Automation versus Intermediation:
Evidence from Treasuries Going Off the Run

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Abstract

This paper examines the choice of trading venue by dealers in U.S. Treasury securities to determine which services provided by human intermediaries are difficult or impossible to replicate in a fully automated trading system. When a Treasury security goes "off the run" its trading volume drops by more than 90%. This decline in trading volume provides a controlled event that allows us to test whether an intermediary's knowledge of the market and its participants can uncover hidden liquidity and facilitate better matching of customer orders in thin markets. Consistent with this hypothesis, the market share of electronic intermediates falls from 80% to 12% when securities go off the run.

1. Introduction

Electronic trading systems have been steadily increasing their share of securities trading in almost all financial markets. As the amount of automation in financial markets increases, it is natural to ask what services human intermediaries provide that are difficult or impossible to replicate in a fully automated trading system. The existing literature suggests that human intermediaries play at least two important functions. First, an intermediary's knowledge of the market and its participants may uncover hidden liquidity that facilitates quicker and more efficient matching of customer orders (Grossman (1992)). The value of this pure matching function will be greater when trading volume is low and matches are difficult to find. Second, when information asymmetry is high, the repeated interaction between an intermediary and its customers allows the intermediary to protect itself against informed trades and offer better prices to its customers (Seppi (1990)). These two factors explain, for example, why electronic communications networks (ECNs) have a greater market share for the largest and most actively traded Nasdaq stocks while Nasdaq market makers have a larger share in smaller, less liquid stocks with greater information asymmetry (Barclay, Hendershott, and McCormick (2003)), and why NYSE specialists have higher participation rates in smaller, less liquid stocks (Madhavan and Sofianos (1998)).

The pure matching function of human intermediaries and their ability to manage the adverse selection problem typically reinforce each other. Stocks of smaller companies generally have lower trading volume, greater information asymmetry and more adverse selection. The greater adverse selection drives liquidity traders out of the market, which makes the security even more thinly traded and more illiquid. Because these two factors are positively correlated, prior research has not attempted to examine separately either source of value created by human intermediaries.

In this paper, we examine the choice of trading venue by dealers in U.S. Treasury securities. When the U.S. Treasury issues a new security (for example, a 2-year, 5-year, or 10-year note), the new security is said to be "on the run" and is very actively traded. Several Treasury securities have average daily trading volume comparable to all U.S. common stocks combined. As a new security comes on the run, the previously issued security of the same maturity goes "off the run" and its trading volume drops by more than 90%. Thus, U.S. Treasury

securities that go off the run allow us to control for small potential differences in information asymmetry and examine the pure matching function of human intermediaries in thick and thin markets.

The majority of interdealer trades in U.S. Treasury securities are conducted through interdealer brokers (IDBs). Several of these IDBs operate completely automated electronic trading systems while other IDBs operate voice-based systems. Electronic brokers provide open limit order books with a variety features that can be accessed directly by the traders.[1] Voice brokers also provide open limit order books. However, with voice brokers, orders are placed and trades are executed over the telephone. Interaction between the dealer and the broker allows the broker to collect additional market information and provide additional services to its customers. By examining the dealers' choice of trading venue, we are able to determine when these additional services are most valuable.

To understand the nature of the competition between voice and electronic brokers, we construct a model in which traders search for a counter party for their trade. Our model differs from most traditional microstructure models in several important respects. First, most microstructure models focus on the effects of trading and information asymmetry in the price discovery process. Because payoff relevant information asymmetry plays only a small role in our setting, we abstract from those issues.[2] Instead, we focus on the role of brokers in the pure search process that matches buyers and sellers. Second, microstructure models typically involve a specialist or market maker who trades on its own account and profits from the bid-ask spread. In contrast, we examine a brokered market in which brokers charge a commission for matching buyers and sellers, but do not take a proprietary position in the traded security. Although brokered markets are the primary mechanism for trading many financial instruments, relatively few papers examine them.[3]

In our model, traders have a liquidity demand for trading a given security. Each period, traders enter the market and enlist a broker to help them search for a counterparty to their trade.

[1] Often they allow bilateral negotiation of quantity, but not price (see, for example, Boni and Leach (2004)).
[2] We assume that information asymmetry concerning nominal cash flows does not change when a Treasury security goes off the run. Non-payoff relevant information, such as dealer inventories or other market conditions, can be affected. See Cao, Evans, and Lyons (2003).
[3] The distinction between organized exchanges and alternative trading systems run by brokers has steadily blurred over time.

The likelihood of finding a match and consummating a trade depends on the matching technology employed by the broker. Traders face both an explicit trading cost in the form of a commission charged by their broker and an implicit trading cost if there is any delay in finding a match. In an active market, finding a match is quick and easy. In more thinly traded securities, finding a match is more difficult and time consuming.

Voice and electronic brokers supply similar trade-execution services. However, by collecting additional market information, voice brokers can find matches more quickly than electronic brokers. The human interaction that allows voice brokers to collect market information is costly. So in our model, as in practice, voice brokers charge higher commissions than electronic brokers. The benefits of voice brokers' better matching technology decline as markets become more active and matches are easier to find. Thus, our model predicts that the voice brokers' market share will increase for more difficult trades in less liquid securities and will decline for easier trades in more liquid securities.

In our model, voice brokers provide better matching of difficult customer orders. In practice, the information obtained by voice brokers that facilitates these better matches is referred to as "market color." In contrast to the more traditional information about future cash flows, market color typically involves soft or qualitative information about short-run variation in supply and demand. For example, a trader with a large order to buy a particular Treasury security will not want to reveal the full size of the order because revealing this information will place him at a competitive disadvantage. Instead, the trader will break up the order, revealing only part of it at any given time. If the trader calls a voice broker to place a limit order, the voice broker naturally will ask whether there is more size behind the original order. Although the trader still may not reveal all of his information, more information is likely to be conveyed. For example, the trader may reveal that there is in fact substantial size behind this order. This additional information will be conveyed because there is repeated interaction between the broker and the trader, and the trader trusts that the broker will reveal the information only to a natural counterparty who has substantial size to sell. The broker, understanding the market and his customer, can interpret this qualitative information and bring together natural counterparties for difficult trades who otherwise would struggle to find each other.

As the fully automated trading systems evolve, they have added features that attempt to replicate the services supplied by voice brokers. For example, a trader with a large order to fill can use an auto-refresh feature to replace a limit order whenever it is executed, a reserve size feature to indicate additional demand, and a negotiation feature to directly negotiate large trades with or without anonymity. Nevertheless, the continued success of voice brokers in certain segments of the market indicate that the electronic systems have note yet been able to capture and exploit all of the market color that makes voice brokers successful in their primary markets. There still appear to be certain types of information that traders convey to a voice broker over the telephone that they are unwilling or unable to convey in a fully automated trading system.

As noted above, when a Treasury note goes off the run, its trading volume declines by more than 90%. This large, exogenous shock to trading volume, which is not accompanied by any significant shift in payoff relevant information asymmetry, allows us to test the predictions of our model. We find that when Treasury securities are on the run, the electronic brokers' market share is 80%. When a security goes off the run, electronic brokers' market share falls to 12%. Regression analysis indicates that this shift in the preferred trading venue cannot be explained by changes in the return volatility, announcements of macroeconomic news, trade sizes, or the identities of the traders. Larger trades and trades by dealers with large daily order imbalances are less likely to be executed by electronic brokers, suggesting that these circumstances increase the value of voice brokers' services. These results also hold for Treasury bills and for repos on Treasury notes.

The remainder of the paper is organized as follows. Section 2 provides an overview of interdealer trading in the U.S. Treasury market. Section 3 reviews related literature. Section 4 provides a theoretical model for the choice of trading venue with fully automated electronic trading systems and human intermediaries. Section 5 provides a general description of our data. Section 6 examines the event of going off the run for Treasury notes. Sections 7 and 8 analyze the choice of trading venue for Treasury notes. Sections 9 and 10 perform similar analyses for repos on Treasury notes and Treasury bills. Section 11 concludes the paper.

2. Interdealer Brokerage and Trading in U.S. Government Securities

Securities dealers are financial intermediaries that provide liquidity in financial markets by standing ready to buy or sell traded securities at any time. In the market for Treasury securities, dealers purchase the securities directly from the Treasury and resell them to investors. Dealers also make a secondary market in these securities by buying and selling them both before and after they are issued. Treasury securities are issued periodically and a security is said to be on the run from issuance until the issuance of the next security with the same maturity.

Through the normal course of market making and/or proprietary trading, a dealer's inventory of a particular Treasury security may become greater or less than desired. In these circumstances, dealers often trade with each other to rebalance their inventories. Interdealer trades of Treasury securities almost always occur though an interdealer broker or IDB.

Unlike dealers, IDBs generally do not buy or sell securities on their own account. They simply match dealers who want to buy with dealers who want to sell. Dealers can trade passively through an IDB by submitting a limit order, or they can trade aggressively by hitting a standing limit order. In either case, because the IDB simply matches the buyer with the seller, the IDB does not profit from the bid-ask spread. Instead, it profits by charging a commission on each trade it is able to broker.

Historically, the IDB market operated strictly over the telephone. If one dealer wanted to trade with another, it would pick up the phone and speak with an IDB. During this conversation, the dealer would learn about the limit orders held by the IDB and decide whether to accept one or more of these offers, place a limit order of its own, or do nothing. As technology improved, IDBs allowed dealers to view their limit orders directly on a computer screen. Subscribing dealers now have continuous access to information about the limit orders held by an IDB without the need to call that IDB on the telephone. In voice-based systems, however, even though a dealer can see the passive orders on its computer screen, it still must call the IDB on the telephone if it wants to place a limit order or hit an existing order.

