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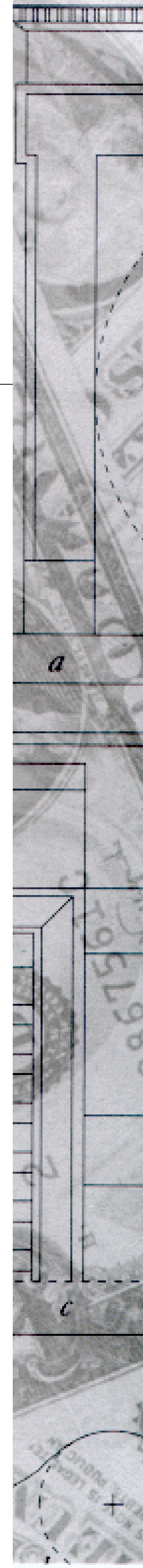

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The Effect of Transaction Size on Off-the-Run Treasury Prices

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The Effect of Transaction Size on Off-the-Run Treasury Prices

Abstract

A price pressure effect is implied by segmentation in the market for a security. An empirical property of a segmented market is that the price of the security is sensitive to supply and demand conditions for that specific security, absent changes in risk and absent any new information. This paper examines intra-day trading data from the inter-dealer broker market for U.S. Treasury securities and finds that there is a price pressure effect in the off-the-run Treasury market. Thus, securities that would appear to be very close substitutes, i.e., on-the-run and off-the-run Treasury bonds, behave as if there is some degree of market segmentation. There have been several studies of price pressure in the equity market and Treasury bill market but this is the first study of the off-the-run Treasury note and bond market to investigate a price pressure effect using intra-day data. It is also the first study to analyze price pressure through matched pairs of securities that differ only in liquidity and with high frequency data.

Introduction

A price pressure effect is implied by a segmentation effect in the market for a security. The market for a security is said to be segmented if substitution to other securities with similar characteristics is limited. An empirical property of a segmented market is that the price of the security is sensitive to supply and demand conditions for that specific security, absent changes in risk and absent any new information. A security with many close substitutes, on the other hand, has a flat demand curve and will not exhibit a price pressure effect. This paper examines intra-day trading data from the inter-dealer broker market for U.S. Treasury securities and finds that there is a price pressure effect in the off-the-run Treasury market. Thus, securities that would appear to be very close substitutes, i.e., on-the-run and off-the-run Treasury bonds, behave as if there is some degree of market segmentation.[2] There have been several studies of the equity market and Treasury bill market but this is the first study of the off-the-run Treasury note and bond market to investigate a price pressure effect.

We investigate the price pressure effect by constructing matched observations of transaction prices in off-the-run securities and corresponding synthetic on-the-run prices. The synthetic prices are calculated by discounting the cash flows of the off-the-run bond using spot rates from the on-the-run market at the same instant as the transaction. The construction of matched pairs of actual off-the-run transaction prices and synthetic on-the-run prices allows us to examine the behavior of the off-the-run prices, particularly the extent to which they change in response to changes in the volume transacted for that issue. The on-the-run market is significantly more liquid than the off-the-run market and therefore less susceptible to price movements due solely to transaction volume. A key difference between a transaction price and its matched synthetic price is liquidity risk. Deviations from the normal, low-volume relationship between transaction prices and matched synthetic prices as transaction volume increases are a measure of price pressure.

The existence and extent of price pressure solely as a function of a transaction is a matter of no small concern for investors and regulators. Those who purchased and sell securities should be interested in how their entry into a market affects the prices they pay or get for a security. Regulators need to understand the valid determinants of prices and changes in prices in order to design and enforce appropriate laws and regulations for security transactions.

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[2] Recently, questions surrounding the existence of a price pressure effect in the Treasury STRIP, note and bond market have resurfaced in connection with the so-called "yield burning" controversy. The yield burning issue arose when municipalities purchased, on a negotiated, noncompetitive basis, advance refunding escrows comprised mainly of Treasury STRIPS and off-the-run notes and bonds. Economists working for the Treasury claimed that the prices paid for the escrows were too high, when compared to a spate of reference prices, and it threatened the tax treatment of the municipal debt offerings. The municipalities countered that in purchasing massive quantities of Treasury securities to defease their liabilities associated with advance refundings, several factors contributed to the observed run-ups in price, one of which is the price pressure effect. The government contended, with the backing of SEC economists, that the Treasury market was too large and too liquid for even the largest refunding escrows to cause price pressure.

