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Financial Intermediation and the Costs of Trading in an Opaque Market*

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Abstract

Municipal bonds trade in opaque, decentralized broker-dealer markets in which price information is costly to gather. Whether dealers in such a market operate competitively is an empirical issue, but a difficult one to study. Data in such markets is generally not centrally recorded. We analyze a comprehensive database of all trades between broker-dealers in municipal bonds and their customers. The data is only released to the public with a substantial lag, and thus the market was relatively opaque to the traders themselves during our sample period. We find that dealers earn lower average markups on larger trades, even though larger trades lead the dealers to bear more risk of losses. We formulate and estimate a simple structural bargaining model that allows us to estimate measures of dealer bargaining power and relate it to characteristics of the trades. The results suggest dealers exercise substantial market power. Our measures of market power decrease in trade size and increase in variables that indicate the complexity of the trade for the dealer.

Keywords: Municipal Bonds, Fixed Income Dealer, Transaction Costs, Liquidity, Transparency, Market Power.

JEL Classification: D40, G14, G24, G28.

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1 Introduction

There is a long-standing debate among regulators, researchers, and practitioners about the costs and benefits of centralization and transparency in financial markets. Fragmentation and lack of transparency may create opportunities for intermediaries to develop and exploit local monopoly power. Centralization may avoid such monopoly power locally, but it may also stifle innovation and entrench intermediaries.

A significant difficulty in resolving these questions is that, almost by construction, it is difficult to obtain transactions-based data in markets that are fragmented and opaque. Most empirical studies of the costs of trading have been in settings where trading is relatively centralized and price information is readily available to buyers and sellers.

We analyze a database that allows us to observe the trading of broker-dealer intermediaries in the municipal bond market. We develop a simple theoretical model that decomposes dealer gains on a trade into the cost of facilitating the trade, a zero-mean forecast error, and a measure of the dealer's bargaining advantage or market power. Our estimates of the model produce measures of dealer market power and show how it varies with the type of trade. Our analysis thus contributes to a better understanding of the consequences of fragmentation and transparency by measuring the risks and rewards earned by intermediaries in an opaque and fragmented market of the sort that has so far been the most difficult to study.

The market for municipal bonds in the U.S. is a large and important financial market by any measure. Aggregate municipal bond holdings currently amount to roughly \$1.75 trillion.[1] New issues in recent years have averaged close to \$300 billion per year. Along with its size, the municipal market is also remarkable for its fragmentary nature and lack of transparency. These characteristics are attributable to several factors.

First, there are many relatively small issuers of municipal bonds. In recent years there have been between ten and fifteen thousand separate municipal bond issues per year. In 2001 the average issue size was \$21 million.[2] Municipal bonds are typically issued in series and each issue in turn is likely to consist of 10-30 separate bonds with different maturities. Second, since municipals are tax-exempt, they are in large measure held by individual retail investors (35% in 2001), insurance companies (10%), or in bank and personal trusts (6.5%). Municipal bonds are therefore unlikely to trade frequently.

Third, municipals are traded in decentralized broker-dealer markets. There is no centralized exchange, and to obtain quotes a buyer or seller must call multiple dealers or solicit bids from them. The lack of a centralized exchange makes comparison shopping relatively costly. Fourth, many states only exempt their own municipalities' bonds from state income tax, further contributing to local segmentation. Finally, for political reasons, or because of local cost advantages, smaller regional firms underwrite many municipal issues. The lack of a large intermediary with access to many different bonds may further increase the costs of efficiently matching buyers and sellers.

The size of spreads in the municipal market has attracted the attention of regulators, the press, and the in-

[1] The source of these aggregate statistics on the municipal market is The Bond Market Association (http://www.bondmarkets.com).

[2] Data on the number of underwritings is available at http://www.financialservicesfacts.org.

vesting public in the last few years. Many argue that the spreads are unreasonably high. A popular web site (www.MunicipalBonds.com) lists the "Worst Ten Spreads" for trades in various categories, along with "Red Flags" and "Worst Spread Reports" based on Municipal Securities Rulemaking Board (MSRB) reports. MSRB rules require that trades with customers should only be executed at prices that are "fair and reasonable, taking into consideration all relevant factors." Both NASD and the SEC have examined specific cases and complaints concerning municipal bond trades. The difficulty for researchers and policy makers lies in identifying "all relevant factors" and quantifying when variation attributable to those factors is "fair and reasonable."

The SEC ruled that markups on trades ranging from 1.42% to 5% "substantially exceeded accepted industry practice," while NASD stated that transactions with spreads between 7% and 27% were not "fair and reasonable."[3] Such blanket rules, because they ignore the variation in costs of financial intermediation, will necessarily be conservative and identify only extreme cases. Our structural model allows us to disentangle competitive compensation for the costs of intermediating trades from the exercise of market power.

Our sample was gathered by the Municipal Securities Rulemaking Board (MSRB) as a first step in their efforts to move municipal bond trading towards a more transparent system. The sample records every transaction in municipal bonds by registered broker-dealers between May 1, 2000 and January 10, 2004. The sample contains a large number of transactions—over 26 million trades—covering a longer time than in a typical microstructure, transactions-based sample.

These data are only made public after a time lag. Initially the lag was one day for bonds that traded more than four times during the day, and one month for all other trades. Over the sample period the time lag has been shortened, and the scope of the daily reports have been increased in several steps. The change in the time lags provides a natural experiment in the consequences of increased transparency.

The sample does not identify the specific broker-dealer associated with a given trade, but does record whether the transaction was between dealers, or between a dealer and a customer. We can measure the markups implicit in transaction prices between dealers, in aggregate, and their customers, and study the determinants of the markups, such as the price concessions to quantity.

Since we cannot directly link individual trades to specific dealers, we must infer their trades and profits indirectly. For example, we study pairs of trades that appear to be direct exchanges of bonds through a dealer: the same par value of the same bond is purchased from a customer and then sold to a customer in a very short time. Alternatively, we consider more generous filters, such as purchases by a dealer followed by a sequence of sales to customers or interdealer trades that return dealer inventories to their original level. Because the individual bonds trade infrequently, we can be reasonably confident that these trades are associated with the same original block of bonds.

Empirical methods alone are of limited use in identifying that portion of dealer profits due to market power. We therefore develop a simple theoretical model of the interaction between dealers and their customers in which the expected profits to the dealer reflect both the dealer's costs and his bargaining power relative to the customer. Both

[3] See "Regulators Know What Bond Dealers Did Last Summer," by Joe Mysak, *Bloomberg News Service*, September 3, 2003, "Munis: What's a Fair Price?" by Dean Foust, *Business Week*, July 7, 2003, and SEC "Opinion of the Commission," Admin. Proc. File No. 3-9499.

of these, in turn, can be parameterized as functions of observable variables, and estimated as a Stochastic Frontier Model. The dealer's cost is the stochastic frontier, which represents the expected markup the customer would obtain if dealers were always driven to their reservation values, as they would be if the provision of dealer services were perfectly competitive. The observed markup differs from dealer costs by a zero-mean forecast error and a one-sided error. The one-sided error reflects the distribution of sellers' reservation values and dealer bargaining power.

Our empirical results suggest dealer costs depend on liquidity measures for the bond and market, the size of the trade, interest rate conditions, and how the trade is processed. The portion of average profits attributed by the estimates to the dealers' advantage in bargaining power is substantially higher than the portion attributed to the actual cost of intermediating the trades. The dealers' market power is highest for small to medium sized transactions. Such transactions are presumably with less sophisticated retail investors: a finding consistent with the theoretical arguments in Duffie, Gârleanu and Pedersen (2004) that less sophisticated investors face higher markups in a bargaining market. The market power of dealers as a group is also higher in situations where more extensive intermediation is required, such as when the trade moves through other dealers, spends more time in inventory, or is broken up into smaller blocks.

The lack of centralized recording and preservation of price information has limited the study of trading costs in bond markets. Exceptions are studies by Hong and Warga (2000), Schultz (2001), and Chakravarty and Sarkar (1999). These authors all study a sample of trades executed on behalf of large insurance companies. Their data identify the institutions and dealers participating in the trade, and whether it was a buy or a sell. The authors use various techniques to estimate the bid-ask spread implicit in the observed trades, and then relate the measured trading costs to characteristics of the bonds and the current market conditions. Of these studies, only Chakravarty and Sarkar (1999) include municipal bonds in their analysis.

Our sample differs from that used in the previous studies in several respects. First, it is comprehensive. It includes all trades by registered broker-dealers in municipal securities, rather than those trades initiated by a subset of institutional investors. We have data on over 26 million transactions in over one million bonds issued by over 46 thousand entities. Our data do not identify dealers or buyers specifically. They only tell us whether a trade was a buy from a customer, a sell to a customer, or a trade between dealers. Thus, we can measure the aggregate flow of bonds to and from the dealers as a group, and the turnover of bonds within that group, but we cannot relate trading costs to the individual characteristics of the buyer or seller. The information in our data about the characteristics of the bonds is limited, and given the huge number of different bonds we have been unable to gather additional data on specific attributes of the bonds for the whole sample.

The paper closest to our work is Harris and Piwowar (2004). They estimate trading costs for municipal bonds using the MSRB data, though over a shorter time period. Their approach is very different from ours, reflecting differences in goals. The two papers share an interest in measuring how large the costs of trading in this market are, and understanding how these costs vary with the size and other characteristics of the trade. The papers also share a central difficulty: while there are many trades in many bonds, trading in any one bond is typically very infrequent. Harris and Piwowar (2004) estimate a time-series model of the trading cost for each bond with a minimal number of trades during the sample period, augmented with a factor model that uses bond market indices to infer movements in the intrinsic value of the bonds between observed trades, which may be months apart. They then analyze how the estimated costs vary cross-sectionally for different types of bonds. We focus on trades that can reasonably be assumed to represent two sides of a single intermediated transaction, and employ a structural model to decompose the cost faced by a customer into a portion that represents the cost the dealer incurs and a portion attributable to the dealer's market power.

These very different approaches produce roughly similar estimates of average costs of trading, and both make clear that smaller trades are much more costly than large ones. The Harris and Piwowar (2004) results provide a richer description of how the costs vary with bond characteristics such as credit quality. That paper is purely empirical in its goals, however. Our paper uses a theoretical model to seek evidence that the high costs of trading are due to dealer market power and to find out how the exercise of market power depends on the characteristics of the trade. The presence of market power, and the way dealers use it, are central policy and research concerns in markets that lack transparency.

The remainder of the paper is organized as follows. The next section describes the institutional setting and our sample. In Section 3 we study dealer profits on round-trip transactions, and illustrate their dependence on size and other characteristics of the trade. In Section 4 we present a structural model that allows us to decompose the profits into portions attributable to dealer costs and market power. We report our empirical estimates in Section 5, and report estimates of the effects of changes in market transparency in Section 6. The final section concludes. The Appendix contains detailed descriptions of procedures we used to filter the data and variable definitions.

2 The Municipal Bond Market and the Sample

We have a sample from the Municipal Securities Rulemaking Board (MSRB) reporting all trades carried out by broker-dealers from May 1, 2000 through January 10, 2004. The sample was gathered as part of the MSRB's efforts to improve transparency in the municipal bond market, and will eventually be incorporated into a system that makes transactions prices publicly available to market participants. The sample is self-reported, and there are many systematic errors made in entering the data, especially early in the sample period when member firms were still becoming accustomed to the system. In the Appendix we describe in detail the procedures we use to identify and filter out data errors.

The transaction-specific information provided about each trade include the price, the date and time of the trade, the par value traded, whether the trade was a dealer buying from a customer, a dealer selling to a customer, or a trade between dealers. There are fields for the yield at which the trade took place, which is not required but is sometimes reported. Information is also provided about the traded bond including the CUSIP number, a text description of the bond, the date interest begins accruing (the "dated date"), the coupon rate, and the bond's maturity. Often some of the fields are empty, but by searching other trades for the CUSIP number we can generally determine the missing information. For example, we calculate measures of age and maturity for the bonds in each of over 26 million trades in the sample.

Table 1 provides descriptive statistics. The first panel includes all transactions in the data. The second panel describes trades occurring in the first ninety days after the dated date for bonds that are issued during our sample period.[4] We refer to such trades as "new issues."

Sales to customers exceed buys from customers, primarily because of activity in new issues. Syndicates of broker-dealers purchase new bond issues, and the resulting inventory is distributed to customers primarily during the first ninety days. The dollar value of trades in newly issued bonds is $3.697 trillion, only 32% of the total value of all trades. The difference between the value of sales to customers and buys from customers for newly issued bonds, $1.689 trillion, is 90% of the corresponding difference for all trades, even though transactions in new issues are less than a third of all transactions.

The value of sales to customers are approximately equal to buys from customers in seasoned issues. The broker-dealers tend to buy bonds from customers in larger par amounts, and then sell the bonds in smaller blocks. The average purchase from a customer is close to four times larger than the average sale to a customer for new issues, and a bit less than three times the corresponding transaction size for seasoned issues. Inter-dealer trades are of intermediate size.

Municipal bonds are actively traded in a "when issued" market, and also immediately after they are issued. Once the bonds find their way into retail and mutual fund portfolios, the volume of trade drops off dramatically. The MSRB reports that from March 1998 to May 1999, 71% of the outstanding issues did not trade at all. Such patterns are very apparent in Figure 1, where we plot the empirical probability of trade as a function of the age of the bond. Four to six months from issuance, less than 10% of the bonds in our sample trade at all. The probability then rises somewhat so that by four years from issuance, roughly 15% of the bonds in the sample trade at least once during a month.

Figure 2 shows the average number of trades per day, conditional on the bond trading on that day. After the bond is reasonably seasoned, the average number of trades stays close to two, suggesting that trades through broker-dealers in a given bond are typically limited to the intermediation of a specific transaction.

Our empirical tests in subsequent sections focus on liquidity provision for seasoned bonds—bonds more than 90 days from issuance—because volume has typically stabilized for seasoned bonds. The value of purchases from customers roughly equal sales for seasoned bonds. Because we see both sides of most transactions in seasoned bonds, we can reliably measure the profitability of the flows to the dealers for transactions in seasoned bonds. Our results are, therefore, most informative about the typical experience of an individual or institution holding bonds who wants to sell them, and thus demands liquidity.

[4] For its monthly trade summaries, the MSRB defines "new issue trades" as "trades where the difference between the trade date and the dated date is less than or equal to 4 weeks (28 days)." We chose a longer time horizon, since our data suggests that transaction volume has not yet flattened out one month after issuance. Substantial transaction volume in new issues through the when-issued market starts as early as 20 days before the dated date.