Recently, several IDBs developed platforms for pure electronic trading in Treasury securities. In addition to a computer screen that displays the existing passive orders, dealers were also provided a keyboard that they could use to enter limit orders or hit existing orders directly.

Of the more than 30 active IDBs reported by the Bond Market Association (2001), three trading platforms, owned by Cantor Fitzgerald, BrokerTec, and ICAP, dominate pure electronic trading in the Treasury IDB markets.[4]

On electronic platforms, buyers are matched with sellers and trades are executed with no human intervention by the IDB. Thus, electronic trading platforms have a lower marginal cost per trade and charge lower marginal commissions. However, when a dealer calls a voice broker, the voice broker may collect more information than just the price and quantity to which the dealer is willing to commit. This additional qualitative information, which often is referred to as "market color," can be valuable to the voice brokers' customers because it allows the broker to match natural counterparties that otherwise would have difficulty finding each other. The better matching of customer orders compensates the dealers for the higher commissions charged by the voice brokers.

Market color can best be described as non-payoff relevant information about short-lived variations in supply and demand that voice brokers collect from interactions with their customers. There is no reason to believe that there are any significant differences in the payoff relevant information about on and off the run Treasury securities. However, because trading volume declines by more than 90% when a Treasury security goes off the run, the non-payoff relevant information about supply and demand is likely to by much more valuable to dealers attempting to trade the off the run securities. Because matching traders is likely to be more difficult in the less liquid off the run securities, traders are more likely to pay the voice brokers' higher commissions for the better matching services when trading these securities. The search model in this paper can be thought of as a metaphor for the cost/value tradeoff of non-payoff information at different levels of volume.

[4] Cantor Fitzgerald differs from BrokerTec and ICAP in several important respects. First, prior to September 11, 2001 Cantor Fitzgerald offered both voice and electronic brokerage services. Our data do not differentiate different between voice and electronic trading within an individual IDB. However, our results are unchanged if we examine only the period from October 2001 to November 2002 when Cantor Fitzgerald offered only electronic brokerage services. Our results are also unchanged if we discard the week of September 11, 2001. Second, Cantor Fitzgerald operated as both an IDB and a securities dealer, and thus sometimes executed trades on its own account. If we observed a trade between Cantor and another dealer, we assumed that Cantor was functioning as an IDB. If we observed a trade between Cantor and another IDB, we assumed that Cantor was functioning as a dealer.

The differences in the trading systems and corresponding differences in the level of services suggest that voice and electronic trades are likely to vary in several dimensions. For example, small routine orders are more likely to be routed to electronic brokers where commissions are lower. However, because voice brokers collect more diverse market information from their customers over the telephone, it may be possible to get better execution for larger and more difficult orders using a voice broker than using an electronic broker.

3. Related Literature

Several recent studies examine the microstructure and price formation process of the U.S. Treasury market. For example, Fleming and Remolona (1999), Huang, Cai, and Wang (2002), and Green (2004) examine the effect of public announcements on trading volume and information asymmetry. Brandt and Kavajecz (2003) examine price discovery on days with no public announcements. Krishnamurthy (2002) and Goldreich, Hanke, and Nath (2003) examine the relation between bond prices, bid-ask spreads and the change in liquidity when Treasury securities go off the run.

This paper abstracts from most issues associated with price formation and focuses instead on the traders' choice of trading venue. Consequently, it is more closely related to the literature on multimarket trading. Easley, Kiefer, and O'Hara (1996) and Bessembinder and Kaufman (1997) find that the regional exchanges skim off the least informed and most profitable trades from the primary exchange. Barclay, Hendershott, and McCormick (2003) find the reverse, however, when the secondary market is purely electronic. Barclay, Hendershott, and McCormick find that traders of Nasdaq stocks are more likely to use electronic platforms (ECNs) rather than traditional market makers for high volume stocks and when trading volume, stock-return volatility, and information asymmetry are high. Our results in the Treasury bond market are consistent with the finding that electronic markets are most effective for high volume securities and on high volume days.

Because we examine a brokered market, our results also relate to the upstairs and off-exchange brokered markets for equities. These markets have been modeled by Grossman (1992) and Seppi (1990) and studied empirically by Keim and Madhavan (1996), Madhavan and Cheng (1997), Smith, Turnbull, and White (2001), Booth, Lin, Martikainen, and Tse (2001), and Bessembinder and Venkataraman (2003). Because the upstairs market is used almost exclusively

by large institutional traders who trade liquid stocks in large companies, prior papers have been unable to characterize the market-wide costs and benefits of fully automated electronic markets compared with markets with human intermediaries.

The interdealer Treasury market is most similar to the interdealer foreign exchange (FX) market, which also has both voice and electronic IDBs (see Lyons (2001) for a detailed overview of the FX market). There is no comprehensive dataset for FX trading comparable to examine the choice between voice and electronic trading. What is known about the growth of electronic interdealer trading in FX, however, is consistent with our results. The active currencies, such as the dollar-euro and dollar-yen, appear to have gone almost completely electronic while the less active currencies have not (Rime (2003)).

Studies of intermediation in equity markets typically focus on trading by a specialist or dealer. Hasbrouck and Sofianos (1993) and Madhavan and Sofianos (1998) find that specialists are more active in lower-volume stocks. We use some of the same empirical methods employed in these papers, but focus on the choices of traders rather than intermediaries. Reiss and Werner (1998, 2003) analyze interdealer trading in equity markets using the now defunct London Stock Exchange's IDB market and find that risk sharing motivates interdealer trading and that dealers send their less informed orders to the anonymous IDBs.

4. Model

Most microstructure models focus on the provision of liquidity by a specialist or dealer who makes a market by buying and selling a security from her proprietary account. Although these traditional microstructure models may capture the essence of the interactions between government bond dealers and their customers, they are not descriptive of the interdealer bond market. To model the pure brokering services of IDBs, we consider a search model in which the broker simply facilitates the matching of buyers and sellers in exchange for a fee. To capture the essential features of the IDB market, we consider two brokers (voice and electronic) that provide different levels of service and therefore charge different fees. Electronic brokers simply collect orders to buy and sell and execute a trade when a match occurs. Voice brokers perform a similar service. However, voice brokers also collect additional information ("market color") that allows them to find and consummate matches that are more difficult for electronic brokers. In exchange for this greater level of service, voice brokers charge a higher fee. The purpose of the model is to

illustrate how the demand for electronic and voice brokerage services, and consequently their respective market shares, vary with the total volume of trade.

The model is based on the search and matching model by Rubenstein and Wolinsky (1987). There are two types of traders, buyers and sellers, each seeking to transact one unit. At the start of each period, buyers and sellers arrive at a given rate, λ, and fraction ϕ of the buyers and sellers choose to search for a counter party. A matching stage then begins during which each trader either finds a match (with probability $\alpha(\phi)$) or does not (with probability 1 - $\alpha(\phi)$). To model liquidity externalities we assume that the probability of finding a match is increasing the fraction of traders searching: $\alpha'(\phi) > 0$. If the traders find a match they negotiate a price, consummate a trade, and exit the market.[5] Traders who do not find a match remain in the market, wait for additional traders to arrive, and repeat this process in the following period. The value of finding a match reflects the traders' liquidity preferences, or the strength of their desires to buy or sell. Each trader's utility from consummating a trade is denoted by u, which is independent and identically distributed (i.i.d.) from a continuous distribution function $F(u)$ with non-negative support where $F(u)$ is the probability that a liquidity trader's liquidity preference is less than u.

The cost of trading consists of an explicit order-execution cost, c, and an implicit opportunity cost of searching to find a match. The opportunity cost of searching is affected by the probability of finding a match in a given period, $\alpha(\phi)$, and by the cost of search and delay within the period. When a trade is consummated, each trader receives a fraction δ of the value of her trade, where $0 < \delta < 1$. It is natural to think of δ as a discount factor reflecting the cost per period of search and delay associated with finding a match. We assume that the costs of search and delay are related to the number of traders in the market and that these costs decrease in the thickness of the market, $\delta'(\lambda) > 0$. This captures the notion that when there are many traders in the market, matches can be found quickly and easily. When there are fewer traders, finding a match is more difficult.[6] Because the implicit costs of trading and liquidity externalities are

[5] Bargaining between buyer and seller is non strategic as in Rubenstein and Wolinsky (1987), Diamond and Maskin (1979), Diamond (1982), and others, so each trader gains their liquidity preference.

[6] Another way to think about this is in steady state the probability of a match times the number of traders in the system equal the arrive rate of new traders (Rubenstein and Wolinsky (1987)). Thus, faster arrival of new traders implies a greater number of traders in the system, and more traders in the system reduces the length of time between matching periods. Where convenient we will suppress the fact that δ depends on λ.

determined by two parameters, $\alpha(\phi)$ and $\delta(\lambda)$, we can separate differences in the matching technology, the role of traders choices, and the effect of aggregate liquidity.