One of the key aspects of this study is that the securities under investigation, off-the-run U.S. Treasury obligations, should respond to external factors in a fashion nearly identical to their on-the-run counterparts. Any change in the price or yield relative to the corresponding matched synthetic security, therefore, can be attributed only to the characteristics of the individual transaction, and any differential effect in information.

Survey of the Literature

General Theory

Following the seminal work of Scholes [1972], Kraus and Stoll [1972], and others, four competing hypotheses have emerged in the literature regarding the effect of large transactions on security prices. These hypotheses can be described as (i) the substitution hypothesis, (ii) the short-run liquidity costs hypothesis, (iii) the information effect hypothesis, and (iv) the segmented market or price pressure hypothesis.

Substitution hypothesis: This hypothesis states that any security has a sufficiently large number of nearly perfect substitutes such that the price of a specific security cannot deviate from the price implied by a perfectly elastic demand curve for that security. A security is characterized in terms of its risk-return profile that can be replicated in an infinite number of ways. Hence, a large purchase or sell order should not materially affect the price of the security, as its supply is essentially infinite. The substitution hypothesis implies that market participants are price-takers and underlies most fundamental asset pricing models, such as CAPM.

Short-run liquidity costs hypothesis: Kraus and Stoll [1972] argue that trading at a price "away from equilibrium" constitutes a mechanism to compensate dealers for holding inventories, providing liquidity and matching sellers to buyers. Liquidity and trader matching is especially important and costly in the case of a large trade. Under this hypothesis, a seller-initiated block transaction will temporarily depress the price of a security, while a buyer-initiated transaction will have the opposite effect. After the transaction, the price will return to its equilibrium level.

Information effect hypothesis: Scholes [1972] also suggests that the price effect of a large transaction may partially reflect informational motivations attributed to the initiator of the transaction. Market participants may infer that a seller-initiated trade was prompted by "bad news," and conversely for a buyer-initiated trade. The size of the trade could be related to the "degree" of good or bad news, so that a price effect related to block size could be explained in terms of an information effect, a pure price pressure effect, or both.

Price pressure hypothesis: The price pressure hypothesis (PPH), originally proposed by Scholes [1972] and Kraus and Stoll [l972], suggests that security prices are affected by temporary changes in demand, even in the absence of any new information on the security. Under this hypothesis a large purchase order for a security will trigger an increase in the price of the security. When the temporary change in demand subsides, prices typically return to their previous levels, absent any new information on the security.

According to the PPH, securities are not perfect substitutes. Block traders face downward-sloping excess demand curves and upward-sloping excess supply curves. Therefore, buyer-initiated block transactions will increase the price of the security, and conversely for seller-initiated transactions, in order to attract "passive suppliers of liquidity." After the demand or supply shock, prices revert to normal levels.

Empirical Studies in the Equity Market

The economic literature is replete with empirical studies of the effect of traded volume on equity prices. Almost all studies find evidence of price responsiveness to increased volume, although they generally do not distinguish between an explanation in terms of a price pressure effect and a liquidity cost effect. Various vehicles have been enlisted to detect the presence of price pressure, including large block trades, announcements of secondary distributions, exchange listings and delistings, and announcements of analyst recommendations.

Among the noteworthy equity market studies are Scholes [1972], Kraus and Stoll [l972], Dann, Mayers and Raab [1977], Mikkelson and Partch [1985], Shleifer [1986], Harris and Gurel [1986], Holthausen, Leftwich, and Mayers [1987], Loderer, Cooney and Van Drunen [1991], Barber and Loeffler [1993], Liang [1999] and Kaserer and Deininger [1999].[3]

Empirical estimates of security price elasticity tend to cluster around unity, consistent with the price pressure or liquidity costs hypotheses. Scholes [1972], for instance, finds that in a secondary distribution where the mean percentage of the firm traded was 2%, the mean price effect was approximately 2%. Hence, the elasticity of demand was approximately one. Shleifer [1986] reports an average price increase of 2.79% for S&P fund purchases thought to average 3% of outstanding shares. Kraus and Stoll find, for instance, that large block purchases are associated with a 1.4% price jump. Chan and Lakonishok [1993] report a smaller price jump associated with a purchase, namely an average price increase of 0.34% based on a sample of both small and large transactions. Davidson and Glascock [1996] find support for the hypothesis that the previously documented stock price reversal following a tender offer announcement is consistent with a price pressure caused by a temporary shift in the security's demand curve.