3 The Magnitude and Characteristics of Dealer Markups

Liquidity in the market for seasoned municipal bonds is typically supplied by broker-dealers who purchase large blocks of bonds from customers and then resell the bonds, either in a block or split into smaller trades. From May 1, 2000 to January 10, 2004, a total of 5,313,692 purchases from customers occurred in seasoned municipal bond issues.

Our data do not identify matched buy-sell transactions for specific bonds, nor the specific dealers carrying out those transactions. We observe bonds flowing into and out of the hands of dealers as a group. In many cases, however, the sequence of transactions in a given bond issue leave little doubt that they are two ends of a transaction intermediated by a specific dealer. We focus on three methods for measuring the profits to dealers from the transactions. The narrowest measure isolates transactions that are most obviously two sides of the same transaction. The broader measures capture more trades, and thus can be viewed as more representative of the profits dealers earn as a group.

First, we study trades where a buy from a customer is followed by a sale to a customer in the same bond for the same par amount on the same day with no intervening trades in that bond. We refer to such trades as "immediate matches." For immediate matches, no added inventory is carried on the books of the dealers at the end of the day.

Of course, some of the immediate matches may be situations where the initial purchase is by one intermediary, the subsequent sale is by another, and it is purely coincidence that the par value of the trades is identical. The information from the previous section about the frequency of trade, however, suggests such events are quite unlikely, particularly when the time between the two trades is short. As is apparent from Figure 2, the mean number of trades per day, conditional on a bond trading once, is close to two. If, in a short period of time, we know one of these trades is a buy, the other is a sale, and they both involve the same par value, it is very likely that they are two sides of a trade intermediated by a single dealer.

Second, we consider a broader set of transactions where buys from customers are followed by transactions that clear dealer inventories in aggregate. In each case, a buy from a customer is followed by one or more sales to customers equal in par value to the initial purchase with no intervening purchases from customers. The purchases and sales may be spread out through time, and there may be intermediate trades between dealers in the bond. The profits earned on such transactions represent rewards to the dealers as a group for the intermediation they provide. We refer to such transactions as "round-trip transactions."

The largest set of transactions we study, or the "FIFO sample," consists of the broad sample of round-trip transactions augmented by all the purchases from customers that over our sample period could be matched with sales to customers using a first-in-first-out (FIFO) rule. For the FIFO sample, there may be intervening purchases from customers, but unless those purchases are selected by the round-trip criteria, the first sales are assigned to the bonds that came into dealer inventories first. The FIFO sample, then, is most likely to assign sales to purchases made by another dealer, but will be more representative of profits to the dealers as a group. This broadest matching procedure covers 86% of the purchases from customers in our database. The Appendix and Table 2 provide more details on the matching procedures used to construct the round-trip and FIFO samples.

Table 4 describes the three samples. Panel (a) reports medians of the measured profits on the trades and some of the explanatory variables associated with the trades that we use in subsequent analyses. The "Gross Markup" is the dealer gain or loss on the trades as a percentage of the purchase price. The "Net Markup" adjusts the markup for yield curve movements. For this purpose, we have obtained data for the Lehman Brothers Municipal Bond Index for various maturities (1, 3, 5, 7, 10, 15, 20, 22+ years) from Datastream. We use a linear spline to interpolate values for other maturities. To arrive at the net holding-period profits, we subtract the maturity-matched price change of the corresponding municipal bond index from the gross markup. We truncate the resulting distribution at the 0.5% and 99.5% quantiles, since there are some very extreme observations that appear to have been the result of clerical errors when the data was entered. Details on the definitions of the various explanatory variables are in Table 3.

Table 4 shows median markups are between 1.3% and 1.9%. The table also shows that median yields on municipal bonds are less than 5% in our sample — selling a bond therefore involves surrendering much of a year's return on a municipal bond.

The sample of round-trip transactions involves about half the purchases from customers. Since there can be no new purchases between the initial transaction and the sale of the same par value, the bonds in the round-trip sample trade less frequently than the immediate matches (14% of all purchases from customers) or the FIFO sample (86% of all purchases from customers). Not surprisingly, perhaps, the measured markups are also larger for the round-trip transactions.

The two stricter criteria—the immediate matches and round trip transactions—select trades involving lower par amounts, smaller issues, and bonds where daily volume in bonds from the same state was lower. From the narrowest sample (the immediate matches) to the broadest sample, (the FIFO sample), the time before the purchases clears from inventory rises from 0.031 days to 3.107 days. Other characteristics of the samples are reasonably similar, or do not vary in ways suggesting obvious biases.

Panel (b) of Table 4 shows estimates of the time before bonds purchased in a block clear dealer inventories for the two broader sample criteria: the round-trip transactions and the FIFO sample. Over half of the purchases from customers are sold within five business days. But the dealers as a group do appear to bear substantial risk of ending up holding bonds for long periods when they supply liquidity. The extent to which holding bonds for long periods is costly for the dealers is unclear, however, since the bonds pay competitive returns.[5]

Table 5 provides information from the FIFO sample about the markups the dealers earn, the frequency of losses, and how trades are processed. We only report this information for the FIFO sample, but similar patters are very evident for the narrower sample definitions and for shorter time periods. For larger trades of over $100,000 par value, just over 40% are resold in a single block. For retail-sized transactions of less than $100,000 in par value, over 60% are resold in a single block. Panel (b) reports statistics describing the percentage markup for trades of different sizes and processed in different ways. Trades are categorized by whether the initial purchase is sold off in smaller blocks ("Split" versus "No Split") and by whether the bonds are traded between dealers before being sold off to

[5]For the dealers, the coupon income in municipal bonds is tax-exempt, and capital gains are taxed on an accrual basis. At the short-end of the term structure, municipal bonds have similar after-tax yields to treasuries, and at longer maturities, municipal bonds tend to have higher after-tax yields than treasuries. See, for example, Green (1993).

customers ("Interdealer" versus "No Interdealer"). Columns in the table divide the trades according to the par value of the initial purchase in millions. Regardless of how the trade is processed, average markups fall as the size of the trade increases, as does the standard deviation of the realized markups. Markups are economically insignificant for institutionally sized trades of over $500,000, if the bonds are resold in a single block.

Within any size category, profits to dealers as a group are higher for trades that require more extensive or elaborate intermediation in the sense that a large number of counterparties are involved in selling off the bonds. Trades that involve a large number of counterparties appear to be riskier than trades that involve a few number of counterparties—dealer profits have higher standard deviations if the trades involve a large number of counterparties. But the causality between profits, risk, and number of counterparties is ambiguous, since the means of selling off the bonds is an endogenous choice of the dealers. For example, dealers may involve more counterparties when they anticipate more difficulties clearing their inventory ex-ante, or they may involve more counterparties ex-post, when market conditions have turned against them and they become more desperate to sell. The positive association between profitability, and both the risk and number of counter parties suggests that dealers involve more counterparties when they anticipate more difficulties clearing their inventories ex-ante.

Overall, the evidence in Panel (b) of Table 5 seems consistent with dealer markups being determined by the risks and costs dealers bear, rather than market power. There are likely economies of scale in handling trades, and percentage markups fall with trade size. More service is provided by the intermediaries when more counterparts are involved, and larger markups are evident for these trades. Types of trades with higher average markups also have higher standard deviation. There is an evident association between risk and return.

Nevertheless, there is also evidence in Table 5 that bargaining power is tilted towards larger trades. While risk, as measured by standard deviation, is higher for smaller trades, dealers rarely lose money on them. Panel (c) reports loss frequencies for the various categories of trades. Dealer losses are most frequent for the categories of trades on which markups are the least variable. There is a high level of skewness in the markups for all trade categories, and for large trades the distribution is simultaneously more concentrated and centered at a lower level.

The skewness is evident in Figure 3 showing the frequency distributions for three different trade-size categories for the FIFO sample. The plots, which all have the same scale, are kernel density estimates. The estimates are computed using the Epanechnikov kernel with the Silverman automatic bandwidth selection method.[6] It is obvious from the plots that the higher loss frequencies for large trades are not the result of the realized percentage profits being more spread out. Their distribution is much more concentrated, but centered at a much lower point.

The combination of these three characteristics—lower percentage profits, higher probability of losses, and less variable profits—suggests the largest traders transact with the dealers on more attractive terms. The next section, which reports estimates of parameters that summarize dealer market power, provides some additional evidence along these lines.

Figure 3 also provides some evidence on how pervasive extremely high markups are for trades of different sizes. On relatively small transactions, a substantial portion of the distribution of realized spreads exceed 5% (the NASD's

[6] Härdle (1990) provides a textbook introduction to kernel smoothing methods.

"cap" for equity trades), while very few trades occur at spreads in excess of 8%. Except for the very largest trades, there is considerable probability mass above 2%. In summary, relative to the norms of fairness and reasonableness cited in SEC opinions and NASD complaints, there are substantial numbers of trades that occur at high spreads, but the extremely high spreads in the range of 20-50% reported in the press are likely to be data errors or extremely unusual events.

4 Dealer Market Power and Transaction Size

In the previous section we established that the markups dealers earn on round-trip transactions are large. They differ in magnitude and variability across trades with different characteristics. To what extent is this evidence that dealers exercise market power in their interaction with certain classes of customers, versus evidence that the costs and risks of intermediating the trades differ with these characteristics?

In this section we speak to the question by developing a simple model that decomposes the observed markup into components associated with the cost to the dealer and the dealer's relative bargaining power with the customer. We then estimate the model as a Stochastic Frontier Model.

4.1 The Model

Consider transactions between a dealer and a customer currently holding bonds she wishes to sell. Customers buying municipal bonds typically have many substitutes for any particular issue. Most round-trip transactions in seasoned municipal bonds are therefore initiated by customers wishing to sell particular bonds.

We assume the seller arrives with a reservation value v, which represents her outside opportunities. The reservation value can be viewed, for example, as the continuation value associated with contacting a different dealer and searching for better terms of trade. The dealer's decision about whether to trade depends on her expectations about the price she will eventually obtain on selling the bond and the costs she anticipates in intermediating the trade. We denote the eventual sales price as p, and its expectation as $E(p \mid X)$, where X is a set of conditioning variables, observable to the dealer and the seller. The anticipated cost of intermediating the trade is $c(X, \theta)$, where θ is a set of parameters to be estimated. Finally, let p^* be the price the dealer offers to the seller.

We assume that the dealer is risk-neutral with indirect utility function equal to $E(p \mid X) - c(X, \theta) - p^*$, the expected profit from purchasing the bond today for p^*, then reselling it in the future for an expected price of $E(p \mid X)$, and incurring the expected intermediation cost, $c(X, \theta)$. The seller is also assumed to be risk-neutral with indirect utility function equal to $p^* - v$, the price she receives for selling the bond today, p^*, less her reservation value for the bond, v.

The seller and dealer engage in an alternating offer game with possibility of breakdown, the solution of which can be described by the generalized Nash solution. Let ρ be the bargaining power of the dealer relative to that of the seller, where $\rho \in [0, 1]$. If $\rho = 0$, the seller has all the bargaining power, and if $\rho = 1$, the dealer has all the bargaining power.

The equilibrium transaction price p^* maximizes the generalized Nash product

$$\max_{p^*} \left(E(p \mid X) - c(X,\theta) - p^*\right)^{\rho} \left(p^* - v\right)^{1-\rho} \tag{1}$$

subject to the participation constraints

$$E(p \mid X) - c(X,\theta) - p^* \geq 0, \tag{2}$$

$$p^* - v \geq 0. \tag{3}$$

Condition (2) requires the price to be less than the dealer's expected net revenues from reselling the bond, and condition (3) requires the price to exceed the seller's reservation value. The participation constraints can only be satisfied if there are positive gains from trade:

$$E(p \mid X) - c(X,\theta) - v \geq 0. \tag{4}$$

If the gains from trade are not positive, the game ends and no trade takes place.

The first-order condition when the gains from trade are positive is

$$(1-\rho)\left(E(p \mid X) - c(X,\theta) - p^*\right) + \rho\left(v - p^*\right) = 0. \tag{5}$$

Solving (5) for p^*, the equilibrium offer price is

$$p^* = \rho v + (1-\rho)(E(p \mid X) - c(X,\theta)). \tag{6}$$

The transaction price is a weighted-average of the seller's reservation value and the dealer's expected net revenues from reselling the bond. The weights are given by the relative bargaining power of the counterparties.

If the seller has all the bargaining power ($\rho = 0$), the offer price is equal to the expected cash flows that the dealer receives from reselling the bond, $E(p \mid X) - c(X,\theta)$, and the dealer makes zero expected profits. If the dealer has all the bargaining power ($\rho = 1$), the offer price is equal to the seller's reservation price for the bond and the dealer makes positive expected profits.

Once the dealer has the bonds she will in turn sell them for p, which will differ from the expected price by an expectational error with mean zero:

$$e \equiv p - E(p \mid X). \tag{7}$$

The realized markup will consist of this expectational error, along with that portion of the surplus the dealer is able to extract from the seller. To see this, note that

$$\begin{aligned} p - p^* &= E(p \mid X) + e - p^* \\ &= E(p \mid X) + e - (\rho v + (1-\rho)[E(p \mid X) - c(X,\theta)]) \\ &= c(X,\theta) + e + \rho\left(E(p \mid X) - c(X,\theta) - v\right). \end{aligned} \tag{8}$$

A transaction takes place, and $p - p^*$ is observed, if and only if

$$\rho\left(E(p \mid X) - c(X,\theta) - v\right) \geq 0. \tag{9}$$

Condition (9) follows because $\rho \in [0,1]$ and because the participation constraints, (2) and (3) can both be satisfied if and only if the gains to trade are positive: $E(p \mid X) - c(X,\theta) - v \geq 0$.

4.2 Estimating the Model

The model in equation (8) fits naturally into a specification that can be estimated using Stochastic Frontier Analysis. Greene (2002) and Kumbhakar and Lovell (2003) provide descriptions of Stochastic Frontier Analysis at a textbook level. The classic applications of Stochastic Frontier Analysis in production, such as Aigner, Lovell and Schmidt (1977), estimate production or cost functions that are viewed as the most efficient outcomes possible. Individual observations deviate from this ideal by a symmetric error that has zero mean, and by a one-sided error that is interpreted as inefficiency specific to that firm. Stochastic Frontier Analysis has been applied in financial economics by Hunt-McCool, Koh and Francis (1996) and Koop and Li (2001) to study IPO underpricing, by Berger and Mester (1997) and Altunbas, Gardener, Molyneux and Moore (2001) to study efficiency in the banking industry, and by Habib and Ljungqvist (2003) to study the role of incentives in mitigating agency costs.

