on June 17, 2004.

inclusion of control variables such as interest rate volatility and bond market trading activity that might alternately explain variation in trade execution costs. We also evaluate the role of large dealer market shares, finding that trading activity is less concentrated and that the large dealer cost advantage previously documented by Schultz (2001) is reduced post-TRACE. Collectively, these results indicate that the public reporting of corporate bond trades has had first-order effects on market quality, even for the relatively sophisticated institutional traders that are the focus of this study.

In an important related working paper, Edwards, Harris, and Piwowar (2004) examine trade execution costs for corporate bonds using a comprehensive but proprietary database of transactions during 2003. They carefully document relations between trading costs and trade size, and also examine the determinants of cross-sectional variation in trade execution costs for corporate bonds. Among other findings, they report that one-way transactions costs for those bonds whose trades are publicly disseminated through TRACE are 1 to 4 basis points lower, after controlling for other relevant factors.

A distinction between this analysis and that provided by Edwards et al is that we estimate the effect of TRACE reporting on bond market quality around the time that public reporting of trades through TRACE was *first initiated*, on July 1, 2002, while Edwards, et al. consider cross-sectional variation in execution costs after transaction reporting was introduced. This distinction is important if transaction reporting for some bond issues also improves market quality for other issues. Amihud, Mendelson, and Lauterbach (1997) document that an improvement in the trading mechanism used for a subset of Tel Aviv Stock Exchange securities led to enhanced liquidity and permanent valuation effects, not only for the affected stocks, but also for correlated stocks with no change in trading mechanism. They attribute (page 367) this *liquidity externality* to "the fact that improved value discovery for one security facilitates value discovery for the other (correlated) security".

If a similar liquidity externality exists for corporate bonds then the analysis of cross-sectional variation in trade execution costs after TRACE initiation will understate the importance of trade transparency in reducing transactions costs. A liquidity externality seems particularly plausible for corporate bonds, since market practitioners often estimate the value of non-traded bonds based on "matrix" algorithms that incorporate bond characteristics and observed prices for bonds that do trade.[2] Improved information about market transactions in some bonds should allow more accurate valuation and better monitoring of trade execution cost for non-reported bonds as well.

Consistent with this reasoning, we document that one-way trading costs for *non*-TRACE-eligible bonds decreased by about four basis points on average after transaction reporting through TRACE was initiated in July 2002. For non-TRACE-eligible bonds issued by firms in the same industry as a firm with at least one bond issue eligible for TRACE reporting, the reductions in one-way trading costs are larger, averaging about five and a half basis points. More to the point, the estimated 6 to 7 basis point reduction in trading costs for TRACE-eligible bonds reported here is substantially larger than the 2.1 basis point cross-sectional estimate for large trades reported by Edwards et al.

Finding larger trading cost reductions in the present sample is all the more striking since we measure trading costs for institutional (insurance company) transactions. If opaqueness is primarily a problem for naïve individual investors then we should observe little or no effect of TRACE reporting. In contrast, the substantial effects documented here support the conclusion that transparency is important to institutional customers as well.

This paper is organized as follows. In section 2 we review recent papers on bond markets and on market transparency. Section 3 discusses methods for obtaining trading cost estimates for corporate bonds. Section 4 describes the available data, and some implementation issues that arise. Section 5 presents the key empirical results and tests of robustness, while section 6 concludes.

2. Studies of Bond Markets and of Transparency

2.1 Recent Studies of the Bond Markets

The increasing availability of data has spurred a substantial volume of recent research work focused on bond markets. Hotchkiss and Ronen (2002) study a sample of fifty five high-yield bonds.

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[2] Both buy and sell side bond traders typically have matrix pricing information available on their computer displays. Sell side traders can also view an automatic matrix valuation for any bond based on observed trades in bonds that are similar in terms of credit rating and maturity.

The source of their data was the Fixed Income Pricing System (FIPS), a predecessor to TRACE, which disseminated hourly summary reports on the pricing of a select set of high yield bonds. They focus on the relative information efficiency of stock and bond markets, reporting that stock price changes do not systematically lead bond price changes, and that market quality as measured by pricing errors in the Hasbrouck (1993) framework is similar across stocks and bonds.

Schultz (2001) provides estimates of trading costs for a large sample of corporate bonds. He obtains a dataset of insurance company trades in corporate bonds from Capital Access International (CAI). For the period January 1995 to April 1997 he estimates average round-trip trade execution costs of about 27 basis points. Schultz also reports that active institutions pay less than inactive institutions, and that trading costs decline with trade size. These results are suggestive that trading costs in the relatively opaque pre-TRACE bond markets depended in part on customer's degree of sophistication and familiarity with the bond markets.

Chakravarty and Sarkar (2003) also study the CAI database of insurance company bond transactions and report average trading costs for municipal bonds of 0.23 percent, compared to 0.21 percent for corporate bonds and 0.08 percent for Treasury bonds. They also report that in the cross-section, spreads rise with bond maturity and credit risk, and fall with trading volume. Hong and Warga (2000) compare insurance company trades in the CAI database to trades on the NYSE Automated Bond System, reporting similar bid-ask spreads on each. Chen, Lesmond, and Wei (2003) adapt the methodology of Lesmond, Ogden, and Trizinka (1999) to examine the liquidity of corporate bonds, using proprietary data from Bloomberg, documenting that their liquidity measure can explain sixteen percent of the variation across bonds in yield spreads. This finding is potentially important because it implies that market liquidity not only determines transactions costs, but may also affect the valuation of the bonds themselves, consistent with the empirical evidence in Amihud and Mendelson (1991) for treasury bonds.

A pair of recent papers, Green, Hollifield, and Shurhoff (2004) and Harris and Piwowar (2004), has focused on trading costs for municipal bonds using data gathered by the Municipal Securities Rulemaking Board (MSRB). Each study reports simple average (not weighted by trade size) one-way trade execution costs in the vicinity of 200 basis points. A striking conclusion of each study is that trading costs are dramatically greater for small transactions. For example, Green et al report trade execution costs of 310 basis points for trades of less than $5000, with estimated execution costs declining monotonically across trade size categories, to only 7.5 basis points for trades greater than $5 million. Harris and Piwowar report that trading costs are lower for high credit quality and less complex (e.g. non-callable) municipal bonds.

In a related study, Edwards, Harris, and Piwowar (2004) examine trading costs for corporate bonds. Their non-public sample includes all transactions reported to the NASD through the TRACE system during calendar year 2003, including those made public through TRACE and those not made public. Edwards et al document several important empirical regularities regarding corporate bond trading costs. First, they report that corporate bond trading costs decrease with trade size, a result that the authors attribute to small traders' lack of sophistication in combination with limited transparency. Second, they provide considerable evidence as to cross-sectional variation in corporate bond trading costs, documenting that costs increase with time since issue, and decrease with better credit rating, issue size, bond complexity, when the interest rate is floating rather than fixed, and if the firm has also issued private equity. Third, they address the role of transparency, reporting that in the cross-section trade execution costs are lower for bonds whose trades are publicly disseminated through TRACE, after controlling for variation in other characteristics. In particular, their Table 5 reports point estimates indicating that one-way trade execution costs are reduced by 0.9 basis points for $10,000 trades, 2.9 basis points for $20,000 trades, 3.8 basis points for $100,000 trades, and 2.1 basis points for $1 million trades.[3] Given the result obtained here that liquidity externalities exist for corporate bonds, the point estimates provided by Edwards et al may be viewed as quantifying the effect of public dissemination of trade information through TRACE *conditional* on transaction prices for other, potentially related, bonds already being

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[3] Edwards et al also report broadly similar point estimates from a time series experiment, as execution costs for a set of bonds phased into the public dissemination of trade reports during 2003 declined by about 3 to 4 basis points on average.

available through TRACE, and therefore providing a lower bound on the overall effect of TRACE reporting on corporate bond execution costs.

2.2 Studies of Market Transparency

Security market transparency refers to the amount of information regarding market conditions and transactions made public on a timely basis. Transparency is often categorized as pre-trade transparency, which concerns the dissemination of quotations or other indications of trading interest (such as unexecuted orders in the limit order book), and post-trade transparency, which concerns the dissemination of data about completed trades. Markets that disseminate little or no price data are referred to as being opaque, or non-transparent.

The model presented by Pagano and Roell (1996) implies that improved transparency should decrease the transactions costs paid by uninformed traders to relatively well informed dealers. In addition, Naik, Neuberger, and Viswanathan (1999) develop a model implying that improved transparency in a dealer market can improve inventory risk sharing, thereby decreasing inventory carrying costs. Consistent with these predictions, Flood, Huisman, Koedjick, and Mahieu (1999) provide experimental evidence that pre-trade transparency reduces bid-ask spreads.

However, some theoretical analyses predict that less transparent markets might improve liquidity. In particular, Bloomfield and O'Hara (1999) argue that an opaque market may give market makers incentives to quote narrow bid-ask spreads, because the order flow attracted by narrow spreads contains valuable information about market fundamentals, while Bloomfield and O'Hara (2000) provide experimental evidence generally consistent with this reasoning.[4]

The empirical evidence from actual asset markets is inconclusive, in part because structural changes in the transparency of actual markets are rare. Gemmill (1996) examines the London Stock Exchange after two changes in required post-trade transparency, and does not detect any change in

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[4] Of course, this argument does require that the quotes themselves be disseminated to traders, and hence may not apply in a market without pre-trade transparency.

liquidity.[5] Madhavan, Porter, and Weaver (2004) examine the liquidity of the Toronto Stock Exchange when during 1990 it began to publicly disseminate its limit order book, and document increased execution costs and greater price volatility after the increase in pre-trade transparency. Boehmer, Saar, and Yu (2004) examine the effect of the New York Stock Exchange beginning to disseminate limit order book information in January 2002. They document that limit order traders are able to use the information to refine their strategies and, in contrast to the findings of Madhavan, Porter and Weaver, report improved liquidity as measured by transaction costs and the informational efficiency of prices. The inconclusive results obtained from these empirical studies may reflect that they studied changes in transparency in equity markets that were already quite transparent. The present analysis, in contrast, focuses on a market that was almost entirely opaque prior to the initiation of transaction reporting.

2.3. The Transparency of the Bond Markets

The corporate bond market has traditionally been opaque. Trades were reported only to the parties involved, so investors could not compare their own execution price to other transactions. Institutional investors had to invest significant time and effort to obtain market information, and were limited in their ability to compare their transaction prices to other investors. Limited information regarding current prices, in the form of "indicative" quotes, was available to institutional investors through a messaging system provided by Bloomberg. Investors could use this system to indicate interest in buying or selling a particular issue in an effort to solicit bids or offers, or could telephone dealers for quotes. The situation was even more difficult for individual investors, who were precluded from accessing virtually all real-time market information.