Empirical Studies in the Fixed-Income Market

This section reviews evidence of segmentation in the Government securities market. Earlier papers that provide evidence that Treasuries are segmented by maturity include Modigliani and Sutch [1966] and Poterba [1989]. Beyond these two papers, almost all of the published studies over the past fifteen years have focused exclusively on the Treasury

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[3] An annotated bibliography is available, upon request, in a lengthier version of this paper.

bill market. The evidence implies that block trading in a T-bill of a particular maturity will almost surely be subject to a price pressure effect. Empirical evidence suggests that a T-bill issue appears to have no close substitutes, even among otherwise identical securities of adjacent maturities.

The market for T-bills is one of the most liquid and efficient markets. Nevertheless, several studies have found evidence of segmentation in the T-bill market. Park and Reinganum [1986] report significant differences between the first bill maturing in a month and the last bill maturing in the previous month. Ogden [1987] shows that the yield differential is due to increased demand by firms and individuals who face a concentration of cash flows at month-ends.

Simon [1991] reports that segmentation in the T-bill market is widespread and not limited to bills maturing across month ends. He finds that announcements of cash management bills, which represent unexpected additional supplies of outstanding T-bills of a particular maturity, cause the yields on these bills to rise significantly relative to yields on adjacent maturity bills. Simon concludes that adjacent maturity bills are not close substitutes because investors do not arbitrage away interest rate differentials between adjacent maturities. He also finds that the segmentation effect is stronger for short-maturity bills, a result similar to findings reported by Park and Reinganum.

In a related paper, Simon [1994] presents strong evidence that segmentation in the T-bill market is even more widespread than previously documented. He reports that, controlling for other factors, differences in supplies of 13- and 12-week bills have a statistically significant effect on yield spreads between 13- and 12-week T-bills. The factors controlled for include the general slope of the yield curve, the tendency of bills maturing during the last week of calendar months to have lower yields than adjacent maturity bills, and the tendency of bills whose supply is augmented by cash management bills to have higher yields than adjacent maturity bills. The reported regression coefficients indicate, for instance, that a $1 billion increase in the supply of 13-week bills relative to 12-week bills is associated with a 0.4 basis point increase in yield spreads.

Simon measures the price responses to cash management bill announcements from one day before to one day after the announcement, as well as from one day before to nine days after the announcement. A statistically significant 8 basis point interest rate differential between cash management bills and adjacent maturity bills on the day before announcement suggests that cash management bill issuances are somewhat anticipated. Further, unexpected cash management announcements (i.e. additional supplies) have significant effects on cash management bill rates but not on adjacent maturity bill rates.

Simon interprets this as evidence that the T-bill market is segmented across adjacent maturities. From one day before to one day after announcement, the average interest rate differential between cash management bills and adjacent maturity bills increases by a statistically significant 20 basis points to a statistically significant 28 basis points. This increase in interest rate differential is the result of a statistically significant 34 basis point increase in cash management bill rates and a statistically insignificant 14 basis point average increase in adjacent maturity bill rates. The interest rate differentials are not transitory. From one to nine days after announcement, the average interest rate differential increases by another statistically significant 16 basis points to 44 basis points. Simon also reports that the size of new offering is a significant determinant of changes in interest rate differentials from one day before to one day after announcement. This result is consistent with the price pressure hypothesis.

The reported interest rate differentials are significantly in excess of transactions costs, especially nine days after announcement. Hence, they represent unexploited arbitrage opportunities. The observation that the yields on adjacent maturity bills also increase in response to supply shocks (although the increase is statistically insignificant) indicates that there is some substitution across maturities but in insufficient amounts to arbitrage the yield differential away entirely.