In our application, the cost of intermediating the trade to the dealer, $c(X_i, \theta)$, can be viewed as the "efficient" markup from the standpoint of seller i, where we now use i to index the transactions in the data. Such a markup would be attained on average by sellers who have sufficient bargaining power to drive dealers to their reservation prices. Even in that case, equation (8) implies that observed markups would vary around this cost by an expectational error, e_i. If sellers lack bargaining power relative to dealers, the observed markup will also deviate from the dealer's cost by a one-sided error which reflects the dealer's market or bargaining power and the seller's reservation price. Measures of the relative "size," or variance, of the expectational and one-sided errors provide information about the relative importance of the dealers' market power.

It is natural to interpret the markup in the model in percentage terms. For trades taking place across days, we also interpret the model as applying to excess returns over what would be earned on an index of municipal bonds. Let $R_{index,i}$ be the return on a municipal bond index, and define the forecast error η_i

$$\eta_i = R_{index,i} - E(R_{index,i} \mid X_i). \tag{10}$$

To rewrite the model in percentage terms divide equation (8) by the initial bond price, p_i^*, and subtract the return on the municipal bond index:

$$\frac{p_i - p_i^*}{p_i^*} - R_{index,i} \quad = \quad \left(\frac{c(X_i, \theta)}{p_i^*} - E(R_{index,i} \mid X_i)\right) + \epsilon_i + \xi_i, \tag{11}$$

with

$$\epsilon_i \equiv \frac{e_i}{p_i^*} - \eta_i, \tag{12}$$

and

$$\xi_i \equiv \frac{\rho_i \left(E(p_i \mid X_i) - c(X_i, \theta) - v_i\right)}{p_i^*}. \tag{13}$$

Here $\frac{c(X_i,\theta)}{p_i^*} - E(R_{index,i} \mid X_i)$ are the dealer' s costs in excess of the expected return on an index of municipal bonds. We will refer to $\frac{c(X_i,\theta)}{p_i^*} - E(R_{index,i} \mid X_i)$ as the cost of intermediation. Since p_i^* is positive, the normalization in equation (13) does not change the one-sided nature of the second error term.

To arrive at an econometric specification, we put parametric structure on the distribution of the error, ϵ_i, and the distribution of the seller's reservation value, v_i. We assume $\epsilon_i \sim \mathcal{N}(0, \sigma_i^2)$. We allow the distribution to depend on the characteristics of the bond or the seller through the variance. Reservation values are drawn from a distribution centered on the dealer's expected net proceeds from selling the bond. That is,

$$E(v_i \mid X_i) = E(p_i \mid X_i) - c(X_i, \theta). \tag{14}$$

It is natural to assume potential sellers' reservation values are "rational" in this sense. They reflect correct expectations on average. Define ν_i as the deviation of v_i around its mean normalized by the price:

$$\nu_i \equiv \frac{E(v_i \mid X_i) - v_i}{p_i^*}. \tag{15}$$

Substituting equation (15) into equation (13),

$$\xi_i = \rho_i \nu_i. \tag{16}$$

We parameterize ν_i as a double exponential, where the density on each side of the mean is 0.5 times the exponential density with parameter λ_i. Again, we allow the distribution from which the reservation price is drawn to depend on the characteristics of the trade. The distribution conditional on $\nu_i \geq 0$ is exponential with parameter λ_i. The one-sided error ξ_i, conditional on $\xi_i \geq 0$, therefore is exponentially distributed with parameter $\frac{\lambda_i}{\rho_i}$. The first two moments of ξ_i are

$$E(\xi_i \mid \xi_i \geq 0) \quad = \quad \frac{\rho_i}{\lambda_i}, \tag{17}$$

$$\mathrm{Var}(\xi_i \mid \xi_i \geq 0) \quad = \quad \left(\frac{\rho_i}{\lambda_i}\right)^2. \tag{18}$$

A natural specification is to allow the distribution to depend on features such as the par value of the trade and how the trade is handled by the dealer. We would expect large trades to originate with institutional investors, who are likely to be better informed about market conditions and who, because of the repeat business they bring to dealers, can bargain more effectively over any given transaction. We might also expect dealers to accept trades anticipating the involvement of other dealers, or planning to split the bond between multiple buyers, only in situations where they anticipate a large share of significant gains to trade.

We estimate specifications where the exponential error term has parameter $\frac{\rho_i}{\lambda_i}$ that is a log-linear function of the explanatory variables $Z = (Z_{ik})_{k=1,...,K}$:

$$\frac{\rho_i}{\lambda_i} = a_0 \prod_{k=1}^{K} e^{a_k Z_{ik}}. \tag{19}$$

The variables $Z_{i1}, ..., Z_{iK}$ include the natural logarithm of trade size (par value), and dummies for whether the trade is split, or moves through other dealers. We also allow the standard deviation of the symmetric error, σ_i, to depend on the same variables:

$$\sigma_i = b_0 \prod_{k=1}^{K} e^{b_k Z_{ik}}. \tag{20}$$

If $a_0 = 0$, then $\frac{\rho_i}{\lambda_i} = 0$. In this case, the sellers have all the bargaining power and there is no asymmetric error in the realized markup. If $a_0 \neq 0$, then $\frac{\rho_i}{\lambda_i} \neq 0$. In this case, the dealers have bargaining power and there is an asymmetric error in the realized markup. Variables that are positively related to $\frac{\rho_i}{\lambda_i}$ in this specification suggest higher bargaining power for the dealers.

The heterogeneity across customers in the distribution of the asymmetric error can be viewed either as variation in ρ_i or variation in the distribution of the customer reservation prices, λ_i. There is no natural econometric or economic way to distinguish between variation in ρ_i or variation in λ_i across customers. We would expect more sophisticated customers to come to the market with a better understanding of the dealers' costs and resale opportunities. More sophisticated customers would therefore demand prices leading to lower dealer profits. This could be interpreted either as a more concentrated distribution for their reservation prices, in which case we could allow λ_i to depend on characteristics of the trade, or as greater bargaining power for the customer and thus heterogeneity in ρ_i.

Finally, we parameterize the cost of intermediation as a linear function of the explanatory variables:

$$\frac{c(X_i, \theta)}{p_i^*} - E(R_{index,i} \mid X_i) = \theta_0 + \sum_{l=1}^{L} \theta_l X_{il} \tag{21}$$

where L is the number of regressors. Our methods also allow for the parties to condition their decisions on unobserved heterogeneity in the cost function.[7]

We report estimates of the stochastic frontier models for both narrowly and more broadly defined samples. The

[7]The model can be generalized to allow the cost function to consist of two parts: $c^*(X_i, \theta) + w_i$, where the conditioning variables in X_i are observed by the econometrician, and w_i is a mean-zero source of heterogeneity observed by both the buyer and the seller, but not the econometrician. Then replacing $c(X_i, \theta)$ in equations (6)-(11) with $c^*(X_i, \theta) + w_i$ yields

$$\frac{p_i - p_i^*}{p_i^*} - R_{index,i} = \left(\frac{c^*(X_i, \theta)}{p_i^*} + \frac{w_i}{p_i^*} - E(R_{index,i} \mid X_i) \right) + \epsilon_i + \xi_i$$

where, now,

$$\xi_i \equiv \frac{\rho_i (E(p_i \mid X_i) - c^*(X_i, \theta) - w_i - v_i)}{p_i^*}.$$

general conclusions of our analysis are very robust to the selection criteria we employ.

5 Empirical Results

Table 6 reports the results of fitting the empirical model in equations (19)–(21) to Immediate Matches, conditioning on the variables defined in Table 3. The sample consists of transactions in seasoned bonds where the purchase from a customer was sold off to customers on the same day with no intermediate purchases. There are 738,857 observations used in the estimation. We use daily returns on the Lehman Brothers Municipal Bond Index as the index return, R_{index}. Since we use daily returns, $R_{index} = 0$ if both sides of the transaction are completed on the same day.

In order to aid the interpretation of the coefficients, we transformed the independent variables by subtracting their sample means. The intercept term in the cost of intermediation function therefore measures the expected cost of a typical trade. The intercept term in the volatility of the symmetric error measures the volatility of the symmetric error for a typical trade, and the intercept term in the exponential error term measures the expected profit from market power.

The first two columns of Table 6 report the results of fitting the model with all the parameters in the one-sided error constrained to zero. With the one-sided error constrained to zero, the model corresponds to the case where the sellers have all the bargaining power, and is a standard, cross-sectional regression analysis of the determinants of the costs of trading. The model is estimated by maximum likelihood. The first panel in Table 6 reports the coefficients on the cost of intermediation function, $\frac{c(X_i,\theta)}{p_i^*} - E(R_{index,i} \mid X_i)$. The second panel of the table reports the coefficients in the residual standard deviation.

Almost all the explanatory variables have significant t-statistics. The signs are generally consistent with higher markups where one would expect to see them if dealers do demand compensation for bearing liquidity costs and interest rate risk. In environments with high interest rates, and more volatile rates, markups are larger. Bonds with higher liquidity, measured by purchase frequency, earn dealers lower spreads. Pre-refunded bonds, which are riskless because they are backed by trusts funded with treasury bonds, earn much lower spreads.

The second two columns of Table 6 report maximum-likelihood estimates of a stochastic frontier model with specification (19)-(21), with the parameters unrestricted. The first panel of Table 6 reports the coefficients in the linear model for the "efficient" markup, or, $\frac{c(X_i,\theta)}{p_i^*} - E(R_{index,i} \mid X_i)$. The second and third panels report the estimates for the two error distributions. The final panel reports the likelihood ratio.

Since the explanatory variables are demeaned in the model, the intercept terms are estimates of the expected efficient cost and the expected loss to dealer market power on an average transaction. The constant in the estimates for the asymmetric error (98.30) is much larger than the constant in the cost function (23.29). The constant in the cost function has a natural interpretation of the average efficient cost of search or intermediation. Thus, much of the

We can now interpret $\frac{w_i}{p_i^*} + \epsilon_i$ as the symmetric portion of the error in the model, and assuming that

$$E(v_i \mid X_i) = E(p_i \mid X_i) - c^*(X_i, \theta) - w_i,$$

we can interpret ξ_i as the asymmetric portion of the error, and parameterize each as in the body of the paper.

spread on the average transaction is attributed by the model to the dealer's advantage in bargaining power. Similarly, the intercept in the cost function and the constant in the volatility of the symmetric error both fall by over two-thirds when the model allows for the one-sided error. Thus, more than two-thirds of the expected costs of trading and the conditional volatility of that cost are ascribed to the dealers' market power.

Several of the coefficients in the specification with a one-sided error decrease in absolute value relative to the model with only a symmetric error distribution, both in economic and statistical significance. For example, the coefficients on the size of the transaction are over five times larger in absolute value without the one-sided error, and even switch sign for transactions larger than $500,000. The portion of the markup due to bargaining power, however, is significantly negatively related to size.

Table 7 confirms that the qualitative results are robust to the sample selection, and adds variables that describe how the trade was processed.[8] The table reports estimates using the Round-Trip Transactions, which include all matched transaction pairs in seasoned bonds. There are 2,684,845 observations used in the estimation. The first two columns report estimates and t-statistics for the restricted model and the last two columns results for the unrestricted model. The estimates for the restricted model reported in the first two columns are similar to those reported in the first two columns of Table 6, although they do not tend to fall as much in absolute value or switch sign when we allow for the asymmetric error. Again, allowing for a one-sided error dramatically decreases the size of the intercept terms in the cost of intermediation function, and the volatility attributed to the one-sided error is much larger than that of the symmetric error. The reduction in the absolute value of the coefficients is particularly evident for liquidity related variables. For example, the coefficients on *Transaction Frequency* and *Issue Size* are one-third as large in absolute value. That the effects of these variables are subsumed by the asymmetric error term suggests that their explanatory power for the markups may be due to the ability of dealers to extract greater rents in illiquid bonds rather than their effect on the dealer's costs.

The models in Table 7 include dummy variables for the intermediation services interacted with the transaction size in both the cost function and the specifications of the error terms. To interpret the coefficients in the asymmetric error term's specification, note that they enter the expected markup in exponential form. For example, for a large trade with par value over $500,000, knowing the trade was split increases the expected gain to the dealer by a factor of $\exp(0.41) = 1.51$, or 51 per cent. The estimated coefficients in the cost function suggest transactions that involve other intermediaries or involve selling the bonds to multiple buyers earn higher markups for the dealers collectively. This is what one would expect, since the dealers are clearly providing more service in these situations.

Interacting the size dummy variables with the other variables is both empirically and economically important, since trade size proxies for heterogeneity in customer type. For instance, one would expect that pre-negotiation is

[8] We have also experimented with using a half-normal distribution for the one-sided error. Our empirical findings are robust to such a change. For example, using this alternative specification, the intercept terms for the cost function and the asymmetric error are -1.51 (-97.45) and 158.12 (6134.12), respectively, for the immediate matches (t-statistics in parentheses). The same parameter estimates for the FIFO sample are 12.28 (67.56) and 188.20 (4088.93). Like the estimates in Tables 6 and 8 for the corresponding samples, in each case the intercept term in the cost function is much lower than that in the asymmetric error specification. The likelihood ratios associated with allowing for the asymmetric error are also very large regardless of the specification used.

more pervasive for larger trades. Cases of large purchases remaining in dealer inventory over night suggest that the seller urgently demanded liquidity. Such an interpretation is confirmed in Table 7, by the positive coefficients on *Overnight* and *Inventory Duration* for par greater than $500,000 in the specification of the asymmetric error, while they appear with negative signs in the cost function.

Variables for how the trade is handled, such as whether it is split and whether other dealers are involved, appear significant in both the efficient cost function and in the specification of the asymmetric error. The positive coefficients suggest they increase the cost of processing these trades to the dealers. We would expect this as more intermediation is clearly involved in such trades. These variables also appear as significant in conditioning the distribution of the one-sided error term. Trades that involve more extensive intermediation earn higher markups than the apparent increase in the dealer's cost. Dealers appear to undertake these transactions only in situations where they expect to earn high returns.

A partial explanation for the result that involving other dealers increases the dealers' bargaining power may involve the types of dealers who tend to sell bonds to other dealers. Blocks of bonds purchased from institutions are likely to be split into smaller blocks in order to sell them to retail investors. Some large dealers have no retail distribution capacity. They will step forward to provide liquidity to an institution wishing to sell a large position knowing they will probably need to sell the bonds to another dealer, and appear to do so only when the terms are particularly advantageous.