Rubenstein and Wolinsky (1987) show that in this matching process, the price negotiated between buyer and seller is independent of the matching probabilities and the implicit costs of trading. Given this result and our symmetry assumption regarding buyers and sellers, we can recursively write the expected surplus of a trader with liquidity preference u as

$$V(u) = \delta(\alpha(\phi)(u-c) + (1-\alpha(\phi))V(u)), \tag{1}$$

where the first term on the right hand side of (1) represents the gains from trade conditional on finding a match this period and the second term represents the gains from continuing to search if a match is not found. Solving (1), the expected gains for a trader with liquidity preference u are given by

$$V(u) = (u-c)\frac{\delta\alpha(\phi)}{1-\delta(1-\alpha(\phi))}. \tag{2}$$

The expected gains in (2) can be seen as the net value of trading (u - c) times the expected implicit costs of searching. It is also evident that traders with value great than c will participate and, therefore, $\phi = 1 - F(c)$. The implicit cost of searching is nonlinear in both the discount factor, δ, and the probability of a match, $\alpha(\phi)$. Thus, the benefits of collecting additional information to increase the probability of a match are highest when the discount factor is low or, equivalently, when the market is thin.

As described above, there are two IDBs, voice (v) and electronic (e). By utilizing human intermediation voice brokers facilitate matches that would not be found in the electronic system. All traders eventually trade in this model, but through additional service and information, voice brokers increase the probability of a trade in any given period ($\alpha_v(\phi) > \alpha_e(\phi)$). Because this service is costly to provide, voice brokers also charge a higher commission ($c_v > c_e$). Therefore, assuming that fraction ϕ_v of the traders use the voice IDB and fraction ϕ_e use the electronic IDB, we can express the traders' expected gains from using each system as

$$V_e(u) = (u - c_e)\frac{\delta\alpha_e(\phi_e)}{1-\delta(1-\alpha_e(\phi_e))} \quad \text{and} \quad V_v(u) = (u - c_v)\frac{\delta\alpha_v(\phi_v)}{1-\delta(1-\alpha_v(\phi_v))}. \tag{3}$$

Traders with less intense liquidity demands (lower values of u) will prefer the electronic system because it is cheaper. The decisions of traders with more intense liquidity demands are dominated by the implicit costs of search. If the voice system provides a higher probability of a match each period ($\alpha_v(\phi_v) > \alpha_e(\phi_e)$) and, therefore, lower implicit trading costs, traders with higher values of u will choose the voice system. In equilibrium, there is a critical value u^* such that traders with $u < u^*$ will use the electronic system and traders with $u > u^*$ will use the voice system. Assuming that the highest-value traders prefer the voice system, the fraction of traders using the electronic and voice system are $\phi_e = F(u^*) - F(c_e)$ and $\phi_v = 1 - F(u^*)$ respectively. As u^* increases, traders will switch from the electronic system to the voice system and vice versa. Therefore, u^* will reflect the market share of the voice system. The critical value for u^* can implicitly be written by equating the gains (3) and solving for u^*

$$u^*(c_v, c_e, \alpha_v(\phi_v), \alpha_e(\phi_e), \delta) = \frac{\alpha_v(\phi_v)c_v - \alpha_e(\phi_e)c_e}{(\alpha_v(\phi_v) - \alpha_e(\phi_e))} + \frac{\delta\alpha_v(\phi_v)\alpha_e(\phi_e)(c_v - c_e)}{(1-\delta)(\alpha_v(\phi_v) - \alpha_e(\phi_e))}. \tag{4}$$

While (4) implicitly characterizes possible equilibria, determining u^* depends upon traders' beliefs about whether other traders use the voice or electronic system. If the probability of a match in each trading system is independent of the fraction of trades in that market ($\alpha_e(\phi_e)$ and $\alpha_v(\phi_v)$ are constants that do not depend on ϕ_e or ϕ_v), then most of the comparative statics on u^* are straightforward. The market share on each system will increase in the probability of finding a match, α, and decrease in the cost of executing a trade, c, on that system. The relative effect of the size of the market is more subtle. Differentiating the critical value u^* with respect to λ gives

$$\frac{\partial u^*(c_v, c_e, \alpha_v, \alpha_e, \delta(\lambda))}{\partial\lambda} = \frac{\alpha_v\alpha_e(c_v - c_e)}{(1-\delta(\lambda))^2(\alpha_v - \alpha_e)}\delta'(\lambda) > 0. \tag{5}$$

Increasing the size of the market, λ, reduces the implicit search costs by reducing the time required to find a match ($\delta'(\lambda) > 0$). Because it is easier to find a match when the market is thick, fewer traders are willing to pay the higher cost for the voice system's better matching

technology. The model predicts that when the market is thick and trading volume is high, electronic IDBs will have the dominant market share. When the market is thin and trading volume is low, the voice IDBs will have the dominant market share.

If the probability of a match on each trading system depends on the fraction of traders that use that system ($\alpha_e(\phi_e)$ and $\alpha_v(\phi_v)$ are not constants), then u^* will depend on traders' beliefs about how many other traders will use the voice and electronic systems. Under complete information and common knowledge about other traders' actions, multiple equilibria can result from (4). Deriving comparative statics for games with multiple equilibria requires focusing on a particular equilibrium, which often is problematic in situations with network or liquidity externalities.

Fortunately, progress has been made on equilibrium refinement techniques in games with strategic complementarities. Morris and Shin (2003) refer to these as global games and provide an excellent overview. The essence of the approach is that if each trader faces some "noise" about payoffs – in this case uncertainty about which system other traders will choose – a unique equilibrium can be found.[7] Frankel, Morris, and Pauzner (2003) show this result in a setting with a continuum of players into which our model can be translated.

Because our primary focus is empirical, a discussion of equilibrium refinement techniques is primarily a check on the robustness of our model's predictions. However, consistent with the comparative statics results derived above, if we allow liquidity externalities and apply the global games techniques, the unique equilibrium will be with electronic IDBs having the dominant market share when the market is thick and voice IDBs having the dominant market share when the market is thin. This results occurs because liquidity externalities (reflected in the fraction of traders that choose a given trading system) are more important in when markets are thin, while the commission costs of the different systems is invariant to market size.

[7] The five properties/regularity conditions of the payoff function needed for uniqueness are: action monotonicity, state monotonicity, strict Laplacian state monotonicity, limit dominance, and continuity. See Morris and Shin (2003) for details.

5. Data and Descriptive Statistics

Our data are derived from clearing records submitted to the Fixed Income Clearing Corporation (FICC).[8] The FICC provides trade comparison, netting, and settlement of transactions between member firms in eligible Treasury bills, notes, bonds, and zero-coupon securities. The data contain virtually all transactions between member firms from January 2001 through November 2002, and include the identities of the buyer and seller, the identity, amount and price of the traded security, the trade date, settlement date, and other miscellaneous information about the transactions.[9]

Trades that involve an IDB appear twice in our data, once as a trade between the buyer and the broker and once as a trade between the seller and the broker. To avoid double counting the brokered trades, for most of our analysis we discard trades for which the reported seller is an IDB. Finally, the FICC does not accept trade records larger than $50 million par traded. Thus, if two dealers trade $150 million of a given Treasury security, the trade will be reported to the FICC as three trades of $50 million each.[10] Consequently, if on a given day we see multiple $50 million trades of the same security, at the same price, between the same buyer and seller, we cannot determine whether these represent one large trade or multiple smaller trades. In our analysis, we treat these observations as one large trade. However, none of our results are sensitive to this assumption.

Table 1 summarizes the daily interdealer trading activity in 2-year, 5-year, and 10-year U.S. Treasury securities.[11] We focus on these securities because each of them was issued by the Treasury on a regular schedule during our sample period. The monthly issue of 2-year notes and the quarterly issue of 5-year and 10-year notes provide a large number of days on which these securities were both on and off the run. The combined trading volume in the 2-year, 5-year, and 10-year notes is greater than $88 billion per day, which is comparable to the trading volume in

[8] The FICC, which began operations on January 1, 2003, was formed by the merger of the Government Securities Clearing Corporation (GSCC) and the MBS Clearing Corporation (MBSCC).

[9] Because we are using settlement records, we do not have bid and ask quotations and we do not know the time of day when the transactions occurred. The FICC data contain records for transactions between closely related entities, which we discard. We also discard a small fraction of transactions for which there is no broker. The fraction of FICC transactions which we exclude is roughly constant on and off the run, and the paper's results are not sensitive to whether or not we exclude these transactions.

[10] About 7% of our trade records indicate a trade of exactly $50 million.

[11] We classify securities by their maturity at issue. Because the results are similar across maturity, our findings are not sensitive to alternative classifications.

U.S. equity markets. Trading is heavily concentrated in the on-the-run notes. The three on-the-run notes account for more than $75 billion of the $88 billion daily trading volume. There are approximately 59 off-the-run securities trading at any point in time that account for about $14 billion of daily trading volume in aggregate. The average trading volume per security that is off the run is less than 1% of the trading volume of the on-the-run security. The pattern of trading volume for on-the-run and off-the-run securities is similar for the 2-year, 5-year, and 10-year notes.

[Insert Table 1 Here]

As predicted by our model, the market share for electronic brokers is much higher for on-the-run securities than for off-the-run securities. For all notes combined, the market share of electronic brokers is 80.7% for on-the-run notes and 11.7% for off-the-run notes. This difference is consistent across the maturity spectrum. For 2-year notes, the electronic brokers' market share falls from 75.2% to 9.9%, for 5-year notes, their market share falls from 83.5% to 8.5%, and for 10-year notes, their market share falls from 84.5% to 8.9% when the securities go off the run. The standard errors of the daily averages across the 475 trading days in our sample are small.

The average voice trade is about twice as large as the average electronic trade in all three notes. If larger trades have a higher liquidity preference, then this is also consistent with the prediction of our model. Larger trades are also likely to be more difficult to match, and thus benefit more from the services provided by a voice broker.