In one of the few studies outside the Treasury bill market, Jordan and Jordan [1996] analyze a block purchase of short-term Government securities, namely the attempt by Salomon Brothers to corner a portion of the Treasury security market. Their study examines the post-auction price behavior of the two-year Treasury note. They provide quantitative evidence of a substantial price reaction in the Government securities market. Based on a no-arbitrage relation, their results show that the two-year note was substantially overpriced for approximately six weeks following the auction. They estimate, for instance, the typical mispricing during this period at 0.16 to 0.25 percent of par.

The Effect of Anticipation on the Price Pressure Effect

A price pressure effect (PPE) could potentially be underestimated if the measurement does not take an anticipatory price pressure component into account. Empirical studies show that such a component may be substantial, especially in the case of a negotiated block trade. Allen and Postlewaite [1984] argue that the price effect of a large transaction is not necessarily limited to the time of the transaction. If a large trade is anticipated, the current price may react to reflect this; and when the actual transaction takes place the price may not change very much, even if the demand curve for the security is downward sloping. Therefore, price elasticities as measured by price changes at the time of the transaction may underestimate the true PPE. Keim and Madhavan [1996], in a study of the upstairs market for block transactions, shed light on the mechanism of anticipatory price movements. They argue that information leakage typically occurs as the block trade is negotiated ("shopped") prior to the actual trade date. This results in anticipatory price movements prior to the trade date.

Simon [1991] presents a study of the price (i.e., interest rate) effect of unexpected increases, in the form of cash management bills, in the supply of a Treasury bill of a particular maturity. He considers the interest rate differential between the bill subject to the supply shock and bills of adjacent maturities. He reports a statistically significant interest rate differential one day prior to the unexpected announcement of a supply increase. Nevertheless, this is a transaction which, by design, should be unexpected, yet part of the price pressure effect is already captured one day in advance.

The GovPX Data

Our data set consists of transaction prices and volume as well as posted quotes for the U.S. Treasury market, based on the global trading activity of all the primary dealers through five of the six inter-dealer brokers. Dealers trade through inter-dealer brokers in order to maintain anonymity. These dealers post firm quotes with the brokers along with the largest volume they are willing to trade at the posted price. The minimum trade size is one million dollars and the volumes are reported in units of one million dollars. Elton and Green [1998] and Fleming and Remolona [1999] both used GovPX data. These papers provide additional detail on the data source as well as comparisons to other data sources.

The Federal Reserve Bulletin indicates that roughly 60 percent of all securities transactions occur between dealers. The five brokers that report quotes and trading activity through the GovPX system represent about 70 percent of the inter-dealer market. Real-time prices are available for all active and off-the-run Treasury bills, notes, and bonds. Our data set covers the period from June 17, 1991 to December 31, 1996, but because of the sheer volume of data, our analysis focused on the 1993 and 1996 calendar years. These years were periods of generally declining and rising long-term interest rates, respectively. By including both increasing and decreasing interest rate environments we hope to have more stable parameter estimates that are not environment specific.

Each record in the database includes a date and time stamp to the nearest second along with the security's CUSIP, bid price and yield, offer price and yield, transaction price and yield, and volume. For quote updates, the transaction price is the last actual transaction and the volume is the most the dealer will transact at the bid or offer posted. For transactions, the volume indicates the actual size of the transaction. The issue date, coupon dates, coupon rate, and maturity date are all provided for each CUSIP. No new callable bonds were issued during this period. Thus, the active issues were all noncallable in our data set.

Constructing On-the-Run Spot Rate Curves

To serve as a baseline for measuring price pressure effects, we constructed an on-the-run Treasury spot rate curve for each and every off-the-run transaction during 1993 and 1996. In essence, this allows us to value the cash flows of the off-the-run bond as if it were trading as a considerably more liquid on-the-run bond. From the transacted prices recorded by GovPX for the on-the-run securities, we fit a spot interest rate function based on each and every cash flow of the on-the-run securities, which yields a unique estimated spot rate for each point in the maturity spectrum with a very high frequency (essentially, second by second, as needed). For the on-the-run spot rate yield curves we used a very flexible function of the form:[4]

[4] While it is fairly common to use a cubic spline approach to fit a yield curve, the functional form we adopted is often used in practice by major financial institutions. It has been used in Babbel, Merrill and

$$r(t) = b_0 + b_1 \exp(-a_1 t) + b_2 \exp(-a_2 t) + b_3 \exp(-a_3 t) + b_4 \exp(-a_4 t) \tag{1}$$

Where $a_2 = 2a_1$, $a_3 = 3a_1$, $a_4 = 4a_1$, and t is the time to maturity of the spot rate.