The intercept term in the efficient cost function is higher than in Table 6, presumably since the narrow sample biases against trades that involve extensive intermediation.

Table 8 reports the results of estimating the same model as in Table 7 but using our broadest sample, the FIFO sample. The FIFO sample has 4,583,419 purchases from customers. The results are generally similar to the results from the Immediate Matches and the Round-Trip Transactions, except that now the intercept term in the efficient cost function lies between the estimates obtained from the narrow and the broad sample. This difference across samples is presumably due to the inclusion of the FIFO matched trades. The FIFO matched trades add more liquid bonds to the sample, and may also pick up trades where the dealers ended up stuck with bonds that were difficult to unload, and thus not immediately matched, leading to lower measured markups compared to Table 7.

Finally, Table 9 provides evidence that our central results are not due to any particular feature of interest rate movements during the sample period. The table reports results for the stochastic frontier model, separately estimated for days when bond prices were rising, falling, or mixed. Mixed days are ones when yields for different maturities moved in different directions. Rising and falling markets were days when all rates fell or rose, respectively. The intercepts in the cost function are similar to our previous estimates, and the intercept in the asymmetric error term is large, confirming that the model attributes much of the cost of trading to dealer market power across different market conditions. Our results are robust to the overall trend in interest rates.

6 Transparency

The MSRB has enacted changes in reporting requirements over the sample period, increasing transparency in the municipal bond market. Increases in the public availability and immediacy of price information occurred in October 2000, May 2002, November 2002, and June 2003.[9] In October 2000 the MSRB began offering the "Comprehensive Report," which lists all municipal securities transactions with a one-month delay, regardless of the frequency of trading. The one-month delay in comprehensive price data has been shortened in several steps, with comprehensive data currently being disseminated one week after the trade date.

The second report, the "T+1 Daily Report," is published daily by the MSRB and reports individual transaction data from the previous day for each issue that meets a trade threshold. The trade threshold set in January 2000 was four trades including both inter-dealer and customer trades. In May 2002, the trade threshold was lowered to three trades, in November 2002 the trade threshold was lowered to two trades, and in June 2003 the threshold was lowered to one trade. As of June 2003, therefore, all trades are reported in the T+1 Daily Report. By April 2003, there were twenty-four subscribers to the T+1 Daily Report and fifty-one to the Comprehensive Report.

To capture the effects of increased transparency, we add dummy variables for the different regimes associated with the number of days until the release of the comprehensive report. The T+1 Daily Report, on the other hand, introduces variation through time for a given bond. To exploit the variation from the T+1 Daily Report, we introduce a dummy variable for whether the bond has appeared in the Daily Report within the last week of the trade in question. To evaluate if the increased transparency has affected markups in aggregate, we include fixed effects in the cost function, the symmetric error term, and the asymmetric error term.

Table 10 summarizes the estimation results. The negative coefficients on the time dummies in the symmetric error term indicate that price uncertainty has decreased as transparency has increased. The impact on cost and market power is very different for retail-sized compared to institutional-sized transactions. Increases in transparency have decreased the dealers' market power in transactions less that $100,000 and have increased the dealers bargaining power significantly in transactions more than $100,000. It seems clear, then, that the increased transparency has reduced cross-subsidization from smaller traders in favor of larger traders. The model ascribes some of the reduction to reduced costs, perhaps because the greater transparency is encouraging more activity by smaller traders and thus increasing liquidity. The model also ascribes some of the reduction to less bargaining power for dealers in their trading with small traders, perhaps because timely reporting of price information disciplines the dealers.

We also ask how the availability of price information on the most recent transactions in the Daily Report has affected dealer profits. For this purpose, we limit attention to bond issues with sufficient transactions to identify time-series variation in markups due to inclusion in the Daily Report. We eliminate issues with no variation in the Daily Report and focus on the time period May 2000 - June 2003. In addition, we exclude all issuers with less than 50 transactions in any of the three transactions size ranges $0-$100,000, $100,000-$500,000, and greater than $500,000. The estimation includes issuer fixed effects.

[9] See www.msrb.com.

Table 11 summarizes the results. Surprisingly, the dealer's bargaining power seems unaffected by the availability of price information in the Daily Report. Only for medium transaction sizes, is the negative coefficient on "Daily Report" marginally significant.[10] We interpret the finding as evidence that the dealers' bargaining power does not solely arise from a lack of information about the prices of individual bonds but rather from a lack of timely information about market conditions generally.

7 Conclusion

Corporate and municipal bonds have traditionally been traded primarily in opaque, decentralized markets in which price information is costly to gather. This may offer opportunities for intermediaries, in their role of facilitating the matching of buyers and sellers and providing liquidity, to extract monopoly rents or cross-subsidize across different groups of customers. The extent to which they operate competitively is an empirical issue. Data on trade in these markets, however, has been difficult to obtain in the past, and even when such data is available separately identifying costs and rents to the intermediary is problematic.

We analyze a comprehensive database of all trades between broker-dealers in municipal bonds and their customers. The data is only released to the public with a substantial lag, and thus the market remained relatively opaque to the traders themselves even though the data is available to researchers. Because the bonds trade infrequently, this transaction data is low frequency for each bond, but because there are so many bonds we have millions of observations.

We show that the pattern of dealer profits in round-trip transactions implies dealers earn lower average profits on larger trades, even while the dealers bear more risk on larger trades. We formulate a simple structural model that allows us to estimate measures of dealer bargaining power and relate it to characteristics of the trades. The model can be estimated as a Stochastic Frontier Analysis model. The results suggest dealers exercise substantial market power in their trades with customers. Our measures of market power decrease in trade size and appear larger for trades that are more complex to intermediate. Increases in transparency lead to reductions in the dealers' bargaining power in retail sized transactions and increases the dealers' bargaining power in institutional sized transactions.

[10] The results are robust to different sample section criteria, state fixed effects, and the inclusion of variables for the number of transactions on each day during the previous week.

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A Appendix

A.1 Data Filter

A number of transactions in the MSRB database are missing information about the bond issue. In case of missing bond features such as coupon rate, issue date or maturity date, we perform searches over the entire database to recover the missing data. We use the bond description text field to identify the state in which the bond was issued, and the type and purpose of the bond. We identify the issuer from the CUSIP number. If the time stamp of the transaction is missing (or zero) we assume the transaction takes place at 6 am.

Next we eliminate obvious data errors such as negative prices, and maturity or issuance dates that do not make sense. We drop observations where the transaction size is missing, or where the reported par amount is less than $1,000. The remaining observations on the independent variables used in the estimation are winsorized at the 0.5% and 99.5% levels if they are symmetric, or at the 99.5% level if their values are one-sided.

MSRB reporting rules do not explicitly require broker-dealers to report both the transaction price and yield. In many instances no yield is reported, and in fewer cases the transaction price is missing. We drop observations were the transaction price is missing, and truncate the distribution of net markups at 0.5% and 99.5%. [11]

A.2 Sample Selection

The MSRB transactions database does not identify the broker-dealer who is intermediating a given transaction, nor the identity of the retail/institutional buyer/seller. The database, however, allows identifying the type of transaction (purchase from customer, sale to customer, inter-dealer transaction), and the time of the transaction up to the minute.

We use a matching algorithm to select purchase and sales tickets that are likely to be associated with the same dealer. The basic principle is to match a given dealer purchase with consecutive sales to customers up until the next purchase from a customer or the end of the sample period. If the par amount of a sales ticket in this sequence is larger than the initial purchase amount, this particular sales transaction is ignored. All remaining sales transactions are aggregated. If the cumulative par amount of these sales transactions up until the next purchase equals the par amount of the preceding purchase, we have identified a matched pair. If there is a one-to-one match between a

[11] Alternatively, we have used a log-linear regression approach with similar results to recover the price-yield relationship using all observations in the database on the given issue. In this case we use the reported yields to predict the transaction price, or the other way around depending on which information is missing. More specifically, we first run three sets of ordinary-least-squares regressions of log-price on yield to obtain coefficient estimates. For robustness we eliminate outliers by only including price and yield observations within two standard deviations from their corresponding sample median. MSRB reporting rules for yields differ between transactions effected above or below par (see MSRB Rule G-12 (c) (v) (I) for details). We therefore perform two regressions in which we only include transaction prices above or, respectively, below par, and a third using all observations. Depending on whether the reported yield exceeds the coupon rate, coefficient estimates from the first or the second regression are used. Coefficient estimates from the third regression are used whenever in either of the former regressions the R-squared is below 33%, or the number of observations in the sub-samples are less than six and less than one third of all observations. Given the small number of observations for many bond issues, we found these criteria effective at producing sensible values. Finally, if the R-squared in the overall regression is less than 33%, or the total number of observations is insufficient to apply OLS in the first place, we recover the transaction price from the reported yield assuming that the yield is reported as yield-to-maturity.

purchase and a single sale, we call these pairs no-splits. Otherwise the purchase is being split into several smaller units. We record the time of the purchase and the par weighted-average transaction time of the sales. In addition we determine whether transactions occurred between dealers in the same issue at any time between the purchase and sale date, and mark the matched pair as involving inter-dealer intermediation.

We match the remaining purchase and sales transactions by applying a first-in-first-out (FIFO) rule. After eliminating all transactions associated with matched pairs, we start with the first purchase in the remaining transaction sequence for each bond issue. We assign to it all consecutive sales transactions until they aggregate to or exceed the purchase amount—independently of whether other purchases occur in the meantime. If the par amount of these sales tickets exceeds that of the purchase, we allocate the residual to the next purchase if it occurred before the last of the consecutive sales. Otherwise we discard the residual. We record a partial match, if the par amount of the purchase exceeds that of all sales until the end of the sample. The matching process continues with the next purchase until it is filled.

Using these matching rules we construct three separate samples. Table 2 describes the different sampling criteria. We calculate net markups as the difference between the realized gross markup in per cent and the index return on a maturity-matched portfolio of municipal bonds. The gross markup is the relative difference between the dealer's purchase price and the par weighted-average sale price:

$$\text{Net Markup} = \text{Gross Markup - Return on Index}, \tag{22}$$

$$\text{Gross Markup} = \frac{\text{Par-Weighted Average Sale Price - Purchase Price}}{\text{Purchase Price}}. \tag{23}$$

Table 1: Descriptive Statistics

	All Transactions	Sales to Customers	Purchases from Customers	Transactions between Dealers
		All Issues		
Observations	26,803,575	15,678,293	5,689,375	5,435,907
Issues	1,079,689	1,060,692	712,551	635,859
Issuers	46,497	46,132	43,086	37,045
Ave. Par	423,512	372,030	694,030	288,866
Total Value	11,255,791	5,786,067	3,919,355	1,550,370
Coupon rate	4.1%	4.1%	4.0%	4.5%
Age	3.8	3.0	5.6	3.9
Maturity	18.7	18.8	19.4	17.4
		New Issues		
Observations	7,926,083	5,835,686	375,683	1,714,714
Issues	605,137	596,650	143,369	328,282
Issuers	26,093	25,882	17,181	18,613
Ave. Par	471,317	399,476	1,638,496	460,090
Total Value	3,697,634	2,301,170	611,535	784,930
Coupon rate	4.1%	4.1%	3.6%	4.1%
Age	0.03	0.03	0.05	0.03
Maturity	15.1	15.7	14.0	13.7
		Seasoned Issues		
Observations	18,877,492	9,842,607	5,313,692	3,721,193
Issues	649,672	633,587	630,159	389,194
Issuers	41,710	41,268	41,292	34,348
Ave. Par	403,440	355,757	627,255	209,966
Total Value	7,558,157	3,484,897	3,307,821	765,440
Coupon rate	4.4%	4.4%	4.1%	4.9%
Age	5.3	4.8	6.0	5.7
Maturity	20.2	20.7	19.8	19.2

Table 1 reports descriptive statistics for the MSRB transactions data from May 1, 2000 to January 10, 2004. The Total Value is the market value of the trades measured in millions.

Table 2: Sample Selection

Sample	Description
Immediate Matches	All matched transaction pairs in seasoned bonds where the bond purchased by a dealer is not split into smaller lots; there are no inter-dealer transactions between the purchase and the sale date; and the sale and purchase occur on the same day.
Round-Trip Transactions	All matched transaction pairs in seasoned bonds.
FIFO Sample	All Round-Trip Transactions augmented by all purchase transactions in seasoned bonds that can be matched with consecutive sales using a first-in-first-out rule.

Table 3: Definitions of the Explanatory Variables. The table describes the independent variables used in the estimation.

Variable	Description
Markup	Difference between the purchase and the resale price divided by the purchase price. Truncated at 0.5% and 99.5% and measured in basis points.
ln(Par)	Natural logarithm of the par value of the transaction. Measured in millions of dollars.
Maturity	Years between date of transaction and maturity of bond.
Coupon	Coupon rate of the bond. Measured in percent.
Coupon Zero or Missing	Indicator variable for an original issue pure discount bond, or if coupon information is missing after search over database.
Age	Age of the bond on the day of the purchase.
Transaction Frequency	The total number of purchase transactions from customers per business day in the bond over our sample period. The number of business days during the sample period is 930.
Issue Size	Natural logarithm of the par value of the largest trade in the bond over our sample period. This provides information about the size of the issue.
State Volume	The total value of trades in bonds from that state on the day of the transaction. Municipal markets are segmented by state due to differences in state tax treatment and state income tax rates. This is a measure of the liquidity of bonds from a particular state on a given day, and these bonds are close substitutes for the bond being traded. Measured in billions of dollars.
State Order Imbalance	Purchases from customers less sales to customers on that day in seasoned bonds issued by municipalities in that state. Measured in billions of dollars.
State New Issues	Sales of new bonds in the same state on the same day. New issues are more actively traded, so the frequency of trades in issues that are close substitutes for the bond in question may affect customers' reservation prices. Measured in billions of dollars.
Treasury Yield	Closing yield of the maturity matched treasury bond on the same day as the purchase transaction. Measured in percent.
Treasury Range	Intraday range of the maturity matched treasury bond on the same day as the purchase transaction. Measured in basis points. This measures the volatility of interest rates on the day in question.
Overnight	Bond stays in the dealer's inventory for at least one business day.
Inventory Duration	Calendar days the bond stays in dealer inventory.
No Splitting, Interdealer	Dummy variable for round-trips where the bonds are sold in a block, but through at least one other dealer.
Splitting, No Interdealer	Bonds are sold to customers in multiple blocks with no interdealer trades in the meantime.
Splitting and Interdealer	Bonds are sold to customers in multiple blocks with interdealer trades in the meantime.
Revenue Bond	Revenue bond.
Tax Revenue Bond	Bond backed directly by tax revenues from a specific source.
General Obligation Bond	General obligation bond.
Guaranteed	Bond is guaranteed by a municipal bond insurance agency, or is backed by a specific entity. Some of the bonds are backed by an entity with credit risk, and so have credit risk.
Prerefunded	Bond has been prerefunded. These bonds are backed by trusts invested in treasuries, and are therefore riskless.
Certificates of Partnership	Certificate of Partnership.
County Issuer	Issuer is a county.
School District Issuer	Issuer is a school district.
Development Authority	Issuer is a development authority.
Financial Authority	Issuer is a financial authority.
Housing Authority	Issuer is a housing authority.
Sewer Authority	Issuer is a sewer authority.
Utilities Construction	Bond issued to finance utilities construction.
Redevelopment	Issuer is a redevelopment authority.
Improvement	Bond issued for facilities improvements.
Facilities Construction	Bond issued to finance facilities construction.
Refinancing	Bond used to refinance another issue.