Most recent studies of the Treasury market use data from GovPX that consolidates trade and quote information from a subset of the voice IDBs. Fleming (1997) reports that this represents about two-thirds of interdealer broker trading. Researchers using GovPX also typically note that one of the largest IDBs not in GovPX, Cantor Fitzgerald, specializes in the longer end of the yield curve. Our data show that GovPX's coverage of overall interdealer trading is between 20% and 30% for all maturities in 2001 and 2002. Because GovPX currently reflects only a small and narrow segment of the Treasury market, it may no longer provide a representative picture of this market.

6. The Choice of Trading Venue as Securities Go Off the Run

Table 2 lists the 2-year, 5-year, and 10-year notes that were both on and off the run during our sample period. A new 2-year note was issued each month during our sample period, which gives us 23 events in which a 2-year note went off the run. The 5-year and 10-year notes were issued approximately once per quarter during our sample period. On 8 of these occasions, the on-the-run 5-year or 10-year note was "re-opened" and did not go off the run (see Fleming (2002) for a discussion of re-openings). Thus, there are 5 events in which a 5-year note went off the run and 5 events in which a 10-year note went off the run.[12]

[Insert Table 2 Here]

Figure 1 shows the average daily trading volume for the 2-year, 5-year, and 10-year Treasury notes that went off the run during our sample period. The daily trading volume is averaged across securities of the same maturity on a given date in relation to the off-the-run date (the auction date for the subsequent note with the same maturity). As seen in Table 1, all three maturities trade between $20 and $30 billion per day when they are on the run. Trading volume appears to have a day-of-the-week effect that could be induced by the schedule of government macro economic announcements. On the day that these securities go off the run, trading volume falls by over 90% and remains at this new lower level.[13]

[Insert Figure 1 Here]

The dramatic decline in trading volume for securities that go off the run provides an exogenous test for our model's prediction that, other things equal, more active securities should have a higher fraction of trading on electronic IDBs. Our data are well suited to this test. In almost all other markets, both cross-sectional and time-series differences in trading volume are related to differences in the information environment. In contrast, the event of going off the run has no unpredictable information content.

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[12] During our sample period only one 30-year bond was issued and, thus, only one 30-year bond (CUSIP 912810FM5) went off the run. The 30-year bond that went off the run has the same trading characteristics as 2-year, 5-year, and 10-year notes that go off the run during our sample period. Because there is only one such bond, however, we do not include it in the analysis that follows.

[13] Fleming (2002) shows that bid-ask spreads increase from roughly 0.5 basis point to 2 basis points when Treasury securities go off the run.

For the 2-year, 5-year, and 10-year notes depicted in Figure 1, Figure 2 graphs the average daily market share on the different trading venues for each day in relation to the off-the-run date. For the 2-year, 5-year, and 10-year notes, the electronic broker market share is between 80% and 90% on each day that the security is on the run. When these securities go off the run, electronic brokers' market share falls to about 10% immediately and permanently.

[Insert Figure 2 Here]

7. Market Share Regressions

In this section, we examine the extent to which the observed shift in market share from electronic brokers to voice brokers when Treasury securities go off the run can be explained by changes in market conditions that might affect the choice of intermediary. We first calculate the daily market share of electronic IDBs for the 2-year, 5-year, and 10-year U.S. Treasury notes. Similar to Madhavan and Sofianos' (1998) specification of NYSE specialist participation rates, in Table 3 we regress these daily percentage market shares on dummy variables set equal to one if the security has a 5-year maturity (*5-year*), if the security has a 10-year maturity (*10-year*), if there is a macroeconomic announcement that day (*macro*),[14] and an interaction variable set to one if there is a macroeconomic announcement that day and the security is on the run (*macro*on-run*). We also include several independent variables in this regression capturing daily trading conditions: a measure of volatility (σ) equal to the percentage difference between that day's highest and lowest transaction prices,[15] the logarithm of the average trade size on that day in that security (*log(trade size)*), and the logarithm of the total dollar trading volume on that day in that security (*log(volume)*). Finally, we include a dummy variable set equal to one if the security is on the run (*on-run*), or an interaction variable equal to the on-the-run dummy variable times the logarithm of the total dollar trading volume on that day in that security (*on-run*log(volume)*). The regressions are estimated using all 2-year, 5-year, and 10-year notes and using only those notes that were both on and off the run during some part of our sample period.

[14] We us a subset of the macroeconomic announcements in Green (2003): monthly reports on employment, producer price index, consumer price index, durable goods orders, retail sales, housing starts, and U.S exports and imports. At least one of these announcements occurs on approximately one third of the days in our sample period.

[15] Even if the true volatility of on-the-run and off-the-run securities is identical, this measure of observed volatility could be higher or lower for on-the-run securities because of more frequent trading or narrower bid-ask spreads. In our data, this measure of volatility is slightly lower for off-the-run securities than for on-the-run securities and the regression results are not sensitive to its inclusion.

In our panel, correlated trading shocks may occur in multiple securities on the same date causing contemporaneous correlation in the error terms across securities. Therefore, to calculate standard errors controlling for both contemporaneous correlation and heteroskedasticity, we allow for arbitrary correlation across securities at each date. Let X_t , ε_t, and Ω_t denote respectively a single cross-section of explanatory variables, the corresponding residual vector, and the associated error covariance matrix. Assuming independence over time, the OLS estimator has variance: $(X'X)^{-1}X'\Omega X(X'X)^{-1} = (X'X)^{-1}\sum_t (X_t'\Omega_t X_t)(X'X)^{-1}$; substituting fitted values gives the following asymptotic estimate of the variance-covariance matrix as the number of time periods grows large: $(X'X)^{-1}\sum_t (X_t'\hat{\varepsilon}_t\hat{\varepsilon}_t'X_t)(X'X)^{-1}$.

[Insert Table 3 Here]

Consistent with the results in Figure 2, the small coefficients on the 5-year and 10-year dummy variables indicate that the market share of electronic IDBs is similar across maturities. In addition, the small coefficients on the macro and volatility variables indicate that the choice between voice and electronic IDBs is not affected by macroeconomic announcements or bond-price volatility. Barclay, Hendershott, and McCormick (2003) find that equity trades are more likely to occur on ECNs when information asymmetry and stock-return volatility are high. Our results in the Treasury market may reflect the fact that there is less information asymmetry in the Treasuries, which reduces the benefits of speed and anonymity available to an informed trader on an electronic platform.

Our model predicts that electronic brokers will have a larger market share when trading volume is high and matches are easy to find, and voice brokers will have a higher market share when volume is low and matches are more difficult to find. Thus, the volume related variables provide the direct tests of the model's predictions. Although trade size is not directly considered in the model, we find that the market share of electronic IDBs is smaller when the average trade size is larger. If a larger average trade size indicates that traders have more intense liquidity demands, or if larger trades are more difficult to match, then this result is consistent with our model's prediction that voice brokers will have a larger market share when their better matching ability is most valuable to traders. Electronic IDBs also have higher market share on days with

higher total trading volume in the traded security. This result confirms the most direct prediction of our model and indicates that the benefits of human intermediation become progressively less valuable as a security become more actively traded. Finally, the coefficients for the on-the-run dummy variable and this dummy variable multiplied by the logarithm of total trading volume are large and significant. After controlling for the various security characteristics and market conditions in these regressions, we find that when a security goes off the run, the electronic brokers' market share declines by 40 to 55 percentage points. This is the most compelling support for our theory. When a security goes off the run, its trading volume immediately declines by more than 90% and much of the liquidity in that security disappears. Since it is now much more difficult to find a natural counterparty for a trade, the majority of trades immediately move off of the electronic platform and into the voice market where traders can take advantage of the market information and trade-matching services of the voice broker.

The qualitative results in Table 3 are the same if we estimate the regressions using all of the securities in our sample or if we use only those securities that are both on and off the run during our sample period. The regression R^2 is much lower for the sample including all securities, however. The difference between these two samples is caused by the incremental securities that have been off the run for a long period of time. These securities have very low trading volume, often trading only once or twice per day if at all. If there is only one trade on a given day, the electronic market share will be either 0% or 100%. Therefore, although trades in these incremental securities are very likely to occur with a voice broker, they add substantial noise to the regression and lower the regression R^2.

The linear specification of the regressions in Table 3 provides coefficients that are easily to interpret. However, we also examine specifications that account for the fact that market shares are constrained between zero and one. Re-estimating the daily market share regressions using a logistic specification provides coefficients with the same sign and similar statistical significance as reported in Table 3 and are not reported.

8. Transaction-Level Regressions

The market-share regressions in Table 3 confirm our prediction that the market information obtained by voice brokers will be most valuable to traders when trading volume is low and the market is less liquid. There are two natural alternate hypotheses for our results. First,

the choice of intermediary may be driven by the information structure in the market. Second, the choice of intermediary may be driven by clientele effects if different dealers specialize in on-the-run and off-the-run issues and if these dealers have different preferences for voice and electronic brokerage. We discuss these alternate hypotheses below.

Barclay, Hendershott, and McCormick (2003) find that equity traders are more likely to use an ECN when stock returns are volatile and information asymmetry is high. Thus, the shift in market share from electronic to voice brokers could be explained by a dramatic shift in the information structure of the Treasury market when securities go off the run. We reject this explanation for several reasons. First, the total amount of information asymmetry is much less in the Treasury market than in the equity markets. Second, there is no reason to believe that the issuance of a new Treasury security would materially affect the payoff relevant information asymmetry associated with the previous issue. Finally, we control for bond-price volatility in the regressions in Table 3, and this variable does not have a significant effect on the electronic brokers' market share in any of our regressions. Therefore, we conclude that the shift from electronic to voice brokers when securities go off the run is not caused by a shift in the information structure in the market.