We estimate the parameters b_0, b_1, b_2, b_3, b_4 and a_1 of the curve using the on-the-run bond prices. The estimation is conducted by repricing the cash flows of the on-the-run bonds using the spot-rate function (1) to discount them. The computer searches for the values of b_0, b_1, b_2, b_3, b_4 and a_1 that, in combination, minimize the weighted sum of the squared errors between the prices recorded by GovPX and the model prices based on the spot rate curve (1).

Consider, for example, a two-year bond with a semi-annual coupon of 6.25 percent that was issued on July 31, 1996. If we wanted to reprice this bond on December 2, 1996, we would discount the cash flows to arrive at a price of:

$$P^* = 3.125e^{-r(0.164)} + 3.125e^{-r(0.660)} + 3.125e^{-r(1.164)} + 3.125e^{-r(1.660)}$$

where r(t) is given by the spot rate function (1) and 0.164 = 60/184 is the time to the first cash flow, etc. This synthetic price could then be compared to the market price given by GovPX.

After repeating this process for each of the on-the-run bonds, we also reprice off-the-run bonds at the time of an actual transaction using the on-the-run term structure. The pricing begins with an estimate the on-the-run term structure as described above. Given that term structure, we discount the cash flows of the transacted off-the-run securities to determine what the price would be if they traded according to the on-the-run spot-rate term structure. We refer to this price as a matched synthetic on-the-run price. Given the matched synthetic on-the-run price, we also solve for the yield that is consistent with the synthetic on-the-run price and the cash flows of the off-the-run bond.

Empirical Results

The construction of matched pairs of actual off-the-run transaction prices and corresponding synthetic on-the-run prices allows us to examine the behavior of the off-the-run prices, particularly the extent to which they change in response to changes in the volume transacted. The on-the-run market is significantly more liquid than the off-the-run market. A key difference between a transaction price and its matched synthetic price is liquidity risk. Deviations from the normal, low-volume, relationship between transaction prices and matched synthetic prices as transaction volume increases are a possible measure of price pressure.

Panning [1997] and is more fully described in Merrill [1994], who show this functional form provides a good fit to the data.

The data provided by GovPX, contained 182,636 valid transactions[5] involving notes or bonds in 1993 and 1996 that were off-the-run with at least three coupon payments remaining. Over 99% of the note and bond transactions reported through GovPX were for bonds with original issue maturity of ten years or less. The actual off-the-run transaction price was, on average, 10.93¢ per $100 of face value less than the calculated price of an instrument with the same cash flows but priced "as if" it were on-the-run. This translates into a yield difference of 4.1 basis points on average.

The average size of a transaction in this data set was $6.15 million. 37.02% of the transactions were for exactly $1 million; 22.12% were for $2, $3 and $4 million; 21.14% were for $5 million up to $10 million; 12.71% were for $10 million up to $20 million; 6.96% were for $20 million to $150 million; 0.05% were for more than $150 million and the largest single trade listed was $600 million.

The total daily volume in any particular off-the-run issue ranged from $1 million to $5,451 million, with the average daily volume being $111 million. On average, the issues had been trading for just over one year. In fact, about 75% of all transactions occurred in the first year of a bond going off-the-run. On average, the issues had approximately three years remaining to maturity.

The focus for our investigation is the spread between the actual transacted price (or yield) of the specific issue and the synthetic price (or yield) of that issue at the exact time of the transaction. The explanatory variables(s) for this investigation will be function(s) of the volume of trade for the specific trade in that issue, controlling for the effects of maturity and age since issue.

The exact shape of the price or yield response to changes in the volume of specific transactions cannot be specified *a priori*. As described previously, we can conjecture that the general response will be nonlinear. The price pressure effect is likely to differ for buy-motivated transactions and sell-motivated transactions. The starting point for the price pressure response, however, should be the same regardless of the motivation for the transaction. That is, for the smallest transaction volume the relationship between transaction price (yield) and matched synthetic price (yield) should be unique. The spread between transaction price (yield) and matched synthetic price (yield) should differ due only to price pressure effects as transaction volumes increase.