Table 4: Sample Selection

(a) Descriptive Statistics (Medians, Common Sample after Filtering)

	Immediate Matches	Round-Trip Transactions	FIFO Sample	All
Observations	738,857	2,684,845	4,583,419	5,300,265
Gross Markup (bp)	133.9	189.0	169.0	*NA*
Net Markup (bp)	133.9	185.4	161.8	*NA*
Yield (purchase)	4.846	4.781	4.867	4.850
Yield (sale)	4.106	4.100	4.228	4.250
Par (million)	0.025	0.025	0.035	0.035
Inventory Duration (day)	0.031	0.893	3.107	*NA*
Maturity (year)	11.28	10.23	13.07	12.85
Coupon (percent)	5.100	5.000	5.000	5.000
Age (year)	6.478	5.500	5.095	5.142
Transaction Frequency (1/day)	0.029	0.019	0.039	0.039
Issue Size (log million)	-0.693	-0.955	0.000	0.000
State Volume (billion)	0.222	0.231	0.236	0.237
State Order Imbalance (billion)	0.003	0.003	0.003	0.003
State New Issues (billion)	0.060	0.064	0.064	0.065
Treasury Yield (percent)	4.728	4.695	4.860	4.805
Treasury Range (percent)	1.602	1.610	1.597	1.626

(b) Distribution of the Time in Dealer Inventory (Kaplan-Meier Estimate)

Day	Round-Trip Transactions	FIFO Sample	All
1	56.5%	37.6%	33.4%
2	70.8%	48.5%	43.0%
3	78.2%	54.8%	48.6%
4	83.0%	59.3%	52.6%
5	86.4%	62.8%	55.8%
10	94.1%	72.6%	64.5%
30	99.2%	84.4%	75.2%
90	99.9%	92.1%	82.4%
360	100.0%	98.0%	88.9%

Table 5: Descriptive Statistics for Matched Trades

(a) Frequency

	FIFO Sample	$Par \in (0, .1)$	$Par \in [.1, .5)$	$Par \in [.5, \infty)$
Observations	4,583,419	3,100,204	794,227	688,988
No Split × No Interdealer	55.3%	61.4%	40.9%	44.3%
Split × No Interdealer	18.3%	14.0%	22.7%	32.8%
No Split × Interdealer	13.0%	15.6%	11.0%	3.5%
Split × Interdealer	13.4%	9.0%	25.4%	19.4%

(b) Net Markups–measured in basis points

		FIFO Sample	$Par \in (0, .1)$	$Par \in [.1, .5)$	$Par \in [.5, \infty)$
FIFO Sample	Median	162	213	81	0
	Mean	177	230	110	16
	S.D.	199	188	180	151
No Split × No Interdealer	Median	151	201	22	0
	Mean	165	213	41	-9
	S.D.	179	165	142	111
Split × No Interdealer	Median	151	231	141	0
	Mean	152	236	151	-10
	S.D.	186	155	160	147
No Split × Interdealer	Median	208	246	85	28
	Mean	242	276	114	44
	S.D.	248	249	187	168
Split × Interdealer	Median	177	241	156	91
	Mean	202	259	183	113
	S.D.	224	236	206	187

(c) Frequency of Net Loss

	FIFO Sample	$Par \in (0, .1)$	$Par \in [.1, .5)$	$Par \in [.5, \infty)$
FIFO Sample	13.6%	5.7%	19.4%	42.2%
No Split × No Interdealer	12.8%	4.8%	29.2%	45.8%
Split × No Interdealer	18.4%	3.9%	11.5%	51.8%
No Split × Interdealer	10.7%	8.7%	16.4%	29.9%
Split × Interdealer	12.7%	9.7%	11.9%	20.2%

Table 6: Parameter Estimates of the Stochastic Frontier Model: Immediate Matches

	No Market Power		Market Power	
	Cost Function Parameters			
Constant	151.66	(1273.39)	23.29	(96.48)
$ln(Par) \times Par \in (0, .1)$	-42.70	(-604.42)	-7.77	(-96.46)
$ln(Par) \times Par \in [.1, .5)$	-30.38	(-165.16)	-0.22	(-12.28)
$ln(Par) \times Par \in [.5, \infty)$	-5.01	(-52.34)	0.73	(66.16)
Maturity	0.94	(70.18)	0.01	(8.83)
Coupon	-5.22	(-37.74)	0.01	(0.82)
Coupon Zero or Missing	-53.22	(-66.71)	-1.32	(-18.56)
Age	-0.24	(-12.37)	0.00	(-0.52)
Transaction Frequency	-5.72	(-21.59)	0.12	(5.58)
Issue Size	2.03	(31.00)	-0.10	(-13.47)
State Volume	2.10	(12.65)	-0.01	(-1.05)
State Order Imbalance	1.68	(2.22)	0.27	(4.32)
State New Issues	5.06	(12.67)	0.02	(0.53)
Treasury Yield	7.70	(90.47)	0.05	(6.14)
Treasury Range	2.03	(29.48)	0.04	(6.91)
Revenue Bond	-0.72	(-4.04)	0.02	(1.06)
Tax Revenue Bond	3.65	(9.14)	-0.09	(-2.53)
General Obligation Bond	-2.13	(-4.67)	-0.09	(-2.09)
Guaranteed	10.64	(6.75)	0.08	(0.49)
Prerefunded	-34.23	(-51.14)	-0.31	(-2.73)
Certificates of Partn	1.43	(3.77)	0.04	(1.33)
County Issuer	1.10	(6.24)	0.06	(4.25)
School District Issuer	7.77	(22.22)	0.24	(6.88)
Development Authority	-0.36	(-1.19)	0.07	(2.81)
Financial Authority	-1.91	(-5.72)	0.06	(2.19)
Housing Authority	-3.76	(-4.00)	-0.60	(-5.24)
Sewer Authority	2.18	(5.00)	0.11	(2.75)
Utilities	7.96	(15.71)	0.09	(1.80)
Redevelopment	8.94	(10.93)	-0.30	(-2.99)
Improvement	0.22	(0.69)	0.08	(2.97)
Facilities	0.27	(1.31)	0.00	(-0.22)
Refinancing	1.72	(10.30)	0.02	(1.38)
	Symmetric Error Distribution			
Constant	91.55	(5490.75)	15.24	(408.58)
$ln(Par) \times Par \in (0, .1)$	-0.20	(-263.20)	-0.75	(-266.14)
$ln(Par) \times Par \in [.1, .5)$	-0.28	(-146.22)	0.73	(53.91)
$ln(Par) \times Par \in [.5, \infty)$	-0.50	(-183.84)	-0.59	(-84.35)
	Asymmetric Error Distribution			
Constant	-	-	98.30	(2354.31)
$ln(Par) \times Par \in (0, .1)$	-	-	-0.45	(-368.77)
$ln(Par) \times Par \in [.1, .5)$	-	-	-0.55	(-203.30)
$ln(Par) \times Par \in [.5, \infty)$	-	-	-0.92	(-277.44)
Likelihood Ratio		263,508		
Observations		738,857		

Table notes on the next page.

Notes for Table 6

Table 6 reports maximum likelihood estimates from fitting the model

$$\frac{p_i - p_i^*}{p_i^*} - R_{index,i} = \theta_o + \sum_{l=1}^{L} \theta_l X_{il} + \epsilon_i + \xi_i,$$

with p_i the price that the dealer sells the bond for, p_i^* the price that the dealer pays the seller for the bond, X_{il} for $l = 1, \ldots, L$ conditioning variables. The residual ϵ_i is normally distributed with standard deviation $b_0 \prod_{k=1}^{K} e^{b_{ik} Z_k}$, and ξ_i is exponential distributed with parameters $a_0 \prod_{k=1}^{K} e^{a_k Z_k}$, with Z_{ik} for $k = 1, \ldots, K$ conditioning variables. The first two columns report the parameter estimates and t-statistics in parentheses for the model with $a_0 = a_1 = \ldots = a_K = 0$ and the second two columns report the parameter estimates and t-statistics in parentheses for the unrestricted model.

Table 7: Parameter Estimates of the Stochastic Frontier Model: Round-Trip Transactions

	No Market Power		Market Power	
Cost Function Parameters				
Constant	197.07	(2749.20)	100.41	(788.83)
$ln(Par) \times Par \in (0, .1)$	−47.40	(−734.26)	−33.18	(−405.30)
$ln(Par) \times Par \in [.1, .5)$	−39.76	(−229.57)	−9.47	(−60.45)
$ln(Par) \times Par \in [.5, \infty)$	−20.91	(−146.27)	0.05	(0.43)
Overnight $\times$ $Par \in (0, .1)$	40.92	(224.88)	20.91	(69.77)
Overnight $\times$ $Par \in [.1, .5)$	35.58	(91.24)	19.75	(49.34)
Overnight $\times$ $Par \in [.5, \infty)$	7.28	(19.54)	−5.19	(−17.48)
Inventory Duration $\times$ $Par \in (0, .1)$	−0.99	(−59.42)	−2.13	(−114.11)
Inventory Duration $\times$ $Par \in [.1, .5)$	−1.04	(−33.29)	−1.46	(−53.24)
Inventory Duration $\times$ $Par \in [.5, \infty)$	0.54	(13.86)	−0.66	(−21.36)
Split $\times$ No Interdealer $\times$ $Par \in (0, .1)$	40.55	(177.16)	53.86	(134.57)
Split $\times$ No Interdealer $\times$ $Par \in [.1, .5)$	72.59	(175.86)	58.33	(82.16)
Split $\times$ No Interdealer $\times$ $Par \in [.5, \infty)$	30.08	(69.40)	2.53	(8.97)
No Split $\times$ Interdealer $\times$ $Par \in (0, .1)$	68.44	(200.59)	14.37	(29.93)
No Split $\times$ Interdealer $\times$ $Par \in [.1, .5)$	47.01	(81.91)	25.77	(52.09)
No Split $\times$ Interdealer $\times$ $Par \in [.5, \infty)$	65.12	(78.26)	29.09	(39.37)
Split $\times$ Interdealer $\times$ $Par \in (0, .1)$	77.53	(133.95)	30.76	(37.13)
Split $\times$ Interdealer $\times$ $Par \in [.1, .5)$	90.53	(157.50)	45.55	(75.11)
Split $\times$ Interdealer $\times$ $Par \in [.5, \infty)$	106.05	(157.87)	43.38	(66.46)
Maturity	4.41	(355.73)	2.26	(192.68)
Coupon	−1.89	(−18.47)	−4.12	(−49.69)
Coupon Zero or Missing	−3.04	(−5.19)	−45.12	(−93.46)
Age	−0.43	(−23.73)	−0.28	(−19.92)
Transaction Frequency	−33.32	(−79.91)	−11.81	(−45.30)
Issue Size	−1.18	(−25.04)	−0.43	(−10.93)
State Volume	7.95	(47.12)	4.47	(35.86)
State Order Imbalance	1.06	(1.38)	1.36	(2.40)
State New Issues	9.31	(23.75)	6.51	(22.49)
Treasury Yield	9.01	(132.56)	7.40	(139.70)
Treasury Range	4.05	(64.56)	3.18	(67.76)
Revenue Bond	−0.98	(−6.22)	−2.28	(−18.41)
Tax Revenue Bond	7.67	(22.87)	4.97	(18.98)
General Obligation Bond	−5.42	(−11.74)	−5.43	(−16.01)
Guaranteed	8.16	(7.38)	8.64	(9.36)
Prerefunded	−47.28	(−97.61)	−36.57	(−86.66)
Certificates of Partn	3.07	(9.10)	2.61	(10.08)
County Issuer	1.05	(6.45)	0.80	(6.46)
School District Issuer	7.38	(31.58)	5.15	(27.32)
Development Authority	−4.27	(−12.87)	−2.05	(−8.85)
Financial Authority	−3.06	(−8.13)	−0.31	(−1.19)
Housing Authority	0.16	(0.19)	−3.73	(−5.78)
Sewer Authority	1.63	(4.69)	2.23	(8.02)
Utilities	6.85	(16.85)	5.95	(17.90)
Redevelopment	6.16	(10.15)	5.24	(10.90)
Improvement	−1.23	(−4.40)	−0.20	(−0.92)
Facilities	0.59	(2.79)	1.05	(6.80)
Refinancing	2.96	(19.67)	2.14	(18.49)

The table is continued on the next page.