As noted previously, when Treasury securities go off the run, their trading volume declines by more than 90%. This dramatic shift in the nature of the market could cause a shift in the clientele of dealers who trade the on-the-run and off-the-run issues. Therefore, we examine the extent to which our results are affected by changes in dealer clienteles. To conduct this investigation, we move from the daily market share regressions to a transaction-level analysis.

Table 4 reports the estimated coefficients from a probit regression where the dependent variable is equal to one if a trade occurred on an electronic platform and zero otherwise. As in Table 3, we regress these indicators on dummy variables set equal to one if the security has a 5-year maturity (*5-year*) or a 10-year maturity (*10-year*). We also include our measure of volatility (σ) equal to the percentage difference between that day's highest and lowest transaction prices. However, because the macroeconomic announcement variable had no impact on the market-share regressions, we omit it from this regression. Because the probit regressions are estimated at the transaction level rather than the daily market share level, we replace the daily average trade size with the size of each trade (*log(trade size)*). We also add a fixed effect for each dealer, the

logarithm of the total dollar trading volume by the dealer in that security on that day (*log(dealer volume)*), and the logarithm of absolute value of the dealer's net volume (buy volume minus sell volume) in that security on that day (*log(|dealer net volume|)*). In addition to the coefficient estimates, Table 4 also reports the corresponding linear probability slopes and Chi-Square statistics controlling for heteroskedasticity and for contemporaneous correlation within days.

[Insert Table 4 Here]

Consistent with the results in Table 3, the probit regressions indicate that trades are more likely to occur through electronic IDBs when the trade size is smaller, when total trading volume in the security is higher, and when the security is on the run. These results confirm our previous conclusions that the services offered and market information collected by voice brokers is most valuable when it is difficult to find a match because the trade is large or trading volume and liquidity are low. In addition, the coefficients on these variables are not affected significantly by the inclusion of dealer fixed effects. Thus, these results do not appear to be affected by a shift in trader clienteles.

In addition to controlling for market-wide effects, the transaction-level data also enable us to examine individual traders' motives for trading in a particular venue. In particular, we predict that dealers will be more likely to use voice brokers when their trades are more difficult, either because the trades are larger or because the dealers want to trade a large quantity on one side of the market. Consistent with this prediction, trades are less likely to occur with an electronic IDB when the trade is larger and when the dealer has a larger imbalance between buying and selling volume on a given day.

Finally, individual dealers can attempt to replicate some of the services provided by voice brokers by monitoring the market and gathering information about supply and demand beyond what is reported at any one time in the limit order book. In effect, such dealers internalize the brokers' services and consequently would be less willing to pay the higher voice commissions. Dealers are more likely to monitor the market closely when they are more active in a given security on a given day. Consistent with this prediction, higher dealer trading volume in a security leads to greater use of electronic IDBs. The coefficient on *log(dealer volume)* is positive and significant with or without the dealer fixed effects. However, the magnitude of the

coefficient declines significantly when dealer fixed effects are included. This suggests that larger and more active dealers generally are more likely to trade through electronic brokers.

Unlike the daily market share regressions in Table 3, the pseudo R^2s in Table 4 are larger for the "All Securities" sample than for the sample of securities that are both on and off the run. This suggests that it is easier to predict the trading venue for a security that has been off the run for a long period of time than the venue for a security that is recently off the run because securities that have been off the run for a long period of time are very likely to trade by voice.

9. Repos

In addition to the cash-market transactions analyzed above, Treasury securities are also actively traded through repurchase agreements or "repos." In a repurchase agreement, one investor sells a security to another investor and agrees to repurchase it at a specified price on a specific future date. Thus, essentially, a repurchase agreement is a collateralized loan with the traded security serving as the collateral. From the perspective of the buyer of the security, the identical transaction is referred to as a reverse repurchase agreement or "reverse repo." Repos often are overnight agreements, but can have terms as long as 30 days or more.

The varying terms of the repos complicates our analysis slightly. Our model suggests that the term of the repo could affect the choice of trading system. If the market for overnight repos is thick and the market for longer term repos is thin, then the overnight repos would be more likely to trade on the electronic system. In our data, approximately 94% of the repos are overnight repos. Thus, our results are not affected if we restrict the analysis to overnight repos only.

Figure 3 shows the average daily repo volume for the 2-year, 5-year, and 10-year notes that went off the run during our sample period. The daily repo volume is averaged across securities of a given maturity on each day in relation to the off-the-run date. While they are on the run, the 2-year, 5-year, and 10-year notes are each used as collateral for $10 to $20 billion of repo transactions per day. When they go off the run, the repo volume declines gradually over the course of several weeks to approximately $5 to $10 billion dollars per security per day. Although the repo volume is significantly lower than the cash-market volume reported in Figure 1, the trade sizes tend to be significantly larger.

[Insert Figure 3 Here]

There are several differences between the repo-market trading volume documented in Figure 3 and the cash-market trading volume documented in Figure 1. First, the repo market is significantly smaller (both in total dollar trading volume and number of trades) than the cash market. Our model predicts that this should lead to a lower overall market share for the electronic brokers in the repo market. Second, the decline in trading volume when the Treasury notes go off the run is much larger and more abrupt in the cash market than in the repo market. Our model predicts that this should lead to a less pronounced shift in the market share of electronic and voice brokerage services in the repo market when the Treasury notes go off the run. We test these predictions below.

Figure 4 graphs the market share of electronic brokers for repo transactions in the 2-year, 5-year and 10-year Treasury notes for each day in relation to the off-the-run date. While the securities are on the run, the electronic market share ranges from about 20% to about 60% with a mean of about 40%. As predicted, these market shares are considerably smaller than the 80% to 90% electronic market shares in the cash market. When the securities go off the run, the electronic market shares decline gradually to about 25%.

[Insert Figure 4 Here]

Table 5 reports the estimated coefficients from a probit regression where the dependent variable is set equal to one if a trade occurred on an electronic platform and zero otherwise. Consistent with our analysis of the cash market, we regress these indicators on dummy variables set equal to one if the security has a 5-year maturity or a 10-year maturity. We also include our measure of volatility (σ) equal to the percentage difference between that day's highest and lowest transaction prices, the size of each trade (*log(trade size)*), a fixed effect for each individual dealer, the logarithm of the total dollar repo trading volume by the dealer in that security on that day (*log(dealer volume)*), and the logarithm of the absolute value of the dealer's net repo volume (buy volume minus sell volume) in that security on that day (*log(|dealer net volume|)*). In addition to the coefficient estimates, Table 5 also reports the corresponding linear probability slopes and Chi-Square statistics controlling for heteroskedasticity and for contemporaneous correlation within days.

[Insert Table 5 Here]

Consistent with the results from the cash market, the repo trades are more likely to occur through electronic IDBs when the trade size is smaller, when total trading volume in the security is higher, and when the security is on the run. The coefficients on these variables are not affected significantly by the inclusion of dealer fixed effects. Thus, these results appear to be driven by the chang4ing market conditions and not by a shift in trader clienteles.

Also consistent with our results from the cash market, repo trades are less likely to occur with an electronic IDB when the trade is larger and when the dealer has a larger imbalance between buying and selling volume on a given day. Finally, higher dealer repo volume in a security leads to greater use of electronic IDBs, however the magnitude of this effect declines significantly when dealer fixed effects are included. These results confirm our previous conclusion that electronic brokers provide low-cost execution for routine trades, and that voice brokers appear to provide additional services that are most valuable when executing larger and more difficult trades.

The two main differences between the results in the cash and repo markets (Tables 4 and 5) are that the intercept is smaller in the repo market (consistent with a smaller overall electronic market share in the repo market) and the coefficient on the on-the-run variable is smaller in the repo market (consistent with a smaller decline in electronic repo trading when the securities go off the run). Both of these differences are consistent with our model and the different pattern of trading in the cash and repo markets.

10. Treasury Bills

To further test the robustness of our results, we examine the trading of 13-week and 26-week Treasury bills. These securities trade actively on only one electronic IDB. Because we agreed not to disclose information about any individual market participant (such as the market share of a single IDB), we do not report these results here. However, the event-study and regression results for the Treasury bills are qualitatively similar to the results for the repos. Both trading volume and the electronic trading market share drop significantly as the bills go off the run. However, because trading volume drops by only about 75% when Treasury bills go off the run (Fleming (2002)), as compared to the drop of over 90% when the notes go off the run, the drop in the electronic market share is not as large in Treasury bills as it is in Treasury notes. Nevertheless, the coefficients from market-share regressions or transaction-level probit

regressions have the same sign and statistical significance for the bills as for the notes and repos. Therefore, we conclude that the results from 13-week and 26-week Treasury bills support the same conclusions reached in our analysis of the Treasury notes and repos.

11. Summary

As electronic trading systems steadily increase their share of securities trading in almost all financial markets, the natural question to ask is what services, if any, human intermediaries provide that are difficult or impossible to replicate in a fully automated trading system. Theory and past research suggest that human intermediation is most valuable when trading is thin and when information asymmetry is high. Because these two factors are highly correlated, prior research has not attempted to separate the sources of value created by human intermediaries.