In an effort to bring greater transparency to the bond markets and provide additional regulatory oversight, the United States Securities and Exchange Commission (SEC) on January 31, 2001 approved rules requiring the NASD to report all over-the-counter secondary market transactions in a specified set of corporate bonds. The requirement initially applied to a set of 498 bonds with issuance size of $1 billion

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[5] Prior to 1988 LSE dealers had to immediately report their block trades. From 1991 to 1992 they had to do so within 90 minutes, while during 1989 and 2000 they had to report within 24 hours.

or greater, and was implemented July 1, 2002. Previously, the SEC had mandated limited market information reporting (hourly high, low, and volume transacted) for a set of 50 non-investment grade bonds (the FIPS 50), effective April 1994.

During the 2002 sample period NASD members were required to report all corporate bond transactions to the TRACE system within 1 hour and 15 minutes. For each trade the member is required to report bond identification (CUSIP or NASD symbol), the date and time of execution, trade size, trade price yield, and a buy or sell indication. However, not all of the reported information is disseminated to the public: investors receive bond identification, the date and time of execution, as well as the price and yield, for bonds specified as TRACE-eligible. Trade size is provided for investment grade bonds if the par value transacted was $5 million or less, otherwise an indicator variable denotes a trade of more than $5 million.

Investors can access the trade information on the NASD website without charge, but with a four hour delay. The information is also retransmitted without delay via third-party vendors to subscribing investors. Institutional investors typically rely on a third-party vendor to disseminate the pricing information in an easily accessible and useable format, with MarketAxess apparently being the most widely used.

3. Measuring Trading Costs in Bond Markets

Most studies of trade execution costs have focused on equity markets, and are able to exploit the existence of reliable quotation databases to construct measures of quoted (ask price less bid price) and effective (trade price relative to quotation midpoint) spreads. In contrast, data on bid and ask quotations are not broadly available for bond markets.[6] However, the available bond transaction databases often do indicate whether a dealer participated as a buyer or a seller. As a consequence several studies, including

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[6] Bloomberg does record some bid and ask quotations based on dealer-customer messages. Chen, Lesmond, and Wei (2003) were able to hand collect a limited sample of these quotes. Also, the University of Houston Fixed Income Research Program formerly distributed bid quotes for the individual bonds comprising the Lehman Brothers Bond Indices, but switched to NAIC as their primary data source in 1999.

this one, have adopted variations of indicator variable regressions to estimate trade execution costs for bonds.

The indicator variable model used here is an extension of that suggested by Huang and Stoll (1997). Let S denote the effective round trip spread, i.e. the difference between the price at which dealers will sell a bond and the price at which they will purchase the bond, initially assumed to be constant. Let P_t denote a transaction price at time t, V_t denote the unobservable true value of the bond at time t, and let Q_t be an indicator variable that equals 1 if the time t trade is a customer buy and -1 if it is a customer sell. Innovations in the underlying value of the bond are attributable to public information releases and, potentially, private information revealed through buy or sell orders:

$$V_t = V_{t-1} + \gamma Q_{t-1} + \varepsilon_t, \tag{1}$$

where γ reflects the private information content of a buy or sell order, and ε_t represents new public information. We assume that a fraction w of the public information eventually becomes observable to econometricians in the form of data with realizations X_t, while the remaining portion is due to unobservable innovations U_t that represent statistical noise:

$$\varepsilon_t, = wX_t + (1-w)U_t. \tag{2}$$

Assuming that the spread is symmetric, customers buy (sell) at a price that exceeds (is less than) the underlying bond value by half the effective spread:

$$P_t = V_t + Q_t(S/2). \tag{3}$$

Letting Δ denote the difference between observation t and the preceding observation, first differences of expressions (1), (2), and (3) can be combined to give:

$$\Delta P_t = wX_t + \gamma Q_{t-1} + (S/2)\Delta Q + (1-w)U_t. \tag{4}$$

Expressions (3) and (4) are both suggestive that the half spread can be estimated by appropriately specified regressions of observed (changes in) prices on (changes in) buy-sell indicator variables.

Schultz (2001) and Warga (1991) estimate a version of (3), while also using the information in estimated bid quotes. In particular, letting B_t denote the bid quote at time t, V_t can also be expressed as $B_t + S/2$, so that (3) can be expressed as:

$$P_t - B_t = (1 + Q_t)S/2. \tag{5}$$

To implement this method, Shultz constructs estimates of bid quotes prevailing at the time of transactions. He obtains actual bid quotes as of the end of the prior month from the University of Houston Fixed Income database, and then adjusts the end-of-month quotes for changes in Treasury interest rates between the end of the prior month and the trade date. Schultz estimates the half spread by regressing the difference between each bond transaction price and the estimated bid quote at the time of the transaction on the trade indicator variable.[7]

However, this method may not be suitable for future studies. The need to adjust the monthly bid quotes to obtain within-month estimates caused Schultz to limit his study to investment grade bonds. More importantly, the bid quote data disseminated by the University of Houston pertained only to the bonds contained in the Lehman Brothers Bond Indices, and has not been disseminated for transactions since 1999. The indicator variable model (4) in contrast can be implemented for all bonds, and does not require access to quotation data.

Relying on (4), we estimate regressions of the form

$$\Delta P = a + wX + \gamma Q_{t-1} + (S/2)\Delta Q + \acute{\eta}. \tag{6}$$

This specification is identical to regression equation (5) in Huang and Stoll (1997), with one exception: the allowance for the effect of observable public information on underlying bond value. Simulation-based evidence reported in the Appendix verifies that controlling for variation in factors that affect bond values improves the precision of estimates of the half-spread. This is potentially important for corporate bonds, since the elapsed time between trades can be long. Note also that we have assumed the spread to be symmetric, or equivalently, that dealer inventory costs do not affect dealer reservation prices. As the discussion in Huang and Stoll (1997) makes clear, if this assumption is relaxed the γ coefficient estimate can be interpreted to reflect the sum of trades' information content and the dealer inventory cost component of the spread.

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[7] Warga (1991) uses a similar approach to estimate execution costs for bonds traded on the NYSE Automated Bond System by comparing NYSE trade prices to Lehman Brothers Quotes.

Harris and Piwowar (2004) and Edwards, Harris and Piwowar (2004) also rely on an indicator variable regression approach broadly similar to that described by Huang and Stoll (1997), while allowing estimated execution costs to vary depending on trade size. Edwards et al estimate their version of (6) on an issue-by-issue basis, and then examine cross-sectional variation in trading costs across bonds. As they have carefully documented the determinants of cross-sectional variation in trading costs, we also refrain from an extensive cross-sectional analysis. Instead we rely on a pooled approach, which should improve statistical power to detect relations between trading costs and transparency as measured by the public dissemination of trade prices through TRACE.

We include in (6) three public information variables, each measured from the date of the most recent transaction on a prior day to the date of the current transaction. The first is the return on the on-the-run Treasury security matched to the corporate bond based on maturity.[8] Since the treasury return control variable differs across bonds according to maturity, changes in the interest rate term structure are also accommodated. The second control variable is the change in the yield spread between BAA bonds and Treasury Securities, included to allow for changes in market wide risk perceptions and economic activity. The yield spread data is obtained from the Federal Reserve Statistical Release. The third control variable is the percentage return on the issuing firm's common stock, included to allow for company-specific news that may affect bond prices. Stock return data is obtained from the Center for the Research in Securities Prices (CRSP) daily database. If the bond was issued by a subsidiary, we used the parent company for stock return data. Since relations between bond returns and both yield spread changes and common stock returns are likely to differ depending on the credit quality of the issuing firm, we use indicator variables to estimate distinct coefficients on these control variables for investment grade (BBB rated or better) and non-investment grade bonds. In most specifications we assess the impact of TRACE

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[8] On-the-run Treasuries are the mostly recent issued Treasury bonds in each maturity category. These are the most liquid treasury securities, and are typically used to define the Treasury yield curve. The identity of an on-the-run Treasury issue can change over time as the government issues new debt. In cases where the identify of the on the run security changes during the sample period we keep the same benchmark Treasury issue as defined at the beginning of the year, but use the yield from the new on-the-run Treasury security to determine the price of the matching Treasury issue.

reporting by simply including the product of the ΔQ_{it} variable and an indicator variable that equals one for trades occurring after July 1, 2002 and zero for trades before.

4. Data Description and Implementation Issues

4.1 Data Sources and Description

To examine trading costs before and after the implementation of TRACE, we rely on the National Association of Insurance Commissioners (NAIC) transaction data in corporate bonds. NAIC is also the source of the data used by Schultz (2001), Campbell and Taksler (2003) and Krishnan, Ritchken, and Thomson (2004), who provide a more detailed description. As Shultz (2001) notes, the president, secretary, and controller of each insurance company must attest to the validity of the data reported by each insurance company to the NAIC. Shultz also notes that the NAIC data appears to comprise a complete record of insurance company bond trades.

Schultz (2001) and Campbell and Taksler (2003) estimate that insurance companies hold between one third and forty percent of corporate bonds. Of course, insurance companies may not trade as actively as other market participants. A comparison of the NAIC data for TRACE-eligible bonds to the actual TRACE data (provided to us by MarketAxess) indicates that insurance companies completed 12.5% of the dollar trading volume in TRACE-eligible securities during the second half of 2002. So while the NAIC data is not exhaustive, it does represent a substantial portion of the corporate bond market. Importantly for purposes of this study, it provides corporate bond transaction data both before and after the implementation of TRACE.

NAIC data provides detailed transaction information including; trade date, price, size of the trade (market and face value), issue CUSIP, dealer identification, and the type of selling institution. Notably, the NAIC data does not contain transaction times. The effect of this omission is discussed further in section 4.2. To obtain information on the characteristics of each traded bond, including maturity date and bond rating, we use the fixed income security database (FISD).

The NAIC data is divided into two samples: TRACE and non-TRACE. The TRACE sample consists of bond issues for which the NASD began to report transaction information on July 1, 2002, while the non-TRACE sample consists of the remaining issues in the NAIC sample. We analyze trading costs pre- and post-TRACE for both samples. In selecting the time interval to study we want to span enough time to provide accurate measures trading costs, but also minimize the possibility of other factors influencing results. In addition, the post sample should include a long enough time frame for participants to become accustomed to the TRACE system. For the main analysis, the pre-TRACE period is defined as the six months prior to the implementation of TRACE, January 1, 2002 through June 30, 2002, and the post-TRACE period as the following six months, July 1, 2002 through December 31, 2002. To ensure that the results are robust, we also examine results using a shorter window of three months before and after, and find substantially the same results as reported.