Identifying whether a transaction is buy motivated or sell motivated is analogous to the classic identification problem in economics when estimating supply and demand curves. One must somehow determine, based on transaction price and volume alone, whether there is a different price pressure effect for buy-motivated transactions than sell-motivated transactions. In general, researchers have assumed that the price pressure ef-

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[5] A "valid transaction" places conditions on the size of the trade, the transacted price and yield, the calculated synthetic price and yield, and the relation between the transacted and synthetic prices and yields. These conditions are used to filter out data errors as described in Elton and Green [1998] and Fleming and Remolona [1999].

fect is asymmetric and then classified transactions as buy motivated or sell motivated based on the direction of the price pressure effect.

In this study we treat the synthetic price minus the transaction price as a dependent variable.[6] For transaction size of $1 million this price difference measures the baseline difference between the on-the-run market and the off-the-run market. This price difference should be positive because the off-the-run price will be discounted relative to the synthetic on-the-run price due to liquidity risk.[7] We assume that price pressure would tend to drive the transaction price up when a transaction is buy motivated and would tend to drive the transaction price down when a transaction is sell motivated.

Of course, market conditions change over time and off-the-run bonds trade too infrequently to just consider absolute changes in price. It is for this reason that we consider price differences between transaction prices and synthetic prices. Changes in the matched synthetic price over time capture broader market forces. Changes in the price difference capture bond-specific forces. Thus, we compare the price difference for transactions with volume greater than one million dollars with the price difference for the most recent one million dollar transaction. If the price difference increases as volume increases then we call the transaction sell motivated. Conversely, if the price difference decreases as volume increases then we call the transaction buy motivated. Thus, for each transaction larger than one million dollars we compare the price difference to the most recent previous one million dollar transaction price difference to determine whether the transaction was buy motivated or sell motivated.

Determining the motivation for a transaction in this way does not create a self-fulfilling prophecy. If this is an erroneous method for determining the motivation for a transaction then we will fail to find the asymmetric price pressure effect that we hypothesize should exist. If, however, this is a reasonable categorization method and an asymmetric price pressure effect exists, then we should be able to identify it.

Our estimation process begins by categorizing each off-the-run transaction as either buy motivated or sell motivated as discussed above. We then create variables based on the transaction motivation. For a buy motivated transaction the buy variable would be the transaction volume and the sell variable would be zero. Conversely, for a sell motivated transaction the buy variable would be zero and the sell variable would be the transaction volume.

We include two variables in our regression model to control for important characteristics of the bonds. The first variable is the natural log of the maturity of the bond and, second, the natural log of the age of the bond. The maturity is the number of years re-

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[6] The same reasoning presented here applies when we use the yield spread, i.e., the transaction yield minus the synthetic yield, as the dependent variable.

[7] The dimensionality of this liquidity spread is documented in Jordan and Mansi [2000].

maining until the bond matures and the age of the bond is the number of years since the bond was originally issued.

The natural log of maturity is included as a proxy for the duration of the bond. This was viewed as a practical compromise between using duration measures that are based on parallel shifts in the term structure (e.g., Macaulay, modified, and various "effective" duration measures) and those that are based on assumptions or estimations of the term structure of interest rate volatility (e.g., Cox, Ingersoll and Ross [1985], Babbel [1983] and Nelson and Schaefer [1983]). The former measures exaggerate the effect of duration on the price volatility of bonds, whereas the latter would be too onerous for the nearly 200,000 observations we considered, each of which could potentially elicit a different term structure of volatility.

We observed in the data that bonds trade most frequently while they are on the run. The trading frequency declines when a bond is one issue cycle off the run. However, it takes more than one issue cycle for a bond to settle into an off-the-run trading pattern. Thus, we included the natural log of age as a control for the varying relationship between a bond and its synthetic equivalent as the bond ages.

Table 1 presents the regression results. The parameter estimates are presented with the accompanying *t*-statistic below and in square brackets. All parameters are significant at the 0.1 percent level except for the squared buy volume that is significant at the five percent level.[8] The variance inflation factors were mostly near one with the largest being 1.8. Thus, multicolinearity is unlikely to be a problem. We also applied White's adjustment for heteroskedasticity robust standard errors and found no significant difference in *t*-statistics.