We examine the choice of trading venue by dealers in U.S. Treasury securities. New securities are on the run and very actively traded until the Treasury issues another security of the same maturity. The existing security goes off the run and its trading volume drops by more than 90% with no significant change in informational asymmetry. This exogenous shock to trading volume allows us to examine the pure matching function of human intermediaries in financial markets in thick and thin markets. The majority of interdealer trades in U.S. Treasury securities are conducted through interdealer brokers that are completely automated electronic trading systems or open limit order books supplemented by telephone brokers. Interaction with the dealers allows the voice broker to collect additional market information and provide additional services. To understand the nature of the competition between voice and electronic brokers and determine when these additional services are most valuable, we construct a model in which traders search for a counter party for their trade.

Our model focuses on the role of brokers in the pure search process that matches buyers and sellers. Human interaction that allows voice brokers to facilitate matches faster is costly, so voice brokers charge higher commissions than electronic brokers. The benefits of voice brokers' better matching technology decline as markets become more active and matches are easier to find. Thus, our model predicts that the voice brokers' market share will increase for more difficult trades in less liquid securities and will decline for easier trades in more liquid securities. Treasury securities going off the run provide an ideal setting for testing these predictions.

When Treasury securities are on the run, the electronic brokers' market share is approximately 80% and when a security goes off the run electronic brokers' market share falls to 12%. Regression analysis indicates that this shift in the preferred trading venue cannot be explained by changes in the return volatility, announcements of macroeconomic news, trade sizes, or the identities of the traders. Larger trades when a dealer has a larger imbalance between buying and selling are less likely to be with electronic brokers, suggesting that these circumstances increase the value of voice brokers' services.

These results suggest that there is an important role for human intermediation in relatively active securities, e.g., hundreds of millions of dollars per day, with little information asymmetry. However, if these same securities trade ten times as much, complete automation dominates. Therefore, if trading volume for securities continues to increase as it has for the last several decades, the role of human intermediation will continue to diminish.

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Table 1. Descriptive Statistics. Summary statistics for interdealer trading of 2-year, 5-year, and 10-year U.S. Treasury notes from January 2001 through November 2002. Averages are computed daily by security class and time series averages are given with standard errors in parentheses. A note is considered on the run until the auction date of the next note of the same maturity.

Security	Volume ($Billions)	Trades (000s)	CUSIPs	Electronic Market Share (%)	Trade Size ($Millions)	
					Elec	Voice
All Notes	88.4	7.6	62	71.7	10.0	21.8
	(1.1)	(0.1)	(0.5)	(0.2)	(0.1)	(0.1)
on the run	74.6	6.9	3	80.7	9.9	20.4
	(1.0)	(0.1)	(0.0)	(0.2)	(0.1)	(0.2)
off the run	13.8	0.7	59	11.7	14.1	24.1
	(0.5)	(0.0)	(0.5)	(0.7)	(0.4)	(0.1)
2 Year Notes	36.1	2.0	18	69.4	16.1	27.4
	(0.6)	(0.0)	(0.1)	(0.4)	(0.2)	(0.3)
on the run	30.5	1.7	1	75.2	17.1	27.8
	(0.5)	(0.0)	(0.0)	(0.4)	(0.3)	(0.5)
off the run	5.6	0.2	16	9.9	18.3	29.0
	(0.5)	(0.0)	(0.1)	(0.7)	(1.1)	(0.3)
5 Year Notes	29.5	2.8	21	74.4	9.1	19.6
	(0.4)	(0.0)	(0.3)	(0.3)	(0.1)	(0.2)
on the run	25.5	2.6	1	83.5	9.3	17.5
	(0.4)	(0.0)	(0.0)	(0.3)	(0.1)	(0.3)
off the run	4.1	0.2	20	8.5	13.4	23.6
	(0.2)	(0.0)	(0.3)	(0.4)	(0.4)	(0.2)
10 Year Notes	22.7	2.8	23	71.9	7.0	17.4
	(0.3)	(0.0)	(0.2)	(0.3)	(0.1)	(0.1)
on the run	18.6	2.6	1	84.5	7.1	14.9
	(0.3)	(0.0)	(0.0)	(0.3)	(0.1)	(0.2)
off the run	4.1	0.2	22	8.9	10.5	20.6
	(0.2)	(0.0)	(0.2)	(0.4)	(0.3)	(0.1)

Table 2. Dates for Securities Going On and Off the Run. All 2-year, 5-year, and 10-year U.S. Treasury notes that go from on to off the run between January 2001 and November 2002 are listed below. A note is considered on the run until the auction date of the next note of the same maturity.

CUSIP	Reopened	Security	Announce Date	Auction Date	Issue Date	Maturity Date
9128276Q0		2-YEAR	12/20/2000	12/27/2000	1/2/2001	12/31/2002
9128276S6		2-YEAR	1/17/2001	1/24/2001	1/31/2001	1/31/2003
9128276U1		2-YEAR	2/14/2001	2/21/2001	2/28/2001	2/28/2003
9128276V9		2-YEAR	3/21/2001	3/28/2001	4/2/2001	3/31/2003
9128276W7		2-YEAR	4/18/2001	4/25/2001	4/30/2001	4/30/2003
9128276Y3		2-YEAR	5/23/2001	5/30/2001	5/31/2001	5/31/2003
9128276Z0		2-YEAR	6/20/2001	6/27/2001	7/2/2001	6/30/2003
9128277A4		2-YEAR	7/18/2001	7/25/2001	7/31/2001	7/31/2003
9128277C0		2-YEAR	8/22/2001	8/29/2001	8/31/2001	8/31/2003
9128277D8		2-YEAR	9/19/2001	9/26/2001	10/1/2001	9/30/2003
9128277E6		2-YEAR	10/17/2001	10/24/2001	10/31/2001	10/31/2003
9128277G1		2-YEAR	11/21/2001	11/28/2001	11/30/2001	11/30/2003
9128277H9		2-YEAR	12/19/2001	12/27/2001	12/31/2001	12/31/2003
9128277K2		2-YEAR	1/16/2002	1/23/2002	1/31/2002	1/31/2004
9128277M8		2-YEAR	2/20/2002	2/27/2002	2/28/2002	2/29/2004
912828AA8		2-YEAR	3/20/2002	3/27/2002	4/1/2002	3/31/2004
912828AB6		2-YEAR	4/17/2002	4/24/2002	4/30/2002	4/30/2004
912828AD2		2-YEAR	5/22/2002	5/29/2002	5/31/2002	5/31/2004
912828AE0		2-YEAR	6/28/2002	6/28/2002	7/1/2002	6/30/2004
912828AG5		2-YEAR	7/17/2002	7/24/2002	7/31/2002	7/31/2004
912828AK6		2-YEAR	8/26/2002	8/28/2002	9/3/2002	8/31/2004
912828AL4		2-YEAR	9/23/2002	9/25/2002	9/30/2002	9/30/2004
912828AM2		2-YEAR	10/21/2002	10/23/2002	10/31/2002	10/31/2004
9128276N7		5-YEAR	11/1/2000	11/7/2000	11/15/2000	11/15/2005
9128276N7	X	4-YEAR 9-MONTH	1/31/2001	2/6/2001	2/15/2001	11/15/2005
9128276X5		5-YEAR	5/2/2001	5/8/2001	5/15/2001	5/15/2006
9128276X5	X	4-YEAR 9-MONTH	8/1/2001	8/7/2001	8/15/2001	5/15/2006
9128277F3		5-YEAR	10/31/2001	11/6/2001	11/15/2001	11/15/2006
9128277F3	X	4-YEAR 9-MONTH	1/30/2002	2/5/2002	2/15/2002	11/15/2006
912828AC4		5-YEAR	5/1/2002	5/7/2002	5/15/2002	5/15/2007
912828AH3		5-YEAR	7/31/2002	8/6/2002	8/15/2002	8/15/2007
9128276J6	X	9-YEAR 9-MONTH	11/1/2000	11/8/2000	11/15/2000	8/15/2010
9128276T4		10-YEAR	1/31/2001	2/7/2001	2/15/2001	2/15/2011
9128276T4	X	9-YEAR 9-MONTH	5/2/2001	5/9/2001	5/15/2001	2/15/2011
9128277B2		10-YEAR	8/1/2001	8/8/2001	8/15/2001	8/15/2011
9128277B2	X	9-YEAR 10-MONTH	10/4/2001	10/4/2001	10/5/2001	8/15/2011
9128277B2	X	9-YEAR 9-MONTH	10/31/2001	11/7/2001	11/15/2001	8/15/2011
9128277L0		10-YEAR	1/30/2002	2/6/2002	2/15/2002	2/15/2012
9128277L0	X	9-YEAR 9-MONTH	5/1/2002	5/8/2002	5/15/2002	2/15/2012
912828AJ9		10-YEAR	7/31/2002	8/7/2002	8/15/2002	8/15/2012

Table 3. Electronic Market Share Regressions. The market share of the electronic interdealer brokers is calculated each day as a percentage for 2-year, 5-year, and 10-year U.S. Treasury notes from January 2001 through November 2002. These daily percentage market shares for all securities and for those securities that go from on the run to off the run in our sample period are regressed on a variable set equal to one if the security has a 5-year maturity (*5-year*), a variable set equal to one if the security has a 10-year maturity (*10-year*), a variable set equal to one if there is a macroeconomic announcement that day (*macro*), an interaction variable set to one if there is a macroeconomic announcement that day and the security is on the run (*macro*on-run*), the percentage difference between that days highest and lowest transaction prices (σ), the logarithm of average trade size that day in that security (*log(trade size)*), the logarithm of total dollar trading volume that day in that security (*log(volume)*), a variable set equal to one if the security is the most recently auctioned security of that maturity (*on-run*), and the on-the-run dummy variable interacted with total dollar trading volume that day in that security (*on-run*log(volume)*). The standard errors control for heteroskedasticity and contemporaneous correlation within days.