The TRACE sample begins with 51,209 transactions, which represents all NAIC reported transactions in 2002 for the sample bonds eligible for TRACE reporting in July 2002. We exclude some transactions from the analysis. We eliminated transactions if no matching CUSIP could be obtained from CRSP (e.g. for foreign issuers or privately owned equity), which reduced the sample to 48,627 observations and a final sample of 439 TRACE-eligible bonds. We also eliminated sell transactions that involved the bond issuer, including those with the terms called, cancelled, conversion, direct, exchanged, issuer, matured, put, redeemed, sinking fund, tax-free exchange, and tendered in the transaction name field. We excluded transactions in which the dealer descriptions indicate the trade to be with a related party, as well as transactions labeled “no broker” and “private”. These screens eliminate 2,166 transactions, leaving 46,461 observations.

The NAIC data may also suffer from data entry errors, as reports are manually coded. Prior researchers have handled this in different ways. Schultz (2001) discards observations that differ by more than five percent from the beginning and end-of-month bid price. Campbell and Taksler (2003) eliminate the top and bottom 1% of spreads from their analysis. Krishnan, Ritchken, and Thomson (2004) eliminate all “inconsistent or suspicious” observations. We eliminate “reversal” transactions, where a given price exceeds *both* the preceding and following prices by at least 15%, or is less than both prices by the same magnitude. We also drop 5,533 trades that were either the first trade for the bond in the pre or post TRACE periods, or where matching stock and treasury returns cannot be obtained for the TRACE reported date (usually a weekend or a holiday). We also eliminate 1,341 trades where the absolute bond return exceeds 10%. The indicator regression specification (6) relies on the ability to identify "bid-ask bounce" in the series of transaction prices. Price changes exceeding 10% are not plausibly attributable to bid-ask spreads, but increase statistical noise. The final TRACE-eligible sample comprises 39,040 observations.

Identical screens are used for the non-TRACE sample. We begin with 94,400 NAIC transactions during 2002 for bonds not TRACE-eligible as of July 1, 2002. The requirement to match these bonds with both the FISD (bond characteristic) and CRSP databases reduced the sample to 82,647 trades. Eliminating government, quasi government, municipal debt securities and implementing the same filters as for TRACE bonds reduced the sample to 54,601 observations. We also delete bonds that were not in the sample for all of year 2002, leaving a final non-TRACE sample of 53,282 transactions.

To examine industry specific effects we also obtain 3-digit SIC codes for the issuer of each sample bond and from CRSP. We then identify those non-TRACE bonds with issuers in the same 3-digit SIC code as TRACE bonds. Since TRACE eligibility is bond and not firm specific, we also create an indicator variable that equals one if an issuer matched on the basis of the 6 digit CUSIP also has at least one TRACE-eligible bond.

4.2 Estimating Trade Execution Costs without Transaction Times

As noted above, the NAIC database contains transaction dates, but not transaction times. The econometric model (6) relies on the assumption that transactions are appropriately ordered in time. The available information does not allow us to verify whether this is the case for transactions in the NAIC database.

We adopt the following procedure, which exploits the fact that the dataset contains transaction dates, if not transaction times. For each trade, we compute the change as the current observation minus the last observation contained in the dataset (which may or may not be chronologically last) on the prior trading day. Equation (6) is then estimated using the resulting data.

To our knowledge, the effect of imperfect time ordering of data observations on the statistical properties of estimates obtained from models similar to (6) has not been the subject of analytical study. We therefore conduct a simulation analysis in which the underlying parameters are known, and assess whether the approach we use, as well as some plausible alternatives, provide unbiased estimates. Results of the simulation are reported in the Appendix. These results support the conclusion that, although the lack of time stamps reduces statistical power, the method used here provides unbiased parameter estimates.

However, this method also creates overlapping dependent variables on days where a bond trades more than once, which complicates statistical inference. Further, the number of adjacent observations that overlap is a random variable, equal to the number of trades on each day. To our knowledge no established procedure exists to compute consistent standard errors in a datasets with a random number of overlapping observations. We therefore compute probability values for each coefficient estimate using a technique known as the "block bootstrap" that, unlike the standard bootstrap approach (which assumes independence across observations), relies on no specific assumption regarding the structure of the data generating process.[9]

Like the standard bootstrap approach (see for example Efron and Tibshirani, 1993), the block bootstrap relies on drawing observations from the original sample with replacement. The statistical model is estimated once for each bootstrap sample. By repeating the process a large number of times a distribution of bootstrap coefficient estimates can be created. However, instead of drawing single observations, blocks of consecutive observations are drawn. This is done to capture the dependence structure of neighbored observations. We implement the block bootstrap using bond-days to define

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[9] For descriptions of the block bootstrap approach see, for example, Carlstein (1986) and Hall and Jing (1996).

blocks.[10] Thus, if the original sample contains N bond-days with trades, each bootstrap sample is created by drawing N bond-days at random and with replacement from the original sample. We create 1000 bootstrap samples and estimate (6) in each, leading to a distribution of 1000 bootstrap sets of coefficient estimates. Note that this procedure not only accommodates the dependence of the observations within a trading day, but since a given trading day will appear more or less frequently across the bootstrap samples, it also accommodates any commonality in bond price movements attributable to different bonds trading on the same day.

To assess the bootstrap probability value for a coefficient estimated from the actual data, we examine the proportion of the bootstrap estimates that are of the opposite sign as the actual estimate. For example, if the actual estimate is positive, but 121 of 1000 bootstrap estimates are negative, the bootstrap p-value for coefficient is 0.121.

5. Empirical Results

5.1. Descriptive Data

Table 1 reports summary statistics for the TRACE, non-TRACE and the combined TRACE and non-TRACE samples. Panel A provides information about the characteristics of the bonds in the samples. When comparing characteristics, it is evident that the TRACE-eligible bonds are larger (1.45 versus 0.34 billion average issue size) and of higher credit quality than non-TRACE bonds. Information about trading characteristics is provided in Panel B. Sample bond prices were close to par during 2002, but were on average higher after TRACE. In Section 5.5.2 below we investigate whether the increase in sample bond values can be explained by factors such as changes in interest rates.

The corporate bonds in the sample trade relatively infrequently. For the TRACE sample, the average number of insurance company trades is 46 per issue in the six months prior to TRACE and 50 per issue in the six months after TRACE implementation. Non-TRACE bonds trade less with an average of

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[10] To ensure robustness we also estimate results when using a week of trading for each bond to define a block. P-values are almost indistinguishable from those reported.

11 and 13 trades per issue pre- and post-TRACE implementation. However, the size of the trades is relatively large. The average trade in the NAIC database was \$3.0 and \$2.5 million pre-TRACE for TRACE and non-TRACE-eligible bonds respectively. Average trade size increased post-TRACE, to \$3.1 million for the TRACE sample and \$2.9 million for the non-TRACE sample. The increased trade size post-TRACE indicates that orders are not split into smaller trades post-TRACE, as might be expected if liquidity supply had become scarce. Median trade sizes are \$1 million or less, indicating positive skewness in trade sizes.

The NAIC database covers some \$263 billion in bond trading during 2002, including \$119 billion in TRACE-eligible issues and \$144 billion in non-TRACE issues. In the second half of 2002, volume in the sample of TRACE eligible bonds was \$64.5 billion, and for comparison, the total volume (all transactions reported to the NASD under TRACE rules) for these bonds was \$514 billion over the same time period. Consistent with the institutional nature of the NAIC data, the mean (median) transaction size in the NAIC sample is \$3.1 million (\$785 thousand), as compared to \$508 thousand (\$26 thousand) for all TRACE trades.[11]

5.2. The Effect of TRACE reporting on TRACE-eligible Bonds

Table 2 reports the results of estimating specification (6) for the sample of insurance company trades in TRACE-eligible bonds. The dependent variable is the price change in percent, so coefficient estimates can be interpreted in basis points. The left most columns of Table 2 provides estimates obtained while using pooled data from both the pre and post TRACE reporting periods.

The coefficient estimate on the lagged trade indicator variable is very close to zero (point estimate = .0015 basis points, p-value = 0.922). The corresponding point estimate obtained when estimating (6) for non TRACE-eligible bonds is also close to zero. These results are consistent with the reasoning that the insurance companies whose trades comprise the present sample possess no private information about bond values, and are trading for liquidity reasons. Since statistical power is increased

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[11] MarketAxess provided accurate volume information for TRACE eligible bonds.

when fewer parameters are estimated and no bias is introduced if the coefficient on lagged Q equals zero, we omit this variable from the remaining specifications.

Estimated coefficients on the control variables are highly significant, suggesting that the inclusion of these variables improves the precision of the trading cost estimates. Coefficient estimates on stock returns are positive (bootstrap p-value = 0.000), consistent with the reasoning, and the empirical evidence reported by Hotchkiss and Ronen (2002), that stock and bond returns both respond to new information about the value of the issuing firm's underlying assets. As might be expected, the coefficient on stock returns is greater when explaining returns on non-investment grade bonds. The return on the benchmark Treasury bond also enters with a positive coefficient estimate, as both treasury and corporate bonds respond to market-wide interest rate movements. The coefficient estimates on the change in the Baa-Treasury yield spread are negative and significant for non-investment grade bond issues, but are generally close to zero for investment grade bond issues. The broad significance of the control variables underscore the usefulness of controlling for changes in public information that affect corporate bond prices.

For the full sample the coefficient on ΔQ, which estimates one-way trade execution costs for the institutional bond trades, is 9.6 basis points. Column 3 of Table 2 reports results from the pre-TRACE period. The pre-TRACE estimate of the half-spread is 13.7 basis points, which corresponds closely to the Schultz (2001) estimate of 27 basis points for the full spread in his study of insurance company trades in high credit quality corporate bonds. The similarity in point estimates obtained while using markedly different estimation procedures increases confidence in the reliability of the specification.

Column 4 reports results obtained from the post-TRACE sample. Remarkably, estimated trade execution costs for the sample of institutional corporate bond trades drop by fifty percent after TRACE reporting was initiated, from 13.7 basis points during the first six months of 2002, to only 6.7 basis points during the last six months of 2002.[12] Column 5 of Table 2 reports results of a specification that uses data for the full year 2002, but includes the product of an indicator variable that equals one for trades after July

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[12] The R-squared obtained when estimating (6) in TRACE-eligible bonds is notably smaller post-TRACE. This is partially attributable to increased volatility. The standard deviation of daily return volatility for investment grade bonds increased by approximately 33% over this time period.