We begin our discussion with the estimated coefficients on our proxies for the control variables – age and duration. The sign on the coefficient for the natural log of age is always positive and very significant, both for the price spread and yield spread regressions. The further off the run a Treasury security lies, the more its price and yield deviate from its on-the-run counterpart.

The sign on the coefficient for the natural log of maturity changes when using price spread and yield spread, as would be expected. This is because for any given change in price, as (natural log of) maturity lengthens, it requires a smaller change in yield to produce the price change. Therefore, although we found larger changes in price spreads for longer bonds subjected to volume-induced price pressure, these larger changes in price spreads were insufficient in magnitude to require larger changes in yield spreads to produce them.

The signs of the estimates on the volume variables support the price pressure hypothesis. Using the parameters as estimated in Table 1, Figure 1 is a graphical presenta-

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[8] We estimated the model separately for the two sub-periods, 1993 and 1996, and found qualitatively similar results in each subperiod.

tion of the price pressure effect for an average bond. The two graphs in Figure 1 show the price pressure effect as measured by the price spread (yield spread) between the transaction price (yield) and the matched synthetic price (yield) as transaction volume increases for an average bond. (Recall that the price spread equals the synthetic price minus the transaction price and that the yield spread equals the transaction yield minus the synthetic yield.) The solid line represents the price pressure effect for sell-motivated transactions and the heavier dashed line represents the price pressure effect for buy-motivated transactions. The dotted lines represent 95% confidence intervals.

There is no theoretical reason to choose a particular non-linear model. We selected the quadratic model because it satisfies the requirement that both the buy and sell price pressure effects have the same intercept and because the parameter estimates have easily understood statistical properties. Note that 99.9 percent of our transaction data are for transactions less than or equal to $150 million. Thus, for the relevant range of transaction volume the quadratic curves do not reverse their slope. In fact, the shape of the curves would seem to support the notion that there is a boundary to the possible price pressure effect. That boundary is probably due to the increasing possibility of arbitraging a trade using close substitute securities.

Conclusion

In this paper we have studied the price pressure effect in the off-the-run Treasury note and bond market. This effect has been studied in the Treasury bill market but this is the first study of price pressure in the off-the-run Treasury bond market. This is also the first study to analyze price pressure through matched pairs of securities that differ only in liquidity and with high frequency data. We find evidence of price pressure effects, consistent with segmentation in the market for off-the-run Treasury bonds. Our research suggests a supply and demand effect that is a function of volume for a particular transaction. This is consistent with market segmentation in the Treasury bond market. It is also supportive of the liquidity cost hypothesis.

The price pressure effect is non-linear. In fact, it would appear that arbitrage opportunities are limiting the size of the price pressure effect for higher transaction volumes. Because cash flows from one Treasury bond are a good substitute for cash flows from any other Treasury bond, the ability to arbitrage extreme price pressure effects must limit the size of the effect.

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Table I

Price Pressure in the Off-the-Run Treasury Bond Market

OLS regressions of the spread between transaction price and synthetic price or yield on bond characteristics, buy or sell motivation, and transaction volume:

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6$$

where for prices y is the synthetic price minus the transaction price per million dollars of face value or for yields y is the transaction yield minus the synthetic yield stated in basis points, x_1 is the natural log of the age of the bond measured in years since original issue, x_2 is the natural log of the maturity of the bond measured in years, x_3 is the volume of the transaction if the transaction is buy motivated or zero if the transaction is sell motivated, x_4 is $(x_3)^2$, x_5 is the volume of the transaction if the transaction is sell motivated or zero if the transaction is buy motivated, and , x_6 is $(x_5)^2$. The numbers in square brackets are *t*-statistics. Using White's adjustment for heteroskedasticity robust standard errors made no significant difference in *t*-statistics. The variance inflation factors are always less than 1.8.