Variable	Securities that Go Off the Run		All Securities	
Intercept	13.43	12.13	33.86	33.15
	(2.28)	(2.20)	(3.13)	(3.13)
5-year	0.66	1.57	0.77	0.95
	(0.62)	(0.61)	(0.29)	(0.29)
10-year	2.41	3.43	-1.17	-0.69
	(0.63)	(0.62)	(0.36)	(0.35)
Macro	-0.15	-0.14	-0.67	-0.66
	(0.45)	(0.45)	(0.83)	(0.82)
Macro*on-run	0.77	0.24	1.93	0.90
	(0.82)	(0.78)	(1.37)	(1.26)
σ	-0.03	0.01	0.23	0.24
	(0.20)	(0.18)	(0.14)	(0.16)
log(trade size)	-8.71	-7.63	-5.46	-4.89
	(0.44)	(0.44)	(0.30)	(0.28)
log(volume)	6.89	6.04	3.17	2.71
	(0.33)	(0.33)	(0.20)	(0.18)
on-run	40.50		55.72	
	(1.60)		(1.27)	
on-run*log(volume)		1.86		2.46
		(0.06)		(0.04)
Observations	8,829	8,829	37,980	37,980
R^2	0.836	0.840	0.286	0.225

Table 4. Probit Regressions for Electronic Brokerage Usage. The dependent variable is equal to one for electronic interdealer broker trades and zero for voice interdealer broker trades. Coefficient estimate are reported from the probit regression with the corresponding linear probability slopes and Chi-Square statistics for 2-year, 5-year, and 10-year U.S. Treasury notes from January 2001 through November 2002. Regressions are estimated for all securities and for those securities that go from on the run to off the run in our sample period. Independent variable include a variable set equal to one if the security has a 5-year maturity (*5-year*), a variable set equal to one if the security has a 10-year maturity (*10-year*), the percentage difference between that days highest and lowest transaction prices (σ), the logarithm of the trade size (*log(trade size)*), the logarithm of total dollar trading volume that day in that security (*log(volume)*), the logarithm of total dollar trading volume that day by the dealer in that security (*log(dealer volume)*), the logarithm of absolute value of the dealer's net volume (buy volume minus sell volume) in that day in that security (*log(|dealer net volume|)*), and a variable set equal to one if the security is the most recently auctioned security of that maturity (*on-run*). Fixed effects for individual dealers are included where indicated, but not reported. The standard errors control for heteroskedasticity and for contemporaneous correlation within days.

Variable	Securities that Go Off the Run		All Securities	
Fixed Dealer Effects	No	Yes	No	Yes
Intercept	-4.761		-2.731	
	20		12	
5-year	0.248	0.212	0.204	0.173
	0.039	0.032	0.036	0.029
	27	23	22	18
10-year	0.411	0.372	0.321	0.288
	0.063	0.054	0.054	0.047
	36	32	32	29
σ	-0.011	-0.011	-0.001	-0.001
	-0.002	-0.002	-0.000	-0.000
	2	2	6	6
log(trade size)	-0.299	-0.297	-0.336	-0.330
	-0.049	-0.046	-0.060	-0.057
	121	116	150	140
log(volume)	0.278	0.324	0.225	0.286
	0.046	0.050	0.040	0.049
	25	30	20	25
log(dealer volume)	0.188	0.115	0.177	0.094
	0.031	0.018	0.032	0.016
	111	37	94	33
log(|dealer net volume|)	-0.038	-0.009	-0.040	-0.018
	-0.006	-0.001	-0.007	-0.003
	35	7	37	25
on-run	0.466	0.475	0.599	0.604
	0.099	0.097	0.143	0.139
	14	14	13	13
Observations	7,341,984	7,341,984	7,833,355	7,833,355
Pseudo R^2	0.180	0.209	0.269	0.294

Table 5. Probit Regressions for Electronic Brokerage Usage for Repos. The dependent variable is equal to one for electronic interdealer broker trades and zero for voice interdealer broker trades. Coefficient estimate are reported from the probit regression with the corresponding linear probability slopes and Chi-Square statistics for repos for 2-year, 5-year, and 10-year U.S. Treasury notes from January 2001 through November 2002. Regressions are estimated for all securities and for those securities that go from on the run to off the run in our sample period. Independent variable include a variable set equal to one if the security has a 5-year maturity (*5-year*), a variable set equal to one if the security has a 10-year maturity (*10-year*), the percentage difference between that days highest and lowest transaction prices (σ), the logarithm of the trade size (*log(trade size)*), the logarithm of total dollar trading volume that day in that security (*log(volume)*), the logarithm of total dollar trading volume that day by the dealer in that security (*log(dealer volume)*), the logarithm of absolute value of the dealer's net volume (buy volume minus sell volume) in that day in that security (*log(|dealer net volume|)*), and a variable set equal to one if the security is the most recently auctioned security of that maturity (*on-run*). Fixed effects for individual dealers are included where indicated, but not reported. The standard errors control for heteroskedasticity and for contemporaneous correlation within days.

Variable	Securities that Go Off the Run		All Securities	
Fixed Dealer Effects	No	Yes	No	Yes
Intercept	-17.368		-14.570	
	68		60	
5-year	0.064	0.053	0.027	0.028
	0.014	0.010	0.004	0.003
	5	4	8	2
10-year	0.018	-0.014	-0.072	-0.090
	0.004	-0.002	-0.010	-0.010
	1	1	6	8
σ	-0.003	-0.003	0.033	0.002
	-0.001	-0.001	0.000	0.000
	1	1	2	1
log(trade size)	-0.316	-0.329	-0.255	-0.269
	-0.066	-0.058	-0.036	-0.030
	57	59	44	46
log(volume)	0.355	0.448	0.316	0.372
	0.074	0.079	0.045	0.042
	38	42	46	43
log(dealer volume)	0.119	0.006	0.094	0.004
	0.025	0.001	0.013	0.001
	28	2	22	2
log(|dealer net volume|)	-0.004	-0.015	-0.017	-0.028
	-0.002	-0.003	-0.002	-0.003
	2	5	7	11
on-run	0.047	0.054	0.160	0.174
	0.010	0.010	0.024	0.021
	8	8	12	12
Observations	748,247	748,247	1,154,060	1,154,060
Pseudo R^2	0.138	0.212	0.174	0.243

Figure 1. Trading Volume On and Off the Run. Average trading volume is calculated for 2-year, 5-year, and 10-year U.S. Treasury notes that go from on to off the run between January 2001 and November 2002. Daily trading volume is averaged across securities of the same maturity with dates aligned relative to going off the run (the auction of the next security of the same maturity).

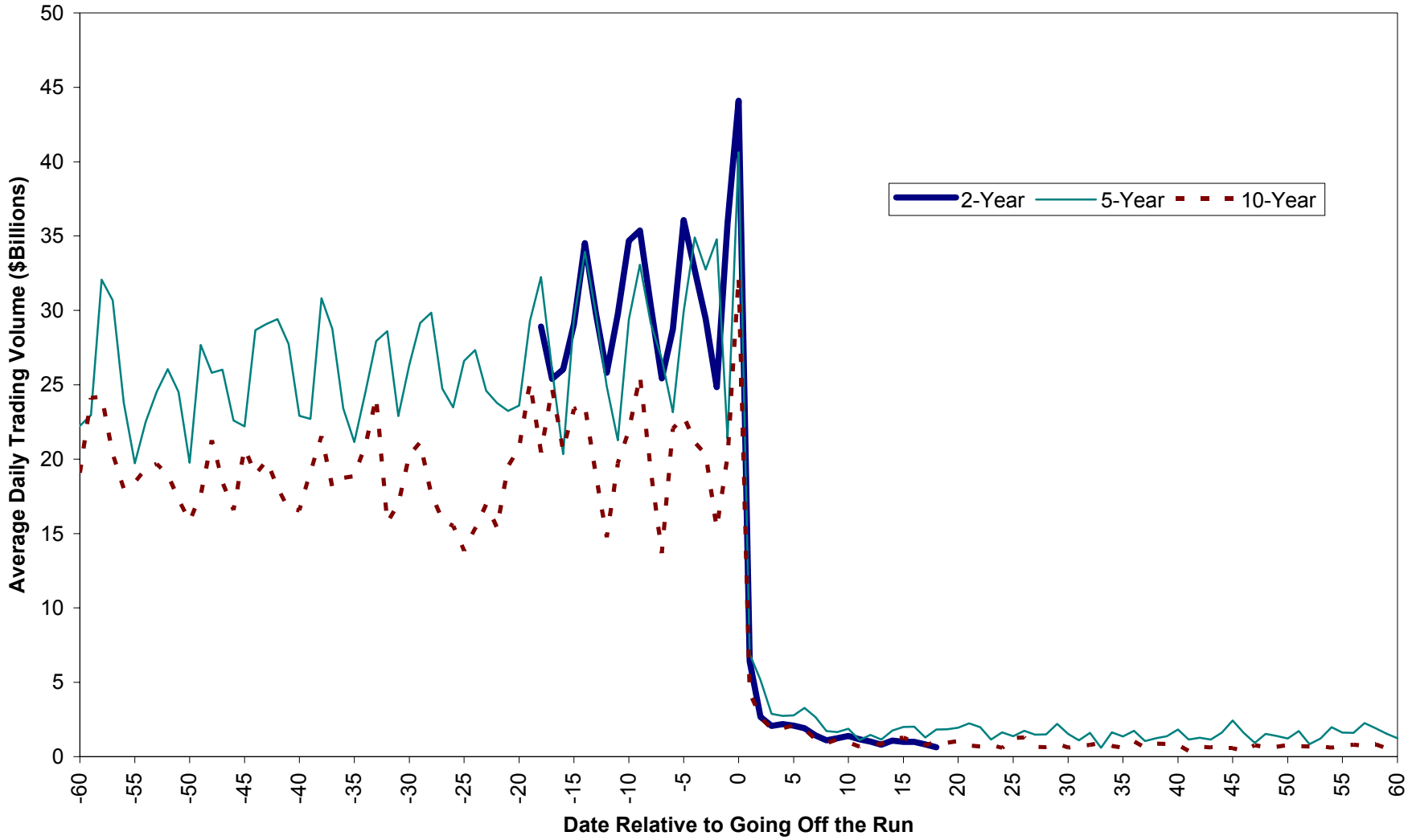

Figure 2. Electronic Market Share On and Off the Run. The daily trading market shares are calculated across securities of the same maturity on a given date in relation to the off-the-run date (the auction date for the subsequent note with the same maturity). Data is for 2-year, 5-year, and 10-year U.S. Treasury notes between January 2001 and November 2002.