Table 7: Parameter Estimates of the Stochastic Frontier Model: Round-Trip Transactions (cont'd)

	No Market Power		Market Power	
		Symmetric Error Distribution		
Constant	112.95	(5000.00)	66.20	(3342.84)
$ln(Par) \times Par \in (0, .1)$	−0.11	(−119.90)	−0.25	(−125.79)
$ln(Par) \times Par \in [.1, .5)$	−0.14	(−52.40)	0.03	(4.16)
$ln(Par) \times Par \in [.5, \infty)$	−0.17	(−56.12)	−0.15	(−22.68)
Overnight $\times Par \in (0, .1)$	0.05	(21.63)	−0.04	(−8.35)
Overnight $\times Par \in [.1, .5)$	0.14	(26.65)	0.33	(19.12)
Overnight $\times Par \in [.5, \infty)$	0.19	(26.15)	0.28	(20.65)
Inventory Duration $\times Par \in (0, .1)$	0.01	(46.52)	0.00	(16.71)
Inventory Duration $\times Par \in [.1, .5)$	0.01	(18.14)	0.01	(10.02)
Inventory Duration $\times Par \in [.5, \infty)$	0.01	(17.96)	0.01	(11.37)
Split × No Interdealer $\times Par \in (0, .1)$	−0.01	(−2.31)	0.24	(35.95)
Split × No Interdealer $\times Par \in [.1, .5)$	0.07	(12.22)	0.55	(27.10)
Split × No Interdealer $\times Par \in [.5, \infty)$	0.16	(19.90)	−0.18	(−9.48)
No Split × Interdealer $\times Par \in (0, .1)$	0.28	(84.86)	0.08	(8.53)
No Split × Interdealer $\times Par \in [.1, .5)$	0.07	(8.95)	0.00	(−0.21)
No Split × Interdealer $\times Par \in [.5, \infty)$	0.00	(−0.04)	−0.02	(−0.65)
Split × Interdealer $\times Par \in (0, .1)$	0.27	(46.67)	0.16	(9.02)
Split × Interdealer $\times Par \in [.1, .5)$	0.17	(25.49)	0.13	(5.40)
Split × Interdealer $\times Par \in [.5, \infty)$	0.16	(15.89)	0.08	(3.23)
		Asymmetric Error Distribution		
Constant	-	-	90.94	(3307.92)
$ln(Par) \times Par \in (0, .1)$	-	-	−0.16	(−143.93)
$ln(Par) \times Par \in [.1, .5)$	-	-	−0.34	(−127.84)
$ln(Par) \times Par \in [.5, \infty)$	-	-	−0.39	(−101.79)
Overnight $\times Par \in (0, .1)$	-	-	0.23	(64.43)
Overnight $\times Par \in [.1, .5)$	-	-	0.18	(32.47)
Overnight $\times Par \in [.5, \infty)$	-	-	0.38	(50.99)
Inventory Duration $\times Par \in (0, .1)$	-	-	0.01	(55.63)
Inventory Duration $\times Par \in [.1, .5)$	-	-	0.00	(21.80)
Inventory Duration $\times Par \in [.5, \infty)$	-	-	0.01	(33.79)
Split × No Interdealer $\times Par \in (0, .1)$	-	-	−0.08	(−15.69)
Split × No Interdealer $\times Par \in [.1, .5)$	-	-	0.18	(23.94)
Split × No Interdealer $\times Par \in [.5, \infty)$	-	-	0.41	(51.36)
No Split × Interdealer $\times Par \in (0, .1)$	-	-	0.44	(107.73)
No Split × Interdealer $\times Par \in [.1, .5)$	-	-	0.16	(22.84)
No Split × Interdealer $\times Par \in [.5, \infty)$	-	-	0.18	(11.73)
Split × Interdealer $\times Par \in (0, .1)$	-	-	0.47	(66.59)
Split × Interdealer $\times Par \in [.1, .5)$	-	-	0.41	(60.17)
Split × Interdealer $\times Par \in [.5, \infty)$	-	-	0.53	(51.44)
Likelihood Ratio		291,778		
Observations		2,684,845		

Table notes on the next page.

Notes for Table 7

Table 7 reports maximum likelihood estimates from fitting the model

$$\frac{p_i - p_i^*}{p_i^*} - R_{index,i} = \theta_o + \sum_{l=1}^{L} \theta_l X_{il} + \epsilon_i + \xi_i,$$

with p_i the price that the dealer sells the bond for, p_i^* the price that the dealer pays the seller for the bond, X_{il} for $l = 1, \ldots, L$ conditioning variables. The residual ϵ_i is normally distributed with standard deviation $b_0 \prod_{k=1}^{K} e^{b_{ik} Z_k}$, and ξ_i is exponential distributed with parameters $a_0 \prod_{k=1}^{K} e^{a_k Z_k}$, with Z_{ik} for $k = 1, \ldots, K$ conditioning variables. The first two columns report the parameter estimates and t-statistics in parentheses for the model with $a_0 = a_1 = \ldots = a_K = 0$ and the second two columns report the parameter estimates and t-statistics in parentheses for the unrestricted model.

Table 8: Parameter Estimates of the Stochastic Frontier Model: FIFO Sample

	No Market Power		Market Power	
	Cost Function Parameters			
Constant	173.37	(2158.04)	53.70	(423.19)
$ln(Par) \times Par \in (0, .1)$	−44.83	(−737.68)	−27.07	(−366.54)
$ln(Par) \times Par \in [.1, .5)$	−33.23	(−219.15)	−5.14	(−39.62)
$ln(Par) \times Par \in [.5, \infty)$	−10.16	(−86.55)	1.33	(12.37)
Overnight $\times$ $Par \in (0, .1)$	33.15	(184.56)	15.90	(55.41)
Overnight $\times$ $Par \in [.1, .5)$	−2.82	(−8.56)	11.43	(30.49)
Overnight $\times$ $Par \in [.5, \infty)$	−4.53	(−16.16)	−26.16	(−90.00)
Inventory Duration $\times$ $Par \in (0, .1)$	−0.46	(−152.13)	−1.00	(−245.93)
Inventory Duration $\times$ $Par \in [.1, .5)$	−0.68	(−132.93)	−1.25	(−183.76)
Inventory Duration $\times$ $Par \in [.5, \infty)$	−0.62	(−115.24)	−1.38	(−185.95)
Split $\times$ No Interdealer $\times$ $Par \in (0, .1)$	45.39	(196.13)	52.08	(139.37)
Split $\times$ No Interdealer $\times$ $Par \in [.1, .5)$	88.97	(233.92)	33.81	(74.45)
Split $\times$ No Interdealer $\times$ $Par \in [.5, \infty)$	15.68	(52.24)	1.05	(3.70)
No Split $\times$ Interdealer $\times$ $Par \in (0, .1)$	71.88	(217.05)	15.79	(35.57)
No Split $\times$ Interdealer $\times$ $Par \in [.1, .5)$	68.30	(120.88)	15.13	(29.25)
No Split $\times$ Interdealer $\times$ $Par \in [.5, \infty)$	57.46	(70.28)	17.55	(23.74)
Split $\times$ Interdealer $\times$ $Par \in (0, .1)$	84.49	(199.57)	40.18	(65.77)
Split $\times$ Interdealer $\times$ $Par \in [.1, .5)$	137.99	(294.24)	49.15	(91.07)
Split $\times$ Interdealer $\times$ $Par \in [.5, \infty)$	122.13	(260.01)	53.28	(101.06)
Maturity	3.84	(361.44)	2.51	(272.24)
Coupon	−4.01	(−40.32)	−8.63	(−103.79)
Coupon Zero or Missing	−39.15	(−68.80)	−81.55	(−168.97)
Age	0.23	(13.53)	0.23	(16.57)
Transaction Frequency	−21.57	(−78.10)	−12.83	(−58.41)
Issue Size	−3.84	(−84.31)	−3.62	(−93.00)
State Volume	1.92	(12.32)	0.92	(7.40)
State Order Imbalance	3.62	(5.12)	3.03	(5.34)
State New Issues	17.02	(46.44)	13.56	(46.31)
Treasury Yield	7.23	(106.74)	6.22	(114.82)
Treasury Range	3.74	(62.08)	2.85	(59.74)
Revenue Bond	−1.76	(−11.47)	−2.56	(−20.36)
Tax Revenue Bond	6.87	(21.30)	4.57	(17.32)
General Obligation Bond	−1.05	(−2.53)	−4.15	(−12.38)
Guaranteed	11.24	(10.18)	10.40	(11.22)
Prerefunded	−51.68	(−110.57)	−39.98	(−98.38)
Certificates of Partn	3.03	(9.13)	3.73	(13.80)
County Issuer	3.33	(21.32)	2.21	(17.51)
School District Issuer	10.26	(42.27)	6.30	(31.64)
Development Authority	−3.55	(−11.96)	−3.35	(−14.16)
Financial Authority	−1.96	(−5.83)	0.00	(0.01)
Housing Authority	−10.44	(−12.38)	−11.15	(−15.85)
Sewer Authority	3.21	(9.62)	3.74	(13.58)
Utilities	8.51	(21.13)	6.21	(18.34)
Redevelopment	8.57	(14.31)	7.03	(14.12)
Improvement	−3.50	(−12.92)	−2.18	(−9.92)
Facilities	1.62	(8.42)	2.08	(13.39)
Refinancing	2.04	(14.20)	1.79	(15.22)

The table is continued on the next page.

Table 8: Parameter Estimates of the Stochastic Frontier Model: FIFO Sample (cont'd)

	No Market Power		Market Power	
Symmetric Error Distribution				
Constant	149.53	(7000.00)	98.66	(6552.03)
$ln(Par) \times Par \in (0, .1)$	−0.14	(−184.13)	−0.21	(−154.40)
$ln(Par) \times Par \in [.1, .5)$	−0.14	(−69.72)	0.03	(7.94)
$ln(Par) \times Par \in [.5, \infty)$	−0.10	(−56.99)	−0.08	(−29.27)
Overnight $\times Par \in (0, .1)$	0.25	(128.52)	0.27	(62.57)
Overnight $\times Par \in [.1, .5)$	0.44	(113.23)	1.10	(111.78)
Overnight $\times Par \in [.5, \infty)$	0.59	(134.43)	0.92	(124.56)
Inventory Duration $\times Par \in (0, .1)$	0.00	(148.59)	0.00	(118.77)
Inventory Duration $\times Par \in [.1, .5)$	0.00	(98.52)	0.00	(92.81)
Inventory Duration $\times Par \in [.5, \infty)$	0.00	(108.29)	0.00	(103.15)
Split × No Interdealer $\times Par \in (0, .1)$	0.04	(16.04)	0.19	(39.84)
Split × No Interdealer $\times Par \in [.1, .5)$	0.10	(23.68)	0.00	(0.47)
Split × No Interdealer $\times Par \in [.5, \infty)$	0.14	(33.11)	0.09	(14.08)
No Split × Interdealer $\times Par \in (0, .1)$	0.32	(134.34)	0.22	(43.54)
No Split × Interdealer $\times Par \in [.1, .5)$	0.14	(26.05)	−0.10	(−10.38)
No Split × Interdealer $\times Par \in [.5, \infty)$	0.12	(12.36)	−0.07	(−4.33)
Split × Interdealer $\times Par \in (0, .1)$	0.34	(112.94)	0.36	(57.10)
Split × Interdealer $\times Par \in [.1, .5)$	0.21	(49.31)	−0.11	(−11.86)
Split × Interdealer $\times Par \in [.5, \infty)$	0.15	(31.20)	−0.05	(−4.73)
Asymmetric Error Distribution				
Constant	-	-	107.88	(4588.58)
$ln(Par) \times Par \in (0, .1)$	-	-	−0.22	(−239.72)
$ln(Par) \times Par \in [.1, .5)$	-	-	−0.34	(−157.50)
$ln(Par) \times Par \in [.5, \infty)$	-	-	−0.19	(−89.83)
Overnight $\times Par \in (0, .1)$	-	-	0.23	(73.18)
Overnight $\times Par \in [.1, .5)$	-	-	0.07	(13.61)
Overnight $\times Par \in [.5, \infty)$	-	-	0.67	(130.98)
Inventory Duration $\times Par \in (0, .1)$	-	-	0.00	(165.23)
Inventory Duration $\times Par \in [.1, .5)$	-	-	0.00	(126.49)
Inventory Duration $\times Par \in [.5, \infty)$	-	-	0.00	(161.77)
Split × No Interdealer $\times Par \in (0, .1)$	-	-	0.00	(0.02)
Split × No Interdealer $\times Par \in [.1, .5)$	-	-	0.50	(94.52)
Split × No Interdealer $\times Par \in [.5, \infty)$	-	-	0.24	(46.60)
No Split × Interdealer $\times Par \in (0, .1)$	-	-	0.45	(142.11)
No Split × Interdealer $\times Par \in [.1, .5)$	-	-	0.47	(77.46)
No Split × Interdealer $\times Par \in [.5, \infty)$	-	-	0.31	(29.73)
Split × Interdealer $\times Par \in (0, .1)$	-	-	0.47	(109.81)
Split × Interdealer $\times Par \in [.1, .5)$	-	-	0.72	(132.60)
Split × Interdealer $\times Par \in [.5, \infty)$	-	-	0.54	(87.49)
Likelihood Ratio		493,254		
Observations		4,583,419		

Table notes on the next page.

Notes for Table 8

Table 8 reports maximum likelihood estimates from fitting the model

$$\frac{p_i - p_i^*}{p_i^*} - R_{index,i} = \theta_o + \sum_{l=1}^{L} \theta_l X_{il} + \epsilon_i + \xi_i,$$

with p_i the price that the dealer sells the bond for, p_i^* the price that the dealer pays the seller for the bond, X_{il} for $l = 1, \ldots, L$ conditioning variables. The residual ϵ_i is normally distributed with standard deviation $b_0 \prod_{k=1}^{K} e^{b_{ik} Z_k}$, and ξ_i is exponential distributed with parameters $a_0 \prod_{k=1}^{K} e^{a_k Z_k}$, with Z_{ik} for $k = 1, \ldots, K$ conditioning variables. The first two columns report the parameter estimates and t-statistics in parentheses for the model with $a_0 = a_1 = \ldots = a_K = 0$ and the second two columns report the parameter estimates and t-statistics in parentheses for the unrestricted model.