1 and zero otherwise and the change in trade indicator variable to estimate the impact of market transparency. The estimated trading cost reduction after TRACE introduction obtained from this specification is 6.4 basis points (p-value = 0.003). A 6.4 basis point decrease in trade execution costs equates to transaction cost savings of about $41.3 million ($64.5 billion in trading times 0.00064) during the last half of 2002 for the insurance companies in the present sample alone.

The estimated decrease in trade execution costs after TRACE initiation of six to seven basis points reported here is substantially larger than the estimate of 2.1 basis points for million dollar trades (the largest trade size reported) obtained in the cross-sectional analysis of 2003 bond trading presented by Edwards et al. Interestingly, these estimates of overall levels of trading costs post-TRACE are similar, though somewhat smaller (as might be expected in this sample of exclusively institutional trades), to those reported by Edwards et al.[13] We conjecture that these estimates of trading cost reductions due to TRACE are greater, even while estimates of levels of trading costs are similar, because a liquidity externality improved market quality for all corporate bonds, including those not reported through TRACE. Before investigating this conjecture, we provide some evidence on cross-sectional variation in trading cost reductions for TRACE-eligible bonds.

In panel B of Table 2, columns 1 and 2 reports the results of estimating equation (6) while including indicator variables to estimate separate parameters for large and small trade sizes. We consider two methods of designating trades as large or small. First, we focus on absolute size, and estimate separate parameters for what is considered a round lot ($1 million or more) and odd lot (less than $1 million) trades in the bond market. Second, we compare each trade to the median trade size for that bond, designating trades smaller than or equal to the median as small and trades larger than the median as large. The results of this analysis indicate that the greatest reductions in trade execution costs after TRACE introduction were for large trades. The estimated decrease in trading costs for round lot trades is 10.4

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[13] For example, their sample C1 in Table 6 is broadly similar to our TRACE-eligible sample. We report post-TRACE trading costs of 6.6 basis points, compared to their estimate of 8.8 basis points for large trades. Their samples T and C3 in Table 6 are broadly similar to our non-TRACE sample. They estimate trading costs of 20.1 and 20.8 basis points, compared to our estimate (Table 4, Panel A, Column 3) of 16.1 basis points for the non-TRACE sample after TRACE reporting was initiated.

basis points (p-value = 0.000), compared to 3.0 basis points (p-value = 0.302) for odd lot trades, while the decrease for larger-than-median trades is 10.5 basis points (p-value = 0.000) compared to an estimate of 2.3 basis points (p-value = 0.396) for smaller than median trades. This finding may reflect that market makers can handle large trades with less difficulty in the more transparent markets, either because of less adverse selection or because of lower inventory costs.

Column 3 of Panel B reports results obtained when separate trading cost estimates are obtained for liquid and illiquid bond issues. To assess liquidity we simply count the number of trades during the pre-TRACE sample period, and assign bonds to volume terciles based on transaction frequency. The results indicate a monotonic trend where illiquid bonds paid considerably larger trade execution costs pre-TRACE (32.1 basis points for low volume versus 10.7 basis points for high volume), but also saw much larger decreases in execution costs post-TRACE (11.5 basis points for low volume, compared to 5.5 basis points for high volume). This result may reflect that institutional traders were able to obtain less timely market information for illiquid bonds before TRACE, so that the incremental effect of TRACE reporting was larger.

Finally, column 4 and 5 of Panel B of Table 2 provides estimates of trade execution costs for TRACE-eligible bonds as a function of bond credit rating. We report the results as separate subsamples given the large difference across subsamples in the coefficient on the Treasury return variable. The results indicate substantially larger execution costs pre-TRACE for non-investment grade bonds (defined as those rated BB+ or lower) than for investment grade bonds, 19.1 basis points versus 12.6 basis points. The results also indicate much larger reductions in execution costs (30.8 basis points) after TRACE for non-investment grade bonds, though the estimate seems implausibly large, perhaps reflecting the small number of low-rated bonds that became TRACE-eligible.

To summarize, the estimates obtained here indicate that trade execution costs were reduced by 50% on average for bonds whose transactions began to be disseminated through TRACE during 2002. Execution costs were generally higher pre-TRACE for lower rated bonds and for less liquid bonds. The largest declines in trading costs after the introduction of TRACE were for larger trades, and for trades in less liquid bonds. Finding large reductions in trade execution costs in the present sample of institutional trades, and particularly finding greater reductions for larger trades is not expected if one conjectures that a lack of transparency is mainly a problem for unsophisticated small traders. Rather, these results indicate that even the market for large institutional corporate bond trades has been substantially affected by transaction reporting.

5.3. The Effect of TRACE reporting on non-TRACE-eligible Bonds

As noted above, the public reporting of transactions in a subset of corporate bond issues could result in a liquidity externality of the type described by Amihud et al (1997) that also improves the accuracy of the valuation of related bonds. If so, we anticipate investors can also better evaluate the trade execution costs that they pay in bonds whose transactions are not disseminated through TRACE as well.

Table 3 reports the results of estimating expression (6) for the sample of non-TRACE bonds. Not surprisingly, in light of the fact that non-TRACE bonds are of lower average credit quality and trade less frequently, estimated one-way execution costs of 18.0 basis points are considerably greater for non-TRACE bonds than for the TRACE sample as reported on Table 2. Most importantly, and consistent with our conjectures, execution costs for the non-TRACE sample also decreased significantly after the initiation of TRACE reporting, from 20.5 basis points before to 16.3 basis points afterward. When estimating (6) in the full sample and using an indicator variable to accommodate the change in trading costs after TRACE, the estimated decline for the non-TRACE sample is 4.1 basis points (p-value = 0.002). Remarkably, this estimate of the effect of TRACE *initiation* in July 2002 on non-TRACE bonds is larger than the estimated difference in trade execution costs for TRACE-eligible versus non-TRACE-eligible bonds reported by Edwards et al from their post-TRACE sample.

Panels B and C of Table 3 provide evidence on cross-sectional variation in the effect of TRACE reporting on non-TRACE bonds. Methods and definitions generally parallel those used for results reported on Table 2 for TRACE-eligible bonds. Several observations can be made. First, larger trades in non-TRACE bonds (Panel B columns 1 and 2) also saw the greatest declines in execution costs (6.2 basis points for large trades versus 1.8 basis points for small trades when focusing on dollar trade size, and 5.2

basis points for large trades versus 3.0 basis points for small trades when focusing on whether a trade is larger than the issue-specific median size). Second, in Panel B column 3 we find that reductions in execution costs were similar across more and less active issues. Third, from Panel C column 1 and 2, lower rated non-TRACE bonds also saw greater reductions in trade execution costs (8.1 basis points for non-investment grade versus 1.7 basis points for investment grade). Fourth, Panel C columns 3 and 4 reports that trade execution costs for large (over $500 million original issue value) and small (under $500 million) bond issues were similar pre-TRACE, but large issues had substantially greater trading cost reductions after TRACE (7.4 basis points versus 1.9 basis points).

Finally, Table 3 Panel C column 5 and 6 reports results for the subsets of the non-TRACE sample, based on the relation between individual bond issues and bonds in the TRACE sample. There is no significant change (point estimate = 2.5 basis points, p-value = 0.322) in the cost of trading non-TRACE bonds issued by firms that also have TRACE-eligible bonds. This is somewhat surprising. However, these bonds are smaller (the median bond issue size is $350 million, compared to $1.1 billion for TRACE-eligible bonds) and trade less frequently (the median number of trades pre-TRACE is only five), and in general we have found that smaller bonds had smaller reduction in spreads from the implementation of TRACE.

Interestingly, we do find evidence that other bonds in the same industry (defined by the 3 digit SIC code) as an issuer with a TRACE-eligible bond have a significant reduction, 5.6 basis points with an associated p-value of 0.003, in their half-spread after TRACE initiation. For bonds issued by firms outside the industries included in the TRACE sample, the decrease in trade execution costs is not statistically significant. This last pair of results is to be expected if observing TRACE trade reports is most useful for improving the pricing and monitoring the trade execution costs for economically similar bonds issued by firms in the same industry.

5.4. Testing for Valuation Effects

Amihud and Mendelson (1986, 1991) present theory and empirical evidence implying that stocks and bonds with lower trading costs have higher market valuation, ceteris paribus, as investors will discount prices to recover anticipated future trading costs. Amihud et al (1997) present evidence of increases in the market valuations of Tel Aviv stock exchange stocks when liquidity was improved due to the introduction of continuous trading. We next test whether a similar liquidity externality occurs for corporate bonds around the time that liquidity improved due to TRACE transaction reporting.

Application of the Amihud-Mendelson reasoning to TRACE-eligible bonds provides an unambiguous prediction that valuations should increase due to improved liquidity. For non-TRACE eligible bonds the prediction is less clear cut. Estimated trading costs for non-TRACE bonds declined, but these decreases are proportionally smaller than for TRACE-eligible bonds. Since bond returns tend to be highly correlated, some investors who might otherwise have traded non-TRACE bonds might choose to hold TRACE-eligible bonds instead.

To assess valuation effects associated with TRACE introduction, we focus on intercepts estimated from versions of equation (6) for various time horizons. As in any regression specification, intercepts estimate the mean of the dependent variable, conditional on zero realizations for the explanatory variables. Since the explanatory variables include changes in the buy-sell indicator variable, stock returns, and treasury security returns, intercepts estimate average changes in corporate bond prices conditional on no change in stock returns, treasury interest rates, or customer selling.

To test for valuation effects immediately surrounding TRACE introduction, Table 4 column 1 and 2 report results of a specification that includes an indicator variable that equals one for trades occurring on the first trading day after TRACE introduction, and equals zero otherwise, for the TRACE and non-TRACE eligible bonds. Since this specification also includes returns on maturity-matched treasury obligations, an intercept indicator can potentially detect valuation effects from sources other than broad interest rate changes. However, there is no significant valuation effect (point estimate = -5.3 basis points, p-value = 0.555) for TRACE-bonds, and a negative (point estimate = -51.7 basis points, p-value = 0.000) effect for non-TRACE bonds. The latter result is particularly surprising, though it is consistent with the notion that, on the first day after the rule change market participants may have transferred their demand to transparent bonds that are close substitutes to non-trace bonds.