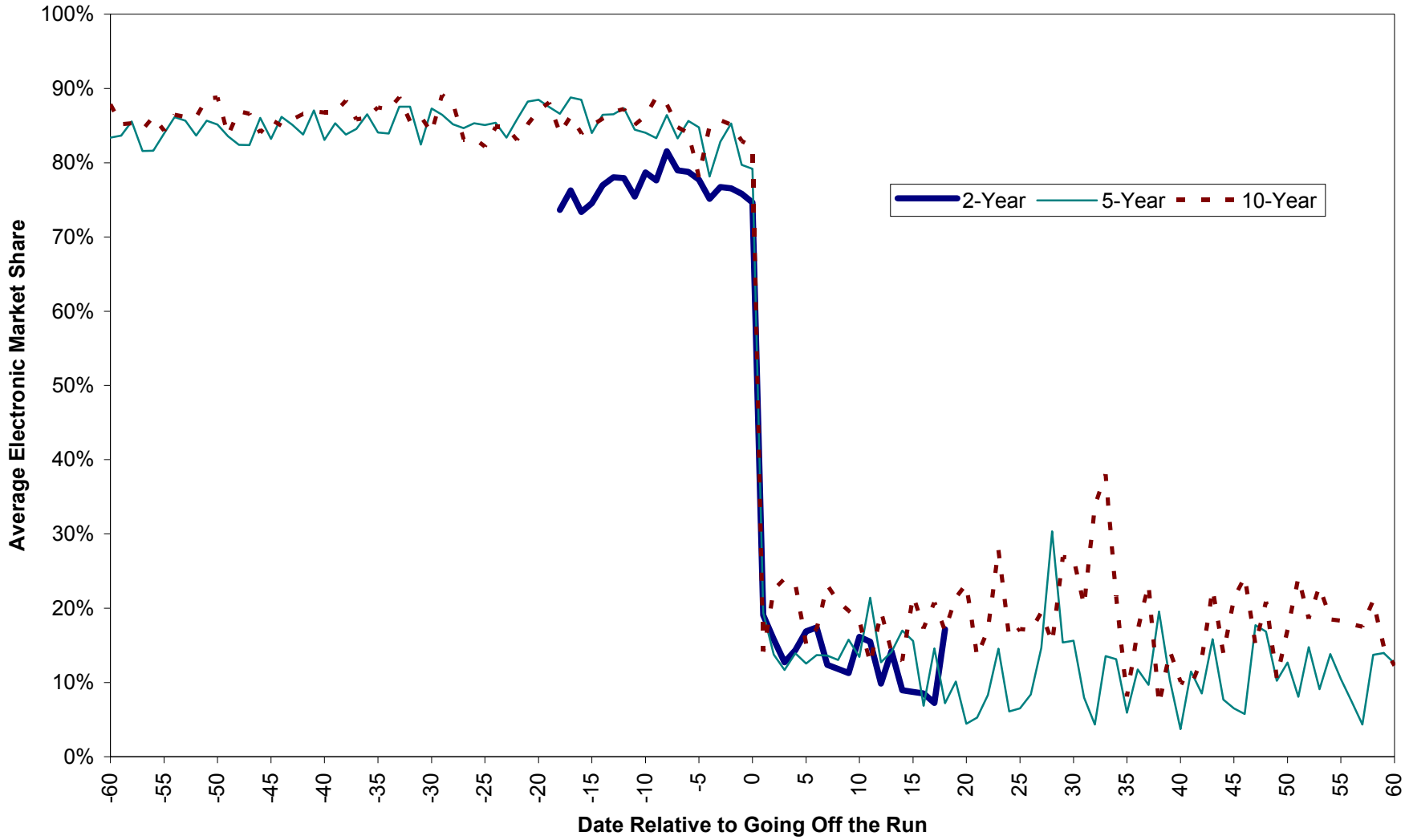

Figure 3. Repo Trading Volume On and Off the Run. Average repo trading volume is calculated for 2-year, 5-year, and 10-year U.S. Treasury notes that go from on to off the run between January 2001 and November 2002. Daily trading volume is averaged across securities of the same maturity with dates aligned relative to going off the run (the auction of the next security of the same maturity).

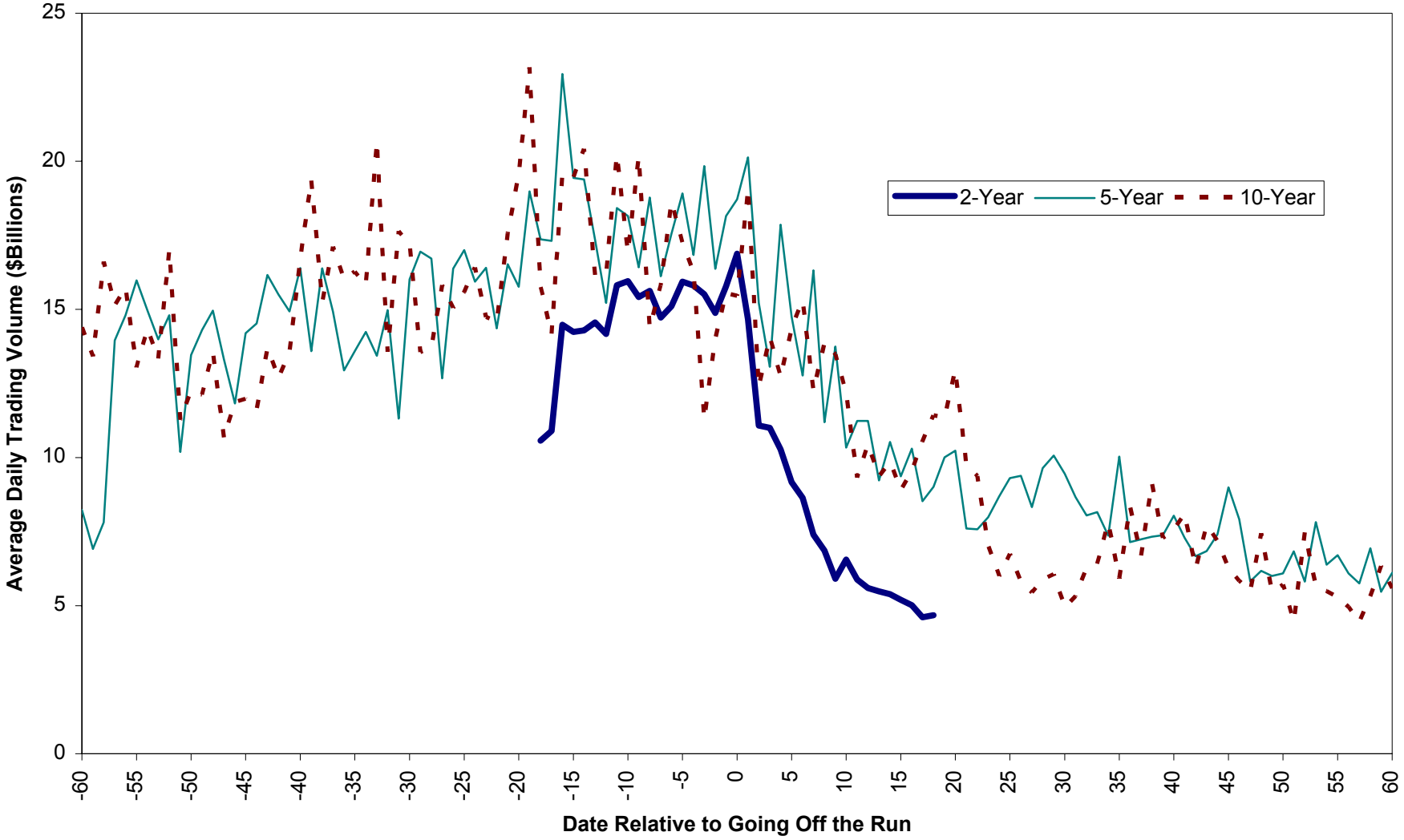

Figure 4. Repo Electronic Market Share On and Off the Run. The daily trading market shares are calculated across securities of the same maturity on a given date in relation to the off-the-run date (the auction date for the subsequent note with the same maturity). Data is for 2-year, 5-year, and 10-year U.S. Treasury notes between January 2001 and November 2002.