Table 9: Parameter Estimates of the Stochastic Frontier Model: Stratified by Rising vs Falling Market, FIFO Sample

	Rising Market		Mixed Market		Falling Market	
			Cost Function Parameters			
Constant	49.30	(233.26)	52.30	(253.39)	61.35	(244.36)
$ln(Par) \times Par \in (0, .1)$	−26.34	(−215.12)	−27.44	(−226.97)	−27.57	(−191.84)
$ln(Par) \times Par \in [.1, .5)$	−4.35	(−20.75)	−5.34	(−25.01)	−5.83	(−22.49)
$ln(Par) \times Par \in [.5, \infty)$	1.58	(9.14)	1.54	(8.82)	0.85	(3.95)
Overnight $\times$ $Par \in (0, .1)$	7.19	(14.97)	16.01	(34.20)	27.56	(49.78)
Overnight $\times$ $Par \in [.1, .5)$	2.87	(4.61)	9.89	(16.78)	25.94	(34.13)
Overnight $\times$ $Par \in [.5, \infty)$	−37.97	(−80.24)	−22.10	(−48.65)	−13.03	(−21.69)
Inventory Duration $\times$ $Par \in (0, .1)$	−0.94	(−139.15)	−1.01	(−153.99)	−1.10	(−133.66)
Inventory Duration $\times$ $Par \in [.1, .5)$	−1.16	(−104.09)	−1.33	(−117.46)	−1.32	(−97.76)
Inventory Duration $\times$ $Par \in [.5, \infty)$	−1.25	(−103.38)	−1.52	(−123.75)	−1.41	(−95.76)
Split $\times$ No Interdealer $\times$ $Par \in (0, .1)$	53.43	(85.39)	49.43	(81.77)	53.69	(74.24)
Split $\times$ No Interdealer $\times$ $Par \in [.1, .5)$	32.19	(43.24)	34.92	(47.19)	34.97	(38.86)
Split $\times$ No Interdealer $\times$ $Par \in [.5, \infty)$	0.02	(0.04)	1.05	(2.31)	1.94	(3.40)
No Split $\times$ Interdealer $\times$ $Par \in (0, .1)$	18.36	(24.77)	14.64	(20.43)	14.42	(16.58)
No Split $\times$ Interdealer $\times$ $Par \in [.1, .5)$	16.00	(19.33)	17.38	(20.40)	11.44	(10.92)
No Split $\times$ Interdealer $\times$ $Par \in [.5, \infty)$	18.79	(16.87)	16.45	(13.30)	16.92	(10.46)
Split $\times$ Interdealer $\times$ $Par \in (0, .1)$	42.60	(41.61)	38.56	(38.95)	39.49	(33.37)
Split $\times$ Interdealer $\times$ $Par \in [.1, .5)$	50.75	(55.98)	50.46	(58.81)	45.87	(42.83)
Split $\times$ Interdealer $\times$ $Par \in [.5, \infty)$	54.87	(63.02)	54.29	(65.16)	48.85	(44.84)
Maturity	2.28	(148.74)	2.68	(181.65)	2.53	(135.70)
Coupon	−8.60	(−61.85)	−9.64	(−72.25)	−7.00	(−42.58)
Zero Coupon Bond	−81.63	(−101.39)	−87.50	(−112.22)	−71.94	(−75.82)
Age	0.17	(7.33)	0.17	(7.52)	0.38	(13.91)
Transaction Frequency	−14.99	(−41.09)	−10.33	(−29.41)	−13.74	(−31.36)
Issue Size	−3.36	(−51.92)	−3.83	(−60.52)	−3.65	(−48.08)
State Volume	0.38	(1.82)	1.36	(6.66)	0.52	(2.17)
State Order Imbalance	2.07	(2.20)	2.81	(3.05)	5.36	(4.79)
State New Issues	13.80	(30.10)	13.73	(27.72)	15.76	(26.35)
Treasury Yield	6.32	(67.84)	5.36	(61.80)	7.13	(64.16)
Treasury Range	1.19	(14.01)	2.15	(27.13)	4.15	(47.45)
Revenue Bond	−2.90	(−13.90)	−2.58	(−12.65)	−1.93	(−7.80)
Tax Revenue Bond	5.17	(11.95)	4.35	(10.06)	3.81	(7.37)
General Obligation Bond	−4.30	(−7.73)	−4.46	(−8.25)	−3.90	(−5.92)
Guaranteed	10.85	(7.20)	12.97	(8.48)	6.44	(3.53)
Prerefunded	−39.42	(−58.00)	−39.29	(−60.32)	−41.76	(−52.06)
Certificates of Partn	3.18	(7.05)	3.88	(8.92)	4.07	(7.65)
County Issuer	2.31	(11.00)	1.77	(8.70)	2.73	(10.96)
School District Issuer	7.06	(21.53)	5.44	(16.68)	6.33	(16.29)
Development Authority	−2.89	(−7.33)	−3.68	(−9.73)	−3.58	(−7.64)
Financial Authority	0.67	(1.51)	−0.71	(−1.64)	0.03	(0.05)
Housing Authority	−9.33	(−7.95)	−11.04	(−9.89)	−13.95	(−9.86)
Sewer Authority	4.70	(10.28)	3.16	(7.09)	3.29	(6.07)
Utilities	6.68	(11.85)	7.12	(13.00)	3.97	(5.97)
Redevelopment	6.77	(8.14)	6.21	(7.71)	8.46	(8.70)
Improvement	−1.75	(−4.80)	−2.56	(−7.18)	−2.36	(−5.47)
Facilities	2.63	(10.26)	1.32	(5.25)	2.28	(7.47)
Refinancing	1.53	(7.85)	2.28	(12.00)	1.40	(6.03)

The table is continued on the next page.

Table 9: Parameter Estimates of the Stochastic Frontier Model: Stratified by Rising vs Falling Market, FIFO Sample (cont'd)

	Rising Market		Mixed Market		Falling Market	
Symmetric Error Distribution						
Constant	98.52	(3941.42)	97.10	(3969.92)	100.40	(3404.11)
$ln(Par) \times Par \in (0, .1)$	−0.22	(−94.05)	−0.21	(−95.11)	−0.21	(−77.62)
$ln(Par) \times Par \in [.1, .5)$	0.03	(4.59)	0.03	(3.83)	0.04	(5.14)
$ln(Par) \times Par \in [.5, \infty)$	−0.09	(−19.68)	−0.08	(−17.29)	−0.08	(−14.09)
Overnight $\times Par \in (0, .1)$	0.27	(37.00)	0.25	(35.70)	0.28	(34.56)
Overnight $\times Par \in [.1, .5)$	1.12	(68.34)	1.03	(65.14)	1.14	(58.22)
Overnight $\times Par \in [.5, \infty)$	0.94	(76.54)	0.87	(72.24)	0.95	(64.52)
Inventory Duration $\times Par \in (0, .1)$	0.00	(69.39)	0.00	(75.69)	0.00	(60.56)
Inventory Duration $\times Par \in [.1, .5)$	0.00	(54.52)	0.00	(60.18)	0.00	(46.16)
Inventory Duration $\times Par \in [.5, \infty)$	0.00	(60.91)	0.00	(67.80)	0.00	(50.29)
Split × No Interdealer $\times Par \in (0, .1)$	0.20	(25.93)	0.18	(22.67)	0.18	(20.11)
Split × No Interdealer $\times Par \in [.1, .5)$	0.01	(0.37)	0.01	(0.41)	0.01	(0.40)
Split × No Interdealer $\times Par \in [.5, \infty)$	0.10	(9.63)	0.10	(9.27)	0.07	(5.54)
No Split × Interdealer $\times Par \in (0, .1)$	0.23	(27.23)	0.22	(26.64)	0.21	(21.59)
No Split × Interdealer $\times Par \in [.1, .5)$	−0.12	(−7.26)	−0.08	(−4.61)	−0.11	(−5.42)
No Split × Interdealer $\times Par \in [.5, \infty)$	−0.11	(−4.44)	−0.03	(−1.21)	−0.03	(−0.93)
Split × Interdealer $\times Par \in (0, .1)$	0.37	(35.49)	0.36	(35.44)	0.33	(27.65)
Split × Interdealer $\times Par \in [.1, .5)$	−0.09	(−5.93)	−0.10	(−6.52)	−0.13	(−7.39)
Split × Interdealer $\times Par \in [.5, \infty)$	−0.02	(−1.14)	−0.04	(−2.35)	−0.07	(−3.44)
Asymmetric Error Distribution						
Constant	107.86	(2748.78)	108.31	(2869.15)	106.76	(2299.73)
$ln(Par) \times Par \in (0, .1)$	−0.22	(−147.04)	−0.22	(−149.74)	−0.21	(−115.85)
$ln(Par) \times Par \in [.1, .5)$	−0.35	(−96.72)	−0.34	(−95.85)	−0.34	(−79.22)
$ln(Par) \times Par \in [.5, \infty)$	−0.21	(−58.77)	−0.20	(−56.03)	−0.17	(−41.52)
Overnight $\times Par \in (0, .1)$	0.23	(43.57)	0.23	(45.83)	0.22	(36.50)
Overnight $\times Par \in [.1, .5)$	0.07	(8.68)	0.08	(10.52)	0.04	(3.62)
Overnight $\times Par \in [.5, \infty)$	0.66	(77.39)	0.64	(76.37)	0.71	(69.67)
Inventory Duration $\times Par \in (0, .1)$	0.00	(96.09)	0.00	(104.52)	0.00	(86.26)
Inventory Duration $\times Par \in [.1, .5)$	0.00	(71.72)	0.00	(83.28)	0.00	(65.02)
Inventory Duration $\times Par \in [.5, \infty)$	0.00	(95.71)	0.00	(107.49)	0.00	(78.20)
Split × No Interdealer $\times Par \in (0, .1)$	−0.01	(−1.07)	0.02	(3.51)	−0.02	(−2.68)
Split × No Interdealer $\times Par \in [.1, .5)$	0.52	(59.61)	0.50	(58.75)	0.47	(44.30)
Split × No Interdealer $\times Par \in [.5, \infty)$	0.26	(29.31)	0.24	(28.43)	0.24	(23.37)
No Split × Interdealer $\times Par \in (0, .1)$	0.44	(84.72)	0.44	(87.60)	0.46	(73.56)
No Split × Interdealer $\times Par \in [.1, .5)$	0.49	(49.29)	0.45	(45.56)	0.48	(39.02)
No Split × Interdealer $\times Par \in [.5, \infty)$	0.35	(21.86)	0.32	(18.99)	0.24	(11.05)
Split × Interdealer $\times Par \in (0, .1)$	0.48	(67.99)	0.46	(67.06)	0.46	(54.88)
Split × Interdealer $\times Par \in [.1, .5)$	0.74	(81.65)	0.71	(82.07)	0.71	(65.35)
Split × Interdealer $\times Par \in [.5, \infty)$	0.60	(58.83)	0.55	(55.76)	0.46	(37.43)
Log-Likelihood	−10,383,028		−11,085,270		−7,727,899	
Observations	1,630,138		1,740,587		1,212,694	

Table notes on the next page.

Notes for Table 9

Table 9 reports parameter estimates for subsamples associated with rising, falling, or mixed interest rate environments. The first two columns report the parameter estimates and t-statistics in parentheses for the unrestricted model for transactions initiated on days with rising bond prices. Rising markets are defined as days t on which four points on the yield curve (3 month, 5, 10, and 30 year terms) decrease between the close at $t-1$ and $t+1$. Mixed markets are days on which the yield curve does not parallel shift (reported in columns three and four). Falling markets are associated with upward shifts of the yield curve at all maturities. That is days t on which four points on the yield curve (3 month, 5, 10, and 30 year terms) increase between the close at $t-1$ and $t+1$. Estimation results for falling markets are reported in columns five and six.

Table 10: Parameter Estimates of the Stochastic Frontier Model: Transparency, FIFO Sample

	$Par \in (0, .1)$		$Par \in [.1, .5)$		$Par \in [.5, \infty)$	
Cost Function Parameters						
Oct '00 - May '02	−5.72	(−12.94)	5.75	(10.60)	0.19	(0.79)
May '02 - Nov '02	−6.02	(−10.44)	5.93	(8.14)	−21.86	(−48.06)
Nov '02 - Jun '03	−5.12	(−8.58)	4.53	(6.10)	−23.23	(−49.57)
Jun '03 - Jan '04	−7.62	(−12.53)	1.47	(1.98)	−28.69	(−52.91)
$ln(Par)$	−40.69	(−218.46)	−9.41	(−29.13)	3.67	(42.59)
Overnight	17.86	(60.47)	12.32	(32.91)	−14.75	(−45.98)
Inventory Duration	−0.98	(−230.87)	−1.19	(−169.99)	−1.55	(−181.16)
Split × No Interdealer	49.11	(124.49)	31.24	(63.17)	4.76	(22.44)
No Split × Interdealer	16.86	(35.58)	8.44	(15.23)	31.07	(41.13)
Split × Interdealer	36.51	(57.55)	47.14	(78.25)	98.94	(100.00)
Maturity	5.59	(361.24)	2.53	(112.68)	0.86	(58.73)
Coupon	−16.52	(−136.26)	−6.91	(−40.14)	−16.07	(−69.13)
Coupon Zero or Missing	−83.61	(−118.20)	−88.45	(−85.68)	−104.09	(−76.34)
Age	−0.03	(−1.37)	−0.39	(−11.67)	0.36	(20.67)
Transaction Frequency	−43.52	(−80.72)	−18.09	(−30.90)	4.08	(19.18)
Issue Size	−5.05	(−94.88)	−9.00	(−95.92)	−4.37	(−49.76)
State Volume	−5.58	(−16.46)	−2.77	(−6.12)	−1.02	(−4.22)
State Order Imbalance	0.67	(0.71)	−0.31	(−0.25)	−3.26	(−4.88)
State New Issues	4.20	(7.95)	5.65	(8.02)	6.63	(17.36)
Treasury Yield	5.99	(49.55)	2.33	(14.94)	−4.48	(−35.84)
Treasury Range	4.20	(52.38)	3.24	(31.00)	2.70	(40.54)
Symmetric Error Distribution						
Constant	119.96	(2319.73)	84.83	(992.02)	80.20	(1275.73)
Oct '00 - May '02	−0.11	(−47.29)	−0.15	(−29.70)	−0.16	(−43.28)
May '02 - Nov '02	−0.06	(−20.25)	−0.03	(−5.00)	−0.10	(−21.29)
Nov '02 - Jun '03	−0.01	(−4.21)	−0.01	(−2.32)	−0.08	(−18.37)
Jun '03 - Jan '04	0.04	(14.07)	0.07	(12.21)	0.06	(12.36)
$ln(Par)$	−0.11	(−95.83)	0.01	(1.61)	−0.02	(−16.44)
Overnight	0.23	(119.32)	0.98	(158.43)	1.41	(198.25)
Inventory Duration	0.00	(234.29)	0.00	(183.12)	0.00	(205.08)
Split × No Interdealer	0.02	(9.06)	0.05	(10.82)	0.21	(66.54)
No Split × Interdealer	0.13	(50.19)	−0.04	(−7.83)	0.25	(26.56)
Split × Interdealer	0.18	(56.34)	0.03	(5.41)	0.51	(120.89)
Asymmetric Error Distribution						
Constant	109.97	(1336.31)	102.87	(827.62)	37.15	(383.61)
Oct '00 - May '02	0.00	(−0.26)	0.09	(15.07)	0.26	(28.35)
May '02 - Nov '02	−0.05	(−9.56)	0.12	(16.55)	0.54	(50.93)
Nov '02 - Jun '03	−0.06	(−12.86)	0.14	(19.56)	0.58	(56.62)
Jun '03 - Jan '04	−0.13	(−25.26)	0.02	(2.54)	0.62	(55.95)
$ln(Par)$	−0.16	(−91.12)	−0.22	(−54.42)	−0.28	(−95.35)
Overnight	0.24	(68.56)	0.10	(19.98)	0.79	(94.20)
Inventory Duration	0.00	(157.26)	0.00	(110.49)	0.01	(189.45)
Split × No Interdealer	−0.01	(−2.40)	0.45	(81.50)	0.26	(45.56)
No Split × Interdealer	0.54	(158.29)	0.41	(65.19)	0.15	(11.40)
Split × Interdealer	0.52	(112.49)	0.63	(109.65)	0.12	(17.96)
Observations	2,839,401		726,352		656,635	

The table reports the parameter estimates and t-statistics in parentheses for the unrestricted model for different par ranges. The model includes fixed effects for regulatory changes in MSRB reporting requirements, and for the state of issuance (not reported). In October 2000, May 2002, November 2002, and June 2003 the MSRB enacted regulation that gradually increased transparency in the municipal bond market.