The impact of trade transparency may not be immediate if market participants need time to become skilled in using the continuously disseminated transaction information and to ascertain the effect of transparency on liquidity. To address the possibility of valuation effects that do not emerge on the first day after transaction reporting commenced, column 3 and 4 reports results of specifications that include three intercept indicator variables set equal to one for transactions completed during the second, third, and fourth quarter of 2002. Coefficient estimates on these indicators measure the difference in average valuation changes during the indicated quarter relative to the first quarter of 2002.

For TRACE-eligible bonds, the point estimates in Quarter 3 and Quarter 4 are positive and statistically significant, suggesting that corporate bond prices increased on average, after controlling for changes in term structure, stock returns, and yield spreads, during the second half of 2002. Point estimates of 20.5 basis points in the third quarter and 31.9 basis points in the fourth quarter indicate valuation changes that are large enough to be very meaningful in an economic sense. For non-TRACE-eligible bonds, the results are similar, though statistically weaker and smaller in magnitude. Overall, these results provide limited support for the notion that improved liquidity due to TRACE transaction reporting has increased the valuation of corporate bonds. However, the change was not instantaneous. This may reflect gradual realization of the implications of TRACE for market liquidity.

5.5. Robustness Tests

The empirical results reported in the preceding sections establish that estimated trade execution costs for insurance company trades in corporate bonds decreased in the second half of 2002 as compared to the first half, both for bonds whose trades were disseminated through TRACE and for bonds whose trades were not disseminated through TRACE. We next report the results of a series of robustness tests.

5.5.1 Alternative Estimation Methods

Some studies, e.g. Chakravarty and Sarkar (2003) and Hong and Warga (2000) have estimated traded spreads by comparing the average dealer selling price to the average dealer purchase price when both purchases and sales are observed for the same bond within a reasonably short time interval (e.g. the same day). Methods that rely on matched dealer purchases and sales provide estimates of trading costs in those cases where trades can be paired, but require that many transactions be ignored when dealer purchases cannot be well-matched with comparable dealer sales. This shortcoming will be particularly pertinent for bonds that are not frequently traded. For robustness, we also report estimates of transactions costs obtained using this methodology.

First, we construct a sub-sample of trades consisting of buys and sells on the same bond on the same day. This reduces the TRACE (non-TRACE) sample from 39,040 (53,282) trades to 9,567 (9,543) trades. If there are more than one buy (sell) trade during a day, we take the simple average. This leaves 2,296 (2,572) matched pairs of buy and sell prices for the same bond on the same day.

For TRACE-eligible bonds the estimated percentage traded half-spread is 14.7 basis points pre-TRACE and 10.0 basis points post-TRACE. For the non-TRACE sample the estimated percentage half-spread is 14.1 basis points before TRACE and 9.2 basis points after TRACE implementation. Thus, this method also supports the conclusion that execution costs decreased post-TRACE. However, the estimated decline in traded spreads obtained by this method is not statistically significant, either for the TRACE (p-value = 0.230) or non-TRACE sample (p-value = 0.110). This lack of statistical significance mainly reflects the decreased sample size.

As an additional robustness test, we estimate the basic model (6) using a six month window centered on the introduction of Trace. Based on this shorter horizon, the estimated reductions in trading costs are 8.0 basis points (p-value < 0.000) for TRACE-eligible securities and 2.3 basis points (p-value = 0.167) for non-TRACE securities. The decreased statistical power inherent in the use of this short window precludes the ability to identify significant subsample results.

5.5.2. Controlling for Variation in the Economic Environment

We argue that the large decreases in estimated trading costs (50% for TRACE-eligible bonds and 20% for non-TRACE-eligible bonds) after TRACE introduction can be attributed to the improved ability to monitor and control trade execution costs in the more transparent environment. It remains possible, however, that some or all of the reduction in trade execution costs is attributable to changes in the economic environment other than the introduction of TRACE reporting.

To assess this possibility we expand expression (6) to include variables that could potentially affect bid-ask spreads in corporate bond markets. Suppose that the spread for trade t depends on variable Z according to:

$$S_t/2 = b_0 + b_1 \text{ Trace} + b_2 Z_t^*, \qquad (7)$$

where the * denotes that variable Z is expressed as deviations from its own time series mean. Substituting (7) into (6) gives an expanded indicator regression model:

$$\Delta P = a + wX + \gamma Q_{t-1} + b_0 \Delta Q + b_1 \text{ Trace}^* \Delta Q + b_2 Z_t^* \Delta Q + \acute{\eta}. \qquad (8)$$

In expression (8), the coefficient b_0 estimates trading costs pre-TRACE, the coefficient b_1 estimates the effect of TRACE reporting on trading costs conditional on a specific (i.e. the time series mean) outcome on the explanatory variable Z, while the coefficient b_2 estimates the effect of variable Z on the half-spread. Candidates for inclusion in Z should be variables that plausibly affect the costs of corporate bond market making. Numerous authors, beginning with Demsetz (1968), have argued that increased trading volume should reduce bid-ask spreads. We accordingly include a measure of trading activity. Given that many individual bonds trade infrequently and that returns across various bonds are likely to be highly correlated, we employ a simple market-wide measure of trading activity, the total number of trades contained in the sample over the prior five trading days. Other authors, at least since Ho and Stoll (1979), have emphasized that dealers will widen spreads if inventory risk increases. As noted, there was an increase in the average daily volatility in the post-TRACE period. To allow for this possible effects of interest rate risk, we obtain the one-day ahead conditional variance estimate from a GARCH(1,1) model applied to the time series of returns to the 10-year, on-the-run, Treasury note. Though based on a small sample (ten bonds traded on the NYSE Automated Bond System), the results reported by Kalimipalli and Warga (2002) support that that bid-ask spreads for corporate bonds are indeed dependent on volatility and trading volume.

Results of estimating expression (8) are reported in Table 5 column 1 and 2 for TRACE-eligible bonds and non-TRACE bonds, respectively. The results do not support the reasoning that interest rate volatility is a determinant of spreads for corporate bonds in the present sample, as the coefficient estimate on the product of ΔQ and the interest rate volatility measure is not significant (p-values range from 0.343 to 0.445) in either TRACE-eligible or ineligible bonds. The results do support the reasoning that bid-ask spreads for corporate bonds decrease with trading activity, as point estimates on the product of ΔQ and recent trading activity are negative and significant, particularly for TRACE bonds.

Most importantly, the results indicate that allowing for the possible effects of changes in trading volume and interest rate volatility on spreads does not alter the key conclusion that spreads decreased significantly after the introduction of TRACE. The estimated effect of TRACE reporting (b_1) for TRACE-eligible bonds is actually increased slightly in absolute magnitude to 8.4 basis points (compared to 6.4 basis points in Table 2). The corresponding estimate for non-TRACE bonds remains unchanged at 4.1 basis points and is still highly significant (p-value = 0.017). We conclude that changes in interest rate volatility and trading activity do not explain the reduction in corporate bond bid-ask spreads post-TRACE.

5.6 The Effect of Dealer Market Shares

We next examine whether the execution costs of corporate bond trades differ across large and small dealers, and whether the introduction of transaction reporting has altered the competitiveness of the bond market. The NAIC database contains the name of the specific dealer involved in a trade. Based on those trades completed before TRACE implementation, we classify the twelve largest dealers in the database as large dealers, and classify the remaining dealers as small dealers. However, dealer information is missing for some trades. Omitting trades that lack dealer information reduces the sample to 37,645 trades in TRACE-eligible bonds and to 50,854 trades for non-TRACE bonds.

We calculate a Herfindahl Index (HI) of dealer market share before and after trace. For each bond issue, dealer market share is computed as total dollar trading volume by dealer divided by the cumulative volume for the bond issue. Since we cannot ascertain market shares for individual dealers outside the top twelve we set market shares for these dealers to zero, although their trades are included in cumulative volume for the issue. The HI for the bond issue is the sum of squared market share for all dealers in the bond, calculated separately before and after Trace introduction for each bond.

For TRACE-eligible bonds, we estimate an average HI of 1673 pre-TRACE and 1270 post-TRACE (p-value of difference = 0.003), suggesting that increased transparency has reduced the market share of large dealers. For non-TRACE-eligible bonds, the HI is 3187 pre-TRACE, indicating greater concentration of trades at a few dealers, and declines to 2535 post-TRACE (p-value of difference = 0.001). The decline in concentration of trading is consistent with the reasoning that the market has become more competitive after TRACE introduction

Columns 3 and 4 of Table 5 report results of estimating a version of (8) that allows for differential trading costs when transacting with large dealers. Following Schulz (2001), we define an indicator variable that equals one for trades facilitated by one of the 12 large dealers and zero otherwise, and interact the indicator variable with trading cost measures before and after TRACE implementation. For TRACE-eligible bonds, the coefficient on the interaction term pre-TRACE is -0.057 (p-value = 0.009). This implies lower trading costs when transacting with large dealers, which is consistent with Schultz's (2001) finding. More importantly, this effect is diminished in the post-TRACE period, as the coefficient on the interaction term is -0.018 (-0.057 + 0.038), which is statistically insignificant (p-value = 0.242).

This result is consistent with the reasoning that the corporate bond market has become more competitive after TRACE introduction. Large dealers were able to charge lower trade execution costs before TRACE introduction, perhaps because of informational advantages inherent in observing a larger proportion of order flow. The advantage of observing order flow was reduced after TRACE introduction, as even dealers that do not participate in trades can observe prices.

For the non-TRACE eligible bonds, the coefficient of the interaction term pre-TRACE is -0.044 (p-value = 0.065), and is -0.104 (-0.044 - 0.060) post-TRACE (p-value = 0.000). These results indicate that for non-TRACE bonds, large dealers continue to charge less than small dealers even after the initiation of TRACE reporting, and that trading costs may decline further when transaction reporting is mandated for these bonds.

6. Conclusion

We estimate trade execution costs for a sample of institutional (insurance company) trades in corporate bonds before and after the initiation of public transaction reporting for a subset of bonds through the TRACE system in July 2002. The results indicate a remarkable 50% reduction in trade execution costs for bonds eligible for TRACE transaction reporting. In addition, trade execution costs for bonds not eligible for TRACE reporting decreased by about 20%, which likely reflects a liquidity externality by which better pricing information regarding a subset of bonds improves valuation and execution cost monitoring for all bonds. The cumulative dollar impact of these trading cost reductions are large – extrapolating beyond the present sample, a rough "back of the enveloped calculation" suggests annual trading cost reductions of $1.2 billion for the full corporate bond market.[14] This estimate is no-doubt imprecise, as it relies on simplifying assumptions, including that the experience of the insurance companies comprising the present sample is representative of the broader market. However, the magnitude of the estimate emphasizes the potential economic importance of designing market mechanisms optimally.

