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Further evidence on segmentation in the treasury bill market

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This paper shows that differences in supplies of 13- and 12-week Treasury bills have statistically significant and economically meaningful effects on their yield differentials from January 1985 through October 1991, controlling for the general slope of the Treasury bill yield curve, the tendency of bills maturing at month-ends to have lower yields and the tendency of bills whose supply is augmented by cash management bills to have higher yields. The finding that market participants do not arbitrage away yield differentials that owe to differences in supplies indicates that demand curves for individual bills are downward sloping and that segmentation in the Treasury bill market is more pervasive than previously documented.

Key words: Treasury bills; Market segmentation
JEL classification: G12; G14

The Treasury bill market often is viewed as the most liquid and efficient money market. If the Treasury bill market is efficient because bills are perfect substitutes to marginal investors on a risk-adjusted basis, yield spreads between bills should reflect only expectations about future bill yields and perhaps a risk premium, but not relative bill supplies or strong demands for particular bills. To date, evidence of segmentation in the Treasury bill market has been found in two contexts: Park and Reinganum (1986) show that bills maturing during the last week of calendar months have lower yields than adjacent maturity bills, which Ogden (1987) demonstrates stems from an increased demand owing to a concentration of payments flows at month-ends; and Simon (1991) demonstrates that Treasury cash management bill announcements, which represent unexpected announcements of additional

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supplies of outstanding bills, cause the yields on those outstanding bills to rise sharply relative to adjacent maturity bills from 1980 through 1988.[1]

The present paper demonstrates that segmentation in the Treasury bill market is more widespread than previously documented. Differences in supplies of 13- and 12-week bills have statistically significant and economically meaningful effects on their yield spreads over the sample period from January 1985 through October 1991, controlling for other factors. These findings indicate that investors have downward sloping demand curves for individual bills, and as a result do not arbitrage away yield spreads that owe to relative supplies. This paper is arranged as follows: Section 1 provides background information on the Treasury bill market and discusses the model that is estimated; section 2 provides empirical estimates of the model; section 3 assesses the economic significance of the effects of relative supplies by examining the potential for yield pickup, net of transaction costs, and section 4 summarizes the results.

1. The model and background on the treasury bill market

The expectations hypothesis of the term structure implies that yield spreads between 13- and 12-week bills depend on expected 1-week bill yields twelve weeks ahead plus a constant risk premium. One method of examining the effect of relative bill supplies on yield differentials would be to test whether returns from investing in 13-week bills rather than from investing in 12-week bills and subsequently in 1-week bills are positively correlated with relative supplies of 13- and 12-week bills. A potential problem with this approach is that the effects of relative supplies could be obscured by the volatility of one-week Treasury bill yields, which owes largely to a shortfall in trading activity.[2] Instead, this paper examines whether yield spreads between 13- and 12-week Treasury bills are affected by differences in supplies of 13- and 12-week Treasury bills, controlling for other factors. These factors include the general slope of the Treasury bill 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.

[1]In a related paper, Schirm et al. (1989) do not find a significant relationship between changes in 26-week Treasury bill yields and unexpected changes in announced auction sizes of 13- and 26-week Treasury bills from 1982 through 1985. However, these authors examine the effects of announcement surprises on changes in yields of 26-week bills auctioned the previous week rather than on changes in yields of the bills whose auction sizes are announced. As a result, they capture only indirect effects of supply shocks.

[2]The market for very short-term Treasury bills is illiquid because dealers are not willing to incur the risk involved in shorting these bills (selling bills that must be purchased in the market to deliver) because the actively traded supply of these bills is small and can dry up after large purchases. See Stigum (1989) for further discussion.