Table 11: Parameter Estimates of the Stochastic Frontier Model: Availability of Daily Reports

	$Par \in (0, .1)$		$Par \in [.1, .5)$		$Par \in [.5, \infty)$	
	Cost Function Parameters					
Daily Report	−1.70	(−1.75)	−0.70	(−0.67)	2.74	(0.79)
Oct '00 - May '02	−22.72	(−13.54)	−5.19	(−2.88)	−37.38	(−1.12)
May '02 - Nov '02	−55.06	(−27.28)	−38.90	(−16.84)	−60.21	(−1.02)
Nov '02 - Jun '03	−67.72	(−31.57)	−49.63	(−20.42)	−76.56	(−0.98)
$ln(Par)$	−37.52	(−61.36)	−9.93	(−10.30)	−0.40	(−0.37)
Overnight	−5.60	(−5.45)	−20.90	(−18.51)	−30.03	(−4.25)
Inventory Duration	−0.69	(−68.50)	−0.93	(−65.23)	−1.17	(−6.81)
Split × No Interdealer	51.14	(40.85)	43.75	(24.52)	−1.66	(−2.37)
No Split × Interdealer	12.80	(7.56)	−12.72	(−4.71)	18.94	(6.11)
Split × Interdealer	53.71	(31.23)	84.83	(40.68)	110.16	(9.46)
Maturity	5.18	(71.66)	3.63	(42.57)	1.67	(0.85)
Coupon	−71.50	(−96.55)	−44.19	(−39.31)	−53.76	(−0.96)
Coupon Zero or Missing	−449.42	(−110.44)	−324.67	(−51.58)	−313.30	(−1.00)
Age	0.72	(4.76)	0.46	(2.70)	0.77	(0.72)
Transaction Frequency	−37.30	(−22.39)	0.72	(0.42)	−0.05	(−0.08)
Issue Size	−6.93	(−28.24)	−10.52	(−23.49)	−6.82	(−1.61)
State Volume	−1.72	(−1.44)	−0.17	(−0.12)	5.12	(1.30)
State Order Imbalance	−2.92	(−0.91)	−0.25	(−0.07)	−8.88	(−1.12)
State New Issues	5.76	(3.14)	9.21	(4.19)	3.68	(1.03)
Treasury Yield	2.79	(4.10)	−17.81	(−21.57)	−26.84	(−0.90)
Treasury Range	2.49	(7.89)	5.40	(14.11)	1.87	(0.98)
	Symmetric Error Distribution					
Constant	143.94	(2271.00)	113.57	(1238.15)	84.40	(29.43)
Daily Report	0.09	(20.59)	−0.03	(−4.93)	−0.09	(−5.59)
Oct '00 - May '02	−0.21	(−34.36)	−0.16	(−16.58)	−0.26	(−4.51)
May '02 - Nov '02	−0.26	(−35.31)	−0.18	(−15.01)	−0.19	(−5.81)
Nov '02 - Jun '03	−0.25	(−34.61)	−0.19	(−16.12)	−0.22	(−13.14)
$ln(Par)$	−0.06	(−19.26)	−0.04	(−6.42)	−0.07	(−2.78)
Overnight	0.28	(48.76)	0.67	(49.70)	1.02	(1.59)
Inventory Duration	0.00	(74.78)	0.00	(74.70)	0.00	(7.73)
Split × No Interdealer	−0.09	(−12.80)	0.19	(16.07)	0.13	(2.07)
No Split × Interdealer	0.28	(46.19)	0.31	(25.41)	0.46	(8.19)
Split × Interdealer	0.14	(19.81)	0.26	(26.35)	0.48	(6.38)
	Asymmetric Error Distribution					
Constant	120.70	(1117.30)	104.94	(695.03)	42.29	(25.84)
Daily Report	−0.01	(−1.16)	−0.02	(−1.95)	−0.06	(−1.09)
Oct '00 - May '02	0.04	(2.94)	0.16	(7.40)	2.17	(2.04)
May '02 - Nov '02	0.08	(5.04)	0.27	(11.47)	2.20	(1.94)
Nov '02 - Jun '03	0.14	(8.86)	0.32	(14.13)	2.37	(1.91)
$ln(Par)$	−0.13	(−25.49)	−0.15	(−13.60)	−0.10	(−1.99)
Overnight	0.35	(30.57)	0.32	(19.48)	1.12	(2.05)
Inventory Duration	0.00	(49.92)	0.00	(46.77)	0.01	(32.21)
Split × No Interdealer	−0.07	(−5.25)	0.34	(18.10)	0.14	(2.16)
No Split × Interdealer	0.39	(36.15)	0.60	(31.25)	0.14	(0.84)
Split × Interdealer	0.33	(26.69)	0.58	(37.16)	0.13	(0.32)
Observations	345,189		128,757		187,509	

Table 11 reports the parameter estimates and t-statistics in parentheses for the unrestricted model for different par ranges. The model includes fixed effects for inclusion of the bond issue in the Daily Report during the last week, fixed issuer effects (not reported) and fixed effects for regulatory changes in reporting requirements. The sample period is May 2000 - June 2003.

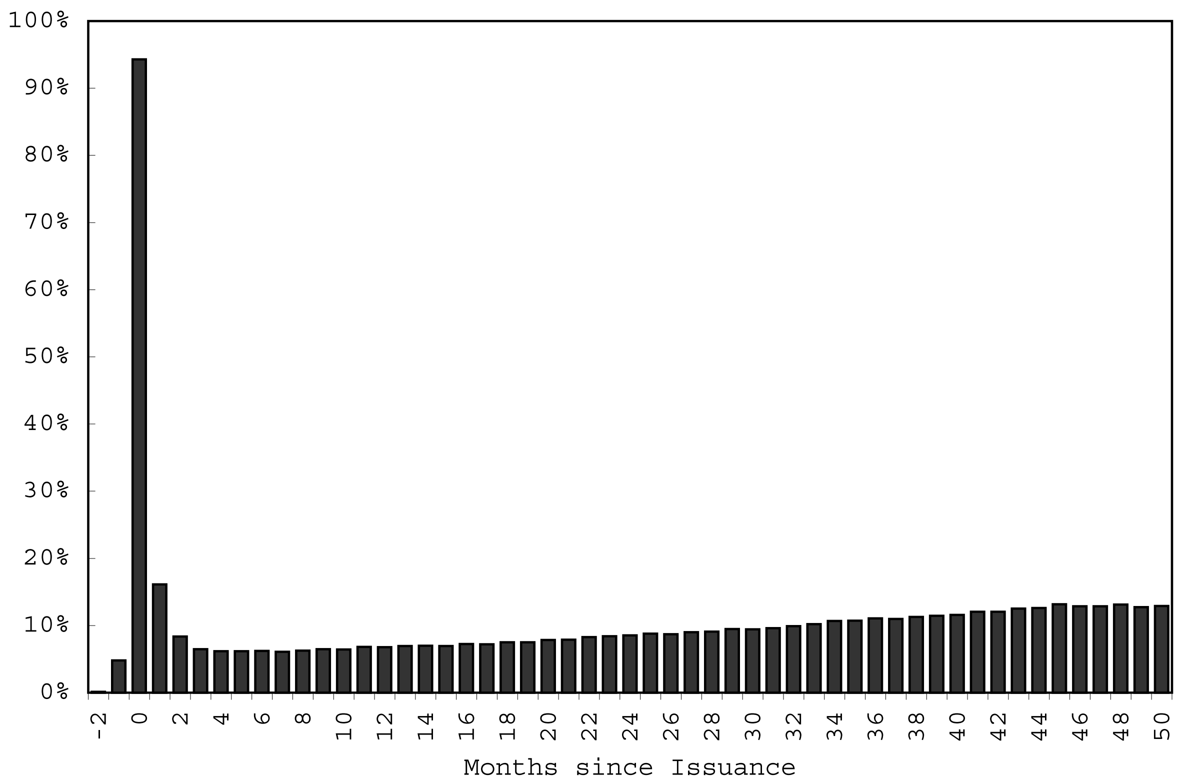


Figure 1: Average probability of trade in a month

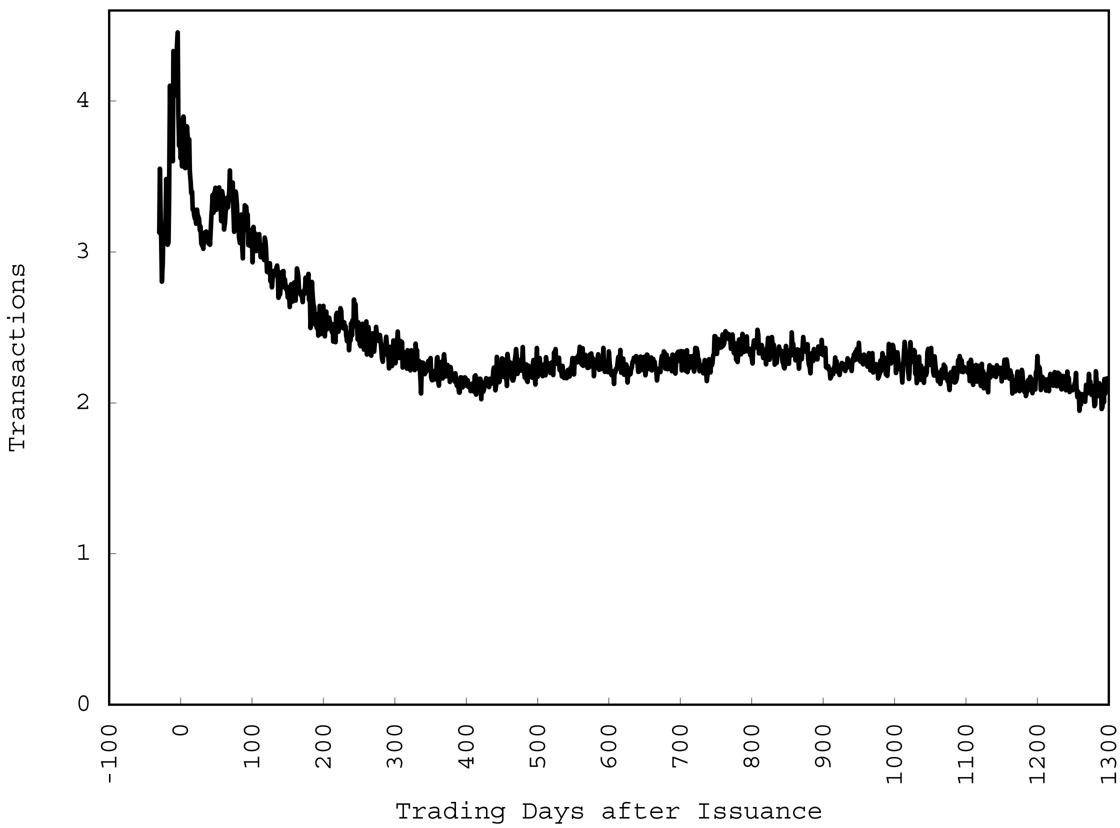
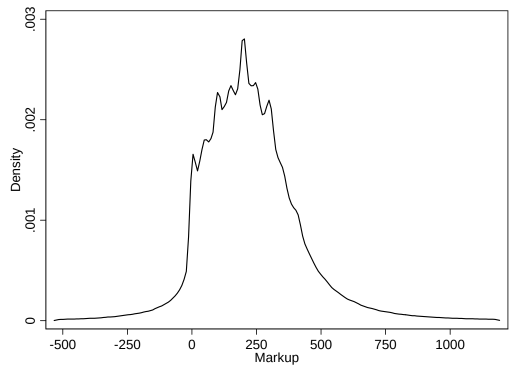
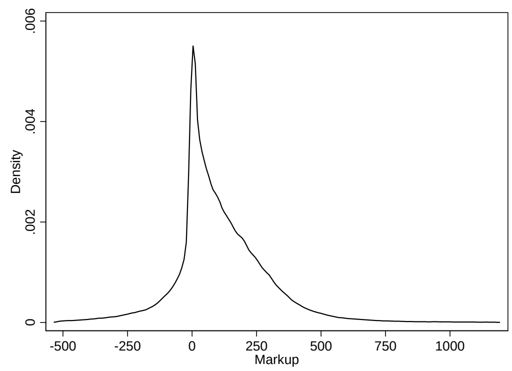


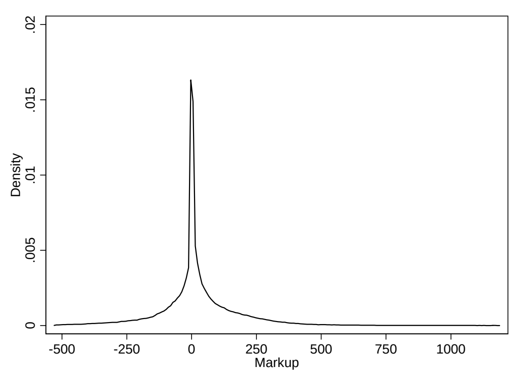
Figure 2: Average number of trades per day conditional on the bond trading on that day.



(a) $Par \in (0, .1)$



(b) $Par \in [.1, .5)$



(c) $Par \in [.5, \infty)$

Figure 3: Distribution of net markups for different transaction sizes. The distributions are estimated using Epanechnikov kernels with the Silverman automatic bandwidth selection.

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