Cross-sectionally, larger trading cost reductions are estimated for less liquid and lower rated bonds, and for larger trades. The key result that trading costs declined once transaction reporting was initiated is robust to controls for other variables, in particular trading activity and interest rate volatility, which might plausibly explain variation in bond trading costs. We document increased valuations for corporate bonds after the introduction of TRACE, though these valuation effects did not occur instantaneously. Further, we document increases in the competitiveness of the corporate bond markets, in that large dealer's market shares were reduced and their cost advantage in TRACE-eligible bonds diminished.

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[14] The post trace sample contains $64.5 billion in trading in TRACE bonds and $83.9 billion in trading in non-TRACE bonds. We estimate trading cost reductions of 6.4 and 4.1 basis points for these samples, equating to $41.3 million and $34.4 million in trading cost reductions respectively, for the two samples, or a total of $75.7 million for our sample of insurance company trades during the second half of 2002. As noted in Section 4.2., insurance companies participated in 12.5% of the dollar volume for TRACE-eligible bonds during the second half of 2002. Assuming this proportion is representative, the annualized equivalent estimate for the full market is (75.7/.125)*2 = $1211 million.

In addition to providing empirical evidence relevant in assessing optimal market transparency, this paper contributes by introducing an econometric technique to estimate trading costs from datasets that contain information on whether trades are customer buys or sells, but do not contain intraday time stamps or quotation data. This technique may also prove useful in cases where the data contain time stamps, but there is reason to believe the times to be inaccurate.

Several extensions of this analysis appear warranted. If customers pay smaller trade execution costs then dealers' gross market making revenues must decline. It is of interest to know whether this revenue decrease reflects lower economic rents, or whether market making costs have declined. The latter is plausible, since dealer losses to informed traders may have been reduced. It would also be productive to assess how TRACE reporting and the associated reduction in trading costs has altered the behavior of investors, market makers, and issuing firms. For example, a reduction in the benefits to superior information could adversely affect incentives for traders to incur costs in order to become informed, which could in turn affect the informational efficiency of the bond markets. Or, improved liquidity in corporate bond markets may alter firms' optimal capital structures, as implied by the model of Chang and Yu (2004).

The results reported here are important because they verify that market design, and in particular decisions as to whether to make the market transparent to the public, have first-order effects on the costs that customers pay to complete trades. Further, since the sample employed here consists of institutional trades, these results indicate that public trade reporting is important not only to relatively unsophisticated small traders, but also to professional investors who make multimillion dollar transactions.

Appendix: Simulation Evidence on Potential Bias in Coefficients Estimated Without Time Stamps

To assess whether unbiased coefficient estimates can be obtained in datasets that do not contain reliable time stamps, we create simulated data where the underlying parameters are known, and then examine the coefficient estimates obtained from applying regression equation (6) while using various techniques with regard to time ordering of the data. The simulated data is created as follows. Bond value is set to an initial value of V_0 = \$1000, and then evolves according to (1). The trade indicator data series Q is created as a binomial random variable that takes the values 1 and -1 with equal probability. The observable and unobservable public information variables X and U are created as normal random variables with mean zero and standard deviation 5.0. Trade prices are specified as in (3). Each random variable is independent of the others. The parameters of the model are set to $w = 0.5$ (the weighting on observable public information), γ = \$1.00 (the price impact of trades) and S/2 = \$1.50 (the half spread). After a simulated data series is created, the parameters of regression specification (6) are estimated and saved. The entire simulation is repeated one thousand times, creating a distribution of parameter estimates.

Table A1 report the mean and standard deviation of the parameter estimates obtained from estimating versions of (6) in the simulated data, when the number of trades in any given simulation is varied from 250 to 100,000. For results reported in Panel A the true time ordering of the data is preserved, so that each change is calculated from the observation that actually preceded it. Expression (6) is the optimal specification for the time ordered data, so we focus primarily on the effect of omitting variables from the regression specification. For results reported in Panels B and C we divide the simulated data series into a large number of "days", and randomly reorder the observations within each day, while maintaining proper time ordering across days.[15] The number of trades per day averages three, but can be as low as one or, on rare occasions, over twenty. For results reported on Panel B we ignore the

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[15] A trading day is ended when a "count" variable that is set to one at the beginning of the day and that either increments by one after each trade or remains unchanged with equal probability, reaches a total of three.

fact that trades are not properly time ordered, and simply compute each change as the difference between the observation and that immediately preceding it in the dataset.

Several results reported on Panel A of Table A1 are worth noting. First, as expected the estimation of specification (6) in correctly ordered data provides unbiased coefficient estimates that quickly converge toward the underlying parameters ($w = .50$, $\gamma = 1.00$, and $S/2 = 1.50$) as the simulated sample size increases. Second, omitting the public information variable X from the regression does not bias coefficient estimates, which still converge to the underlying parameters, but does increase the standard deviation of the estimates. For example, with $N = 1000$ simulated trades the effect of omitting the public information variable X is to increase the standard deviation of the half spread estimate by 44%. As might be expected this effect is greater if the simulation is repeated with a larger standard deviation of the simulated public information variable. Third, omitting the lagged traded indicator variable from the regression leads to bias in the estimate of the half-spread, unless the true value of γ is zero.[16] Even with 100,000 simulated observations the average half spread estimate obtained from the improper specification that omits lagged Q is 1.000, which differs from the true half spread of 1.500 by more than sixty standard deviations.

Two methodological conclusions are supported by the simulation results reported on Panel A. First, it is desirable to include measures of changes in public information when using an indicator variable regression to estimates spreads, in any situation where changes in the public information set between trades are large relative to spreads. This is likely to be particularly true for bonds and other assets that are traded infrequently. Second, it is important to include the lagged trade indicator in the specification, unless there is strong reason to believe that the associated parameter, γ, is zero.

Results reported on Panel B of Table A1 indicate that simply computing changes from the prior observation in data that is not properly time ordered will lead to biased and inconsistent coefficient estimates. Even with $N = 100{,}000$ simulated trades for each round of the simulation, the mean estimates

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[16] This result can be interpreted simply as the effect of omitting a correlated variable. Since Q can take only two values, its changes are highly negatively correlated with its prior level. Omitting lagged Q biases the coefficient estimate on the change in Q, unless the true parameter on lagged Q is zero.

of the half spread and the price impact of the prior trade are 1.165 and 0.329, respectively, which differ from the true parameter values of 1.50 and 1.00 by 26 and 48 standard deviations, respectively.

Panel C of Table A1 investigates the properties of an alternate estimation strategy that allows for improper time ordering within a day, while still taking advantage of knowing transaction dates. For each observation, changes are computed as the current observation minus the last observation contained in the dataset (which may or may not be chronologically last) the prior trading day. Also for Panel C we redefine the public information variable X as the change in the accumulated change since the last observation on a prior trading day. This approach creates overlapping dependent variables, since changes for all trades in a given day are computed relative to the same prior day reference trade.

The most important result to emerge from this simulation exercise is that the estimation procedure used for the results reported in Panel C of Table A1 leads to unbiased coefficient estimates. The average parameter estimates are always close to the true parameter values, and the standard deviation of the estimates decreases rapidly as the number of simulated trades increases. This estimation technique may also prove useful in other cases where datasets do not contain time stamps, or where time stamps may not be fully reliable.[17]

However, as would be expected given that some information is lost due to the lack of proper time ordering, the standard deviation of the estimates are generally two to four times larger than the standard deviations of the estimates obtained in correctly ordered data as reported on Panel A. The lack of time ordering in the data can therefore be expected to reduce statistical power.

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[17] For example, Schultz (2000) reports that trade report times for Nasdaq stocks in the “Trade and Quote” database were inaccurate during portions of 1996 and 1997.

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Table 1: Bond Descriptive Information

This table provides descriptive information regarding the three samples used in the paper; TRACE-eligible bonds, non-TRACE bonds, and TRACE and non-TRACE bonds. Panel A provides information about the bonds in the sample and Panel B provides information regarding trading volume characteristics.

Panel A: Descriptive bond information

	TRACE Bonds	Non TRACE Bonds	TRACE & Non-TRACE Bonds
Total number of bond issues	439	3122	3561
Average Time to Maturity (in years)	8.16	10.22	9.986
Average Issue Size (in $M)	1,447	336	462
Issue Size:			
Large (greater than $500 MM)	423	578	1002
Small (less than $500 MM)	16	2544	2560
Credit Quality			
Investment Grade (BBB- thru AAA)	389	1981	2370
Non-Investment Grade (below BBB-)	50	1141	1191

Panel B: Transaction price, transaction volume and transaction frequency

	TRACE Bonds		Non TRACE Bonds		TRACE & Non-TRACE Bonds	
	Pre-TRACE	Post-TRACE	Pre-TRACE	Post-TRACE	Pre-TRACE	Post-TRACE
Average trade price (% of par value)	99.90	101.87	98.66	102.29	99.19	102.11
Average number of trades by Issue	46	50	11	13	17	19
Trade Size:						
Average trade size (in $MM)	2.98	3.09	2.48	2.93	2.69	2.99
Median trade size (in $MM)	0.81	0.78	0.88	1.00	0.85	0.96
Total number of trades	18,180	20,860	24,528	28,754	42,708	49,614
Cumulative trading volume (in $MM)	54,091	64,522	60,812	83,984	114,885	148,346

Table 2: Spreads on TRACE Bonds

In this table, we examine the half-spread on TRACE eligible corporate bonds during 2002, pre- and post- the TRACE implementation date of July 1. We estimate pooled time series regression models with the following form,

$$\Delta P = a + wX + \gamma Q_{t-1} + (S/2)\Delta Q + \acute{\eta},$$

In the regression, we include two public information variables, each measured from the date of the most recent transaction on a prior day to the date of the current transaction. The first is the change in the interest rate for an on-the-run Treasury security matched to the corporate bond based on maturity. The second is the percentage return on the issuing firm's common stock. In column 1 and 2, we examine the half-spread for TRACE eligible bonds in 2002. To assess the impact of TRACE reporting, we examine results for the Pre- (column 3) and Post- (column 4) TRACE periods. Then we estimate the model for the 2002 and simply interact the ΔQ_{it} variable with an indicator variable that equals one for trades occurring after July 1, 2002 and zero for trades before (column 5). Statistical significance represents bootstrapped probability estimates.