Aside from occasional cash management bills, bill supplies come from three different types of auctions. The Treasury auctions 13- and 26-week bills every week and 52-week bills every 4 weeks. Because bills mature on Thursdays, 13-week bill auctions always represent additional supplies of outstanding bills auctioned 13 weeks earlier with 26 weeks to maturity and every 4 weeks represent additional supplies of bills auctioned 39 weeks earlier with 52 weeks to maturity. Because bills maturing on the same date are identical, regardless of their original issuance date, the supply of bills with 13-weeks to maturity at week t is determined by the size of the current 13-week bill auction plus the size of the 26-week bill auction at week t-13 plus the size of the 52-week bill auction if one occurred at week t-39. The supply of 12-week bills at week t is equal to the supply of 13-week bills at week t-1 because the bill that has 12 weeks to maturity at week t is the same bill that had 13 weeks to maturity at week t-1.

Figure 1 shows the supply of 13-week bills over the sample period from January 1985 through October 1991, as reported by Treasury press releases. The supply of 13-week bills originating from 13- and 26-week bill auctions is shown separately from the supply originating from 52-week bill auctions, depicted by dots at four week intervals. The downward spikes in bill supplies from 13- and 26-week bill auctions reflect debt ceiling constraints, which at times caused the Treasury to cut back temporarily on bill auction sizes. Over the sample, the size of 13- and 26-week bill auctions varies for the most part between \$12.8 billion and \$21 billion, while the size of 52-week bill auctions moves in a range between \$8 billion and \$12 billion. Most of the variation in relative supplies of 13- and 12-week bills owes to whether or not one of the bills previously was auctioned as a 52-week bill because 13- and 26-week bill auctions typically do not vary much from week to week, while 52-week bill auctions occur every 4 weeks.

The model that is first estimated is,

$$\begin{aligned} R_t^{13} - R_t^{12} = {} & \beta_0 + \beta_1 (S_t^{13} - S_t^{12}) \\ & + \beta_2 (R_t^{26} - R_t^{5}) + \beta_3 (\mathrm{DEOM}_t^{13} - \mathrm{DEOM}_t^{12}) \\ & + \beta_4 (\mathrm{DCMB}_t^{13} - \mathrm{DCMB}_t^{12}) + u_t, \end{aligned} \tag{1}$$

where R_t^{26},R_t^{13},R_t^{12} and R_t^5 are 26-, 13-, 12- and 5-week Treasury bill yields at week t, S_t^{13} and S_t^{12} are the total supplies of 13- and 12-week bills at week t, DEOM_t^{13}–DEOM_t^{12} is a dummy variable that takes on the value one (minus one) when the 13-week (12-week) bill matures during the last week of calender months and zero otherwise, DCMB_t^{13}–DCMB_t^{12} is a dummy variable that takes on the value one (minus one) when the supply of 13-week (12-week) bills is augmented by cash management bills and zero otherwise, and u_t is an error term.