	Price Spread		Yield Spread	
	(1)	(2)	(3)	(4)
Intercept	85.1436	88.8652	5.4720	5.4780
	[7.29]	[7.75]	[160.90]	[164.23]
Ln(Age)	420.9013	420.5867	0.9170	0.9165
	[82.23]	[82.21]	[61.71]	[61.69]
Ln(Maturity)	1374.6977	1373.7308	-0.9331	-0.9348
	[138.26]	[138.37]	[-32.31]	[-32.42]
Buy Volume	-3.5489	-2.4304	-0.0297	-0.0211
	[-3.62]	[-3.15]	[-10.51]	[-9.47]
$(\text{Buy Volume})^2$	0.0109		0.0001	
	[2.23]		[5.54]	
Sell Volume	7.3140	4.7771	0.0301	0.0197
	[7.91]	[6.86]	[11.32]	[9.85]
$(\text{Sell Volume})^2$	-0.0200		-0.0001	
	[-4.34]		[-6.36]	
Adjusted R^2	0.1186	0.1184	0.0291	0.0287

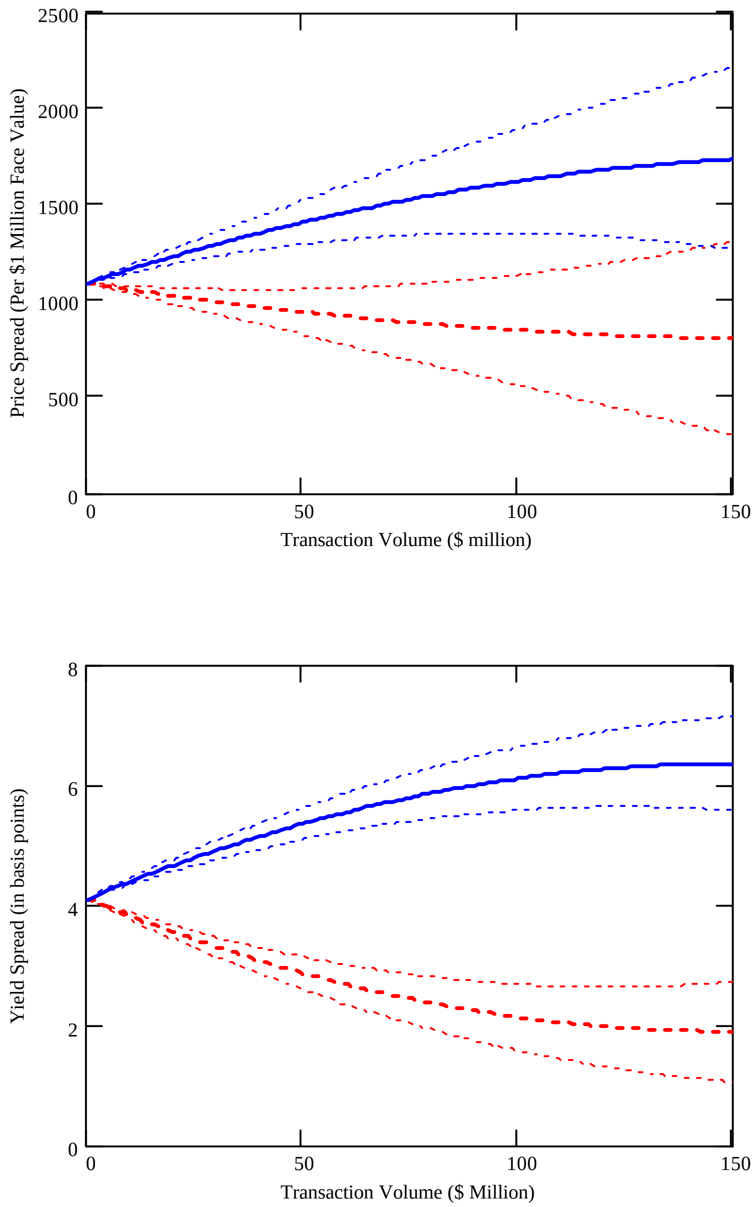

Figure 1. Price Pressure as a Function of Transaction Volume. These two graphs show the price pressure effect as measured by the price spread (yield spread) between the transaction price (yield) and the matched synthetic price (yield) as transaction volume increases for an average bond. (Note that the price spread equals the synthetic price minus the transaction price and that the yield spread equals the transaction yield minus the synthetic yield.) The solid line represents the price pressure effect for sell-motivated transactions and the heavier dashed line represents the price pressure effect for buy-motivated transactions. The dotted lines represent 95% confidence intervals.