Panel A: Aggregate Half-Spread

Column #	Pre & Post TRACE (1)	Pre & Post TRACE (2)	Pre- TRACE (3)	Post- TRACE (4)	Pre & Post TRACE (5)
Intercept	0.0198	0.0192	-0.1313^{***}	0.1658^{***}	0.0192
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Treasury Return	0.2438^{***}	0.2438^{***}	0.1782^{***}	0.2818^{***}	0.2431^{***}
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Investment	0.0462^{***}	0.0462^{***}	0.0730^{***}	0.0331^{***}	0.0463^{***}
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Noninvestment	0.0818^{***}	0.0818^{***}	0.0944^{***}	0.0649^{***}	0.0817^{***}
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ΔBaaTrsy × Investment	-0.0009	-0.0009^{***}	0.0033^{**}	-0.0149^{***}	-0.0008
(probability)	(0.121)	(0.000)	(0.018)	(0.000)	(0.121)
ΔBaaTrsy × Noninvestment	-0.0456^{***}	-0.0454^{***}	-0.0199^{***}	-0.0563^{***}	-0.0457^{***}
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ	0.0966^{***}	0.0964^{***}	0.1371^{***}	0.0674^{***}	0.1307^{***}
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ_{t-1}	0.0003				
(probability)	(0.985)				
DeltaQ × Trace					-0.0638^{***}
(probability)					(0.003)
Adj. R^2	3.56%	3.56%	8.59%	2.25%	3.59%
N	39,040	39,040	18,180	20,860	39,040

$^{***,\ **,\ *}$ denote statistical significance at the 99%, 95% and 90% level respectively.

Table 2: Spreads on TRACE Bonds

Panel A: Aggregate Half-Spread

In this table, we examine the half-spread on TRACE eligible corporate bonds during 2002, pre- and post- the TRACE implementation date of July 1. We estimate pooled time series regression models with the following form,

$$\Delta P = a + w\Delta X + \gamma Q_{t-1} + (S/2)\Delta Q + \dot{\eta},$$

In the regression, we include three public information variables, each measured from the date of the most recent transaction on a prior day to the date of the current transaction. The first is the change in the interest rate for an on-the-run Treasury security matched to the corporate bond based on maturity. The second is the percentage return on the issuing firm's common stock. The third is change in the spread between long-term indexes of Baa rated bonds and US Treasury securities. We then interact these factors with investment and noninvestment grade indicator variables to account for potential differences in sensitivity based on the bond's risk. In column 1 and 2, we examine the half-spread for TRACE eligible bonds in 2002. To assess the impact of TRACE reporting, we examine results for the Pre- (column 3) and Post- (column 4) TRACE periods. Then we estimate the model for the 2002 and simply interact the ΔQ_{it} variable with an indicator variable that equals one for trades occurring after July 1, 2002 and zero for trades before (column 5). Statistical significance represents bootstrapped probability estimates.

Column #	Pre & Post TRACE (1)	Pre & Post TRACE (2)	Pre- TRACE (3)	Post- TRACE (4)	Pre & Post TRACE (5)
Intercept	0.0198	0.0192	-0.1313***	0.1658***	0.0192
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Treasury Return	0.2438***	0.2438***	0.1782***	0.2818***	0.2431***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Investment	0.0462***	0.0462***	0.0730***	0.0331***	0.0463***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Noninvestment	0.0818***	0.0818***	0.0944***	0.0649***	0.0817***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ΔBaaTrsy × Investment	-0.0009	-0.0009***	0.0033**	-0.0149***	-0.0008
(probability)	(0.121)	(0.111)	(0.018)	(0.000)	(0.121)
ΔBaaTrsy × Noninvestment	-0.0456***	-0.0454***	-0.0199***	-0.0563***	-0.0457***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ	0.0966***	0.0964***	0.1371***	0.0674***	0.1307***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ$_{t-1}$	0.0003				
(probability)	(0.985)				
DeltaQ × Trace					-0.0638***
(probability)					(0.003)
Adj. R^2	3.56%	3.56%	8.59%	2.25%	3.59%
N	39,040	39,040	18,180	20,860	39,040

$^{***, **, *}$ denote statistical significance at the 99%, 95% and 90% level respectively.

Table 2, Continued: Spreads on TRACE Bonds

Panel B: Half Spreads by Size of Trade, Volume, and Credit Rating

In this panel, we examine the impact of TRACE on TRACE eligible bonds' half-spread based on trade size (trades over and under \$1MM [column 1] and by if the trade is above or below the median trade in that bond [column 2]), volume in column 3 (bonds are segmented into terciles based on volume), and credit rating in column 4 and 5 (if the firm is investment [BBB- and above] or non-investment [below BBB-] grade). Statistical significance represents bootstrapped probability estimates.

	Trade Size		By Volume	By Credit Rating	
	Large (≥1MM)/ Small (< 1MM)	Large (>50%) /Small (≤50%)	High(>50%) /Low (≤50%)	Investment (min. BBB-)	Non-Investment
Column #	(1)	(2)	(3)	(4)	(5)
Intercept	0.0179***	0.0190***	0.0192***	0.0094***	0.1760**
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.028)
Treasury Return	0.2427***	0.2424***	0.2439***	0.2424***	0.2463***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)
Stock Return × Investment	0.0464***	0.0464***	0.0463***	0.0462***	
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	
Stock Return × Noninvestment	0.0817***	0.0817***	0.0818***		0.0816***
(probability)	(0.000)	(0.000)	(0.000)		(0.000)
ΔBaaTrsy × Investment	-0.0006	-0.0007	-0.0010	-0.0006	
(probability)	(0.145)	(0.132)	(0.110)	(0.121)	
ΔBaaTrsy × Noninvestment	-0.0455***	-0.0446***	-0.0451***		-0.0489***
(probability)	(0.000)	(0.000)	(0.000)		(0.000)
DeltaQ				0.1263***	0.1912
(probability)				(0.000)	(0.209)
DeltaQ×TRACE				-0.0501**	-0.3075***
(probability)				(0.027)	(0.001)
Small Trade×DeltaQ	0.1455***	0.1175***			
(probability)	(0.000)	(0.000)			
Small Trade×DeltaQ×TRACE	-0.0300	-0.0230			
(probability)	(0.302)	(0.396)			
Large Trade×DeltaQ	0.1126***	0.1439***			
(probability)	(0.000)	(0.000)			
Large Trade×DeltaQ×TRACE	-0.1044***	-0.1051***			
(probability)	(0.000)	(0.000)			
Low Volume×DeltaQ			0.3205***		
(probability)			(0.000)		
Low Vol.×DeltaQ×TRACE			-0.1145**		
(probability)			(0.022)		
Mid Volume×DeltaQ			0.1219***		
(probability)			(0.000)		
Mid Volume×DeltaQ×TRACE			-0.0505		
(probability)			(0.189)		
High Volume×DeltaQ			0.1073***		
(probability)			(0.000)		
High Vol.×DeltaQ×TRACE			-0.0553**		
(probability)			(0.050)		
Adjusted R^2	3.64%	3.61%	3.66%	2.72%	10.55%
N	39,040	39,040	39,040	36,876	2,164

***, **, * denote statistical significance at the 99%, 95% and 90% level respectively.

Table 3: Spreads on Non-TRACE Bonds

Panel A: Aggregate Half-Spread

In this table, we examine the half-spread on non-TRACE eligible corporate bonds for 2002 and also pre- and post-TRACE as explained in the Table 3 heading. In column 1, we examine the half-spread for non-TRACE eligible bonds in 2002. Then to assess the impact of TRACE reporting, we examine results for the Pre- (column 2) and Post- (column 3) TRACE periods for non-TRACE bonds. Then we estimate the model for the 2002 and interact the ΔQ_{it} variable with an indicator variable that equals one for trades occurring after July 1, 2002 and zero for trades before (column 4). Statistical significance represents bootstrapped probability estimates.

Column #	Pre & Post TRACE (1)	Pre- TRACE (2)	Post- TRACE (3)	Pre & Post TRACE (4)
Intercept	-0.0201***	-0.0585***	-0.0011***	-0.0199***
(probability)	(0.151)	(0.003)	(0.000)	(0.150)
Treasury Return	0.4759***	0.4261***	0.4820***	0.4757***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Investment	0.0521***	0.0717***	0.0395***	0.0521***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Noninvestment	0.0567***	0.0533***	0.0606***	0.0568***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
ΔBaaTrsy × Investment	-0.0003	0.0867***	-0.0008***	-0.0003
(probability)	(0.370)	(0.000)	(0.000)	(0.387)
ΔBaaTrsy × Noninvestment	-0.0371***	-0.0401***	-0.0345***	-0.0371***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ	0.1800***	0.2050***	0.1634***	0.2022***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ × Trace				-0.0406***
(probability)				(0.002)
Adjusted R^2	10.78%	11.64%	10.59%	10.79%
N	53,282	24,528	28,754	53,282

***, **, * denote statistical significance at the 99%, 95% and 90% level respectively.

Table 3, Continued: Spreads on Non-TRACE Bonds

Panel B: Half-Spreads by Size of Trade and by Firm Trade Volume

In this panel, we examine the impact of TRACE on non-TRACE bonds' half-spread based on trade size (trades over and under \$1MM [column 1] and by if the trade is above or below the median trade in that bond [column 2]) and volume in column 3 (bonds are segmented into terciles based on volume). Statistical significance represents bootstrapped probability estimates.

	By Trade Size		By Volume
	Large (≥1MM) /Small (< 1MM)	Large (>50%) /Small (≤50%)	High(>50%) /Low (≤50%)
Column #	(1)	(2)	(3)
Intercept	-0.0195	-0.0197	-0.0193
(probability)	(0.137)	(0.140)	(0.147)
Treasury Return	0.4756***	0.4757***	0.4762***
(probability)	(0.000)	(0.000)	(0.000)
Stock Return × Investment	0.0521***	0.0521***	0.0521***
(probability)	(0.000)	(0.000)	(0.000)
Stock Return × Noninvestment	0.0567***	0.0567***	0.0567***
(probability)	(0.000)	(0.000)	(0.000)
ΔBaaTrsy × Investment	-0.0003	-0.0003	-0.0002
(probability)	(0.372)	(0.380)	(0.389)
ΔBaaTrsy × Noninvestment	-0.0371***	-0.0372***	-0.0372***
(probability)	(0.000)	(0.000)	(0.000)
Small Trade×DeltaQ	0.2132***	0.2120***	
(probability)	(0.000)	(0.000)	
Small Trade×DeltaQ×TRACE	-0.0183	-0.0299**	
(probability)	(0.142)	(0.049)	
Large Trade×DeltaQ	0.1892***	0.1908***	
(probability)	(0.000)	(0.000)	
Large Trade×DeltaQ×TRACE	-0.0617***	-0.0516***	
(probability)	(0.000)	(0.001)	
Low Volume×*DeltaQ			0.3130***
(probability)			(0.000)
Low Volume×DeltaQ×TRACE			-0.0716
(probability)			(0.103)
Mid Volume×DeltaQ			0.2962***
(probability)			(0.000)
Mid Volume×DeltaQ×TRACE			-0.0614*
(probability)			(0.075)
High Volume×DeltaQ			0.1677***
(probability)			(0.000)
High Vol.×DeltaQ×TRACE			-0.0268**
(probability)			(0.041)
Adjusted R^2	10.80%	10.79%	10.85%
N	53,282	53,282	53,282

***, **, * denote statistical significance at the 99%, 95% and 90% level respectively.

Table 3, Continued: Spreads on Non-TRACE Bonds

Panel C: Half-Spreads by Credit Rating, Issue Size and Industry

In this panel, we examine the impact of TRACE on non-TRACE bonds' half-spread based on credit rating in columns 1 and 2 (if the firm is investment [BBB- and above] or non-investment [below BBB-] grade), the size of the bond issue in columns 3 and 4, if the bond is issued by a firm with TRACE eligible bonds in column 5, and if the bond is in the same industry as a TRACE eligible bond in column 6. Statistical significance represents bootstrapped probability estimates.

Column #	Investment (1)	Non-Investment (2)	Bond Issues <500 MM (3)	Bond Issues ≥500 MM (4)	TRACE Firm/Non-TRACE Bonds (5)	Bonds Same Industry as TRACE bonds (6)
Intercept	-0.0328	0.0123***	0.0769***	-0.1574***	-0.1493***	0.0069
(probability)	(0.292)	(0.004)	(0.000)	(0.000)	(0.000)	(0.156)
Treasury Return	0.6111***	0.1392***	0.4564***	0.5243***	0.5359***	0.4782***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Investment	0.0557***		0.0420***	0.0636***	0.0547***	0.0554***
(probability)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Noninvestment		0.0517***	0.0490***	0.0902***	0.0732***	0.0617***
(probability)		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ΔBaaTrsy × Investment	-0.0069***		-0.0009	-0.0002	-0.0007	-0.0013
(probability)	(0.000)		(0.363)	(0.146)	(0.485)	(0.975)
ΔBaaTrsy × Noninvestment		-0.0191***	-0.0397***	-0.0255***	-0.0166***	-0.0383***
(probability)		(0.000)	(0.000)	(0.000)	(0.008)	(0.000)
DeltaQ	0.1969***	0.2075***	0.2031***	0.2031***	0.1602***	0.2364***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ×TRACE	-0.0173	-0.0807***	-0.0194*	-0.0737***	0.0248	-0.0556***
(probability)	(0.209)	(0.000)	(0.076)	(0.004)	(0.312)	(0.003)
Adjusted R^2	14.96%	7.77%	10.88%	11.45%	11.56%	11.71%
N	35,768	17,514	32,031	21,251	13,229	27,795

***, **, * denote statistical significance at the 99%, 95% and 90% level respectively.

Table 4. Valuation Effects

In this table, we examine the impact of Trace on the valuation of bonds and jointly examine the timing of any valuation impact. To do this, we include an indicator variable which reflects the first trade which spans the pre- and post-Trace periods for Trace and non-Trace eligible bonds in columns 1 and 2 respectively. Next, we jointly test for valuation effects as well as the timing of these effects using quarterly indicator variables for the Trace and non-Trace eligible bonds in columns 3 and 4 respectively. Statistical significance represents bootstrapped probability estimates.

	First Trade Analysis		Quarterly Analysis	
	Trace Bonds	NonTrace Bonds	Trace Bonds	NonTrace Bonds
Column #	(1)	(2)	(3)	(4)
Intercept	0.0181***	-0.0241***	-0.1140***	-0.1327***
(probability)	(0.118)	(0.023)	(0.000)	(0.000)
Treasury Return	0.2319***	0.4181***	0.2447***	0.3894***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Investment	0.0495***	0.0446***	0.0488***	0.0466***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Noninvestment	0.0565***	0.0655***	0.0555***	0.0664***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ	0.1305***	0.2017***	0.1319***	0.2015***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ×Trace	-0.0610***	-0.0410***	-0.0626***	-0.0433***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
First Trade	-0.0529	-0.5175**		
(probability)	(0.555)	(0.000)		
Quarter 2 (Indicator)			-0.0526	0.1365***
(probability)			(0.127)	(0.000)
Quarter 3 (Indicator)			0.2050***	0.0268
(probability)			(0.000)	(0.413)
Quarter 4 (Indicator)			0.3190***	0.1511***
(probability)			(0.000)	(0.000)
Adjusted R^2	3.74%	10.97%	3.74%	10.84%
N	39,708	57,024	39,708	57,024

$^{***, **, *}$ denote statistical significance at the 99%, 95% and 90% level respectively.

Table 5. Robustness and Dealer Analysis

In this table, we include additional control variables and analyze the impact of TRACE by dealer size. In column 1 and 2, we include measures that could be influencing the spread on corporate bonds, volatility of the bond market and prior trading volume. Volatility is estimated as the conditional heteroskedasticity predicted by estimating a $\text{GARCH}_{(1,1)}$ model of the return on the 10 year on-the-run Treasury note. Trading volume is measured as the summation of the prior five day trading volume (number of trades). These variables are then interacted with the spread measure (DeltaQ). In column 3 and 4, we examine if the impact of TRACE differed based on the size of the dealer completing the transaction. To do this, we first segment trades into trades facilitated by large dealers (12 large dealers are identified) or small dealers and create an indicator variable. We then interact this variable with DeltaQ and DeltaQ × TRACE to provide estimates for the differential of trading costs between large and small dealers pre- and post-TRACE. Statistical significance represents bootstrapped probability estimates.

	Economic Controls		Dealer Analysis	
	Trace Bonds	NonTrace Bonds	Trace Bonds	NonTrace Bonds
Column #	(1)	(2)	(3)	(4)
Intercept	0.0309***	-0.0203	0.0077***	-0.0220
(probability)	(0.000)	(0.155)	(0.001)	(0.317)
Treasury Return	0.2449***	0.4757***	0.2408***	0.4688***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Investment	0.0448***	0.0522***	0.0456***	0.0521***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
Stock Return × Noninvestment	0.0819***	0.0566***	0.0810***	0.0566***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
ΔBaaTrsy × Investment	-0.0002*	-0.0002	-0.0000	-0.0003
(probability)	(0.062)	(0.396)	(0.270)	(0.304)
ΔBaaTrsy × Noninvestment	-0.0455***	-0.0372***	-0.0470***	-0.0375***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ	0.1621***	0.1894***	0.1639***	0.2302***
(probability)	(0.000)	(0.000)	(0.000)	(0.000)
DeltaQ × Large Dealer			-0.0568***	-0.0441**
(probability)			(0.009)	(0.012)
DeltaQ × Trace	-0.0835***	-0.0412**	-0.0903***	-0.0172***
(probability)	(0.007)	(0.017)	(0.001)	(0.248)
DeltaQ × Trace × Large Dealer			0.0379	-0.0599**
(probability)			(0.122)	(0.016)
DeltaQ × $\text{TRSYGARCH}_{(1,1)}$	0.0811	0.0383		
(probability)	(0.408)	(0.466)		
DeltaQ × Trading Volume	-0.0034**	-0.0022***		
(probability)	(0.017)	(0.000)		
Adjusted R^2	4.84%	10.88%	3.53%	10.61%
N	39,040	53,282	37,645	50,810

***, **, * denote statistical significance at the 99%, 95% and 90% level respectively.

Table A1. Regression Estimates Obtained in Simulated Data

The simulated data is created as $V_t = V_{t-1} + \gamma Q_{t-1} + \varepsilon_t$ and $P_t = V_t + (S/2)Q_t$, where $\varepsilon_t = wX_t + (1-w)U_t$. The simulation is initiated with $V_0 = \$1000$. Q_t is a random variable that takes the values 1 and -1 with equal probability. X_t and μ_t are independent normal random variables with mean 0 and standard deviation 5.0. The key parameters are S/2 = \$1.50, γ = \$1.00, and w = .50. The regression specification is:

$$\Delta P = a + wV + \gamma Q_{t-1} + (S/2)\Delta Q + \acute{\eta},$$

where Δ denotes change from a prior or reference observation. The simulation is repeated 1000 times. Coefficient and SD denote the mean and standard deviation of the 1000 coefficient estimates. Estimated intercepts are not reported. For results reported on Panel A the data are correctly ordered, but variables are omitted from the first two set of results. For results reported on Panel B the data are randomly ordered within a "day" and changes are computed with respect to the prior observation. For results reported on Panel C data are randomly ordered within a "day", but changes are computed with respect to the last trade on the prior "day".

Number Trades each Simulation	N = 250			N = 1000			N = 10,000			N = 100,000	
	Coefficient	SD		Coefficient	SD		Coefficient	SD		Coefficient	SD
Panel A: Estimation in Correctly Ordered Data											
W	0.500	0.031		0.500	0.016		0.500	0.005		0.500	0.002
γ	1.004	0.228		1.004	0.110		1.001	0.035		1.000	0.011
S/2	1.501	0.156		1.502	0.077		1.500	0.025		1.500	0.008
γ	0.999	0.324		1.001	0.160		1.000	0.049		1.000	0.016
S/2	1.499	0.224		1.499	0.111		1.500	0.036		1.500	0.011
S/2	0.999	0.159		0.999	0.078		0.999	0.025		1.000	0.008
Panel B: Estimation in Data Randomly Ordered Within Each "Day"											
W	0.499	0.074		0.500	0.037		0.500	0.011		0.500	0.004
γ	0.374	0.302		0.324	0.152		0.320	0.049		0.329	0.014
S/2	1.186	0.274		1.162	0.126		1.159	0.042		1.165	0.013
Panel C: Estimation in Data Where Changes are Computed Based on Prior Day Reference Trade											
W	0.498	0.085		0.499	0.045		0.500	0.015		0.500	0.005
γ	0.982	0.831		1.001	0.416		0.995	0.137		1.001	0.039
S/2	1.463	0.312		1.493	0.164		1.495	0.053		1.500	0.016