The Treasury bill supply data are taken from Treasury press releases (and

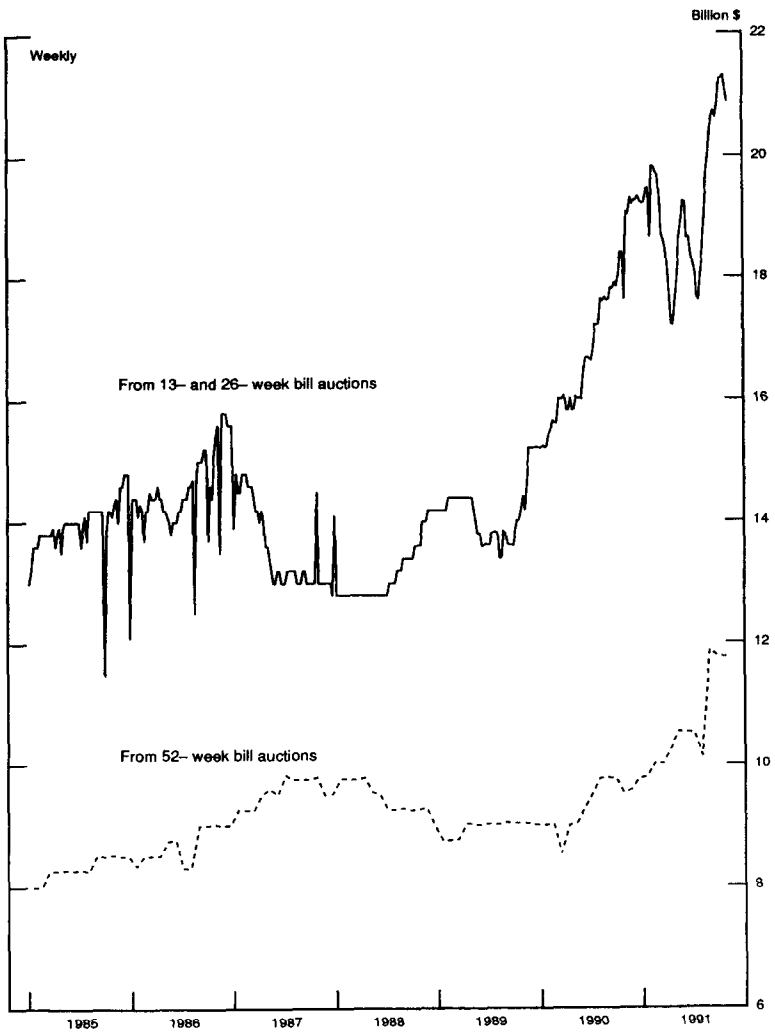

Fig. 1. 13-Week treasury bill supply.

are expressed in $ billions), while the interest rate data are taken directly from the Composite of Closing Quotations from the Federal Reserve Bank of New York. The interest rate data are ask-side investment yields, taken at the close of trading each Thursday. Ask-side quotes are used because bills can be bought immediately at the ask-side of the market.[3] Thursday Treasury bill yields are used for two reasons; by measuring yields on Thursday, distortions that would arise from comparing when-issued quotes on 13-week bills with cash market quotes on 12-week bills are avoided because 13-week bills, which are auctioned each Monday and issued the following Thursday, are typically traded and quoted before Thursday on a when-issued basis.[4] In addition, measuring yields on Thursday allows me to examine the effect of relative supplies on yield spreads after market participants have had time to reshuffle their portfolios and arbitrage yield spreads.

The yield spreads between 13- and 12-week bills over the sample from January 1985 through October 1991 are shown in basis points in fig. 2.[5] Because 13- and 12-week bills mature only one week apart, they reflect similar expectations about monetary policy, the macroeconomic environment and risk. As a result, these factors are left out of the model. Variables are included, however, to reflect the general slope of the Treasury bill yield curve and special factors that affect the relative demand for these bills. Spreads between 26-week and 5-week Treasury bill yields are included in the model to capture the influence of the general slope of the Treasury bill yield curve on yield spreads between 13- and 12-week bills. When the Treasury bill yield curve steepens, 13-week bill yields should tend to rise relative to 12-week bill yields, and thus the estimated coefficient on this term should be significantly positive.[6]

A dummy variable, $DEOM_t^{13}$–$DEOM_t^{12}$, also is included in the model to account for the tendency of bills maturing during the last week of calendar months to have lower yields than adjacent maturity bills. This variable takes on the value one (minus one) when the 13-week (12-week) bill is the last bill

[3]These quotes are the results of surveys of five government security dealers by the Federal Reserve Bank of New York. Ask-side quotes represent the rates at which dealers are willing to sell, while bid–side quotes represent the rates at which dealers are willing to buy. Ask–side quotes are lower than bid–side quotes. The results of this paper are little changed when I use bid–side quotes or midpoints between bid and ask quotes.

[4]When-issued and cash market yields on the same bill diverge when the cost of financing a bill in the repo market is not equal to the yield on that bill. When Thursdays are holidays, bill auctions settle on Fridays and yield differentials are measured on Friday.

[5]The results are little changed when I omit the outliers of the dependent variable from the sample. Most of the large positive yield spreads between 13- and 12-week bills are explained by the very steep slope of the Treasury bill yield curve, such as in the aftermath of the stock market crash in October 1987.

[6]To some extent, the choice of maturities to proxy the slope of the Treasury bill yield curve is arbitrary, as long as they are far enough apart so that they mainly reflect the general slope of the yield curve. The results are little changed when I use other proxies of the general slope of the Treasury bill yield curve, such as the spread between 52- and 5-week bill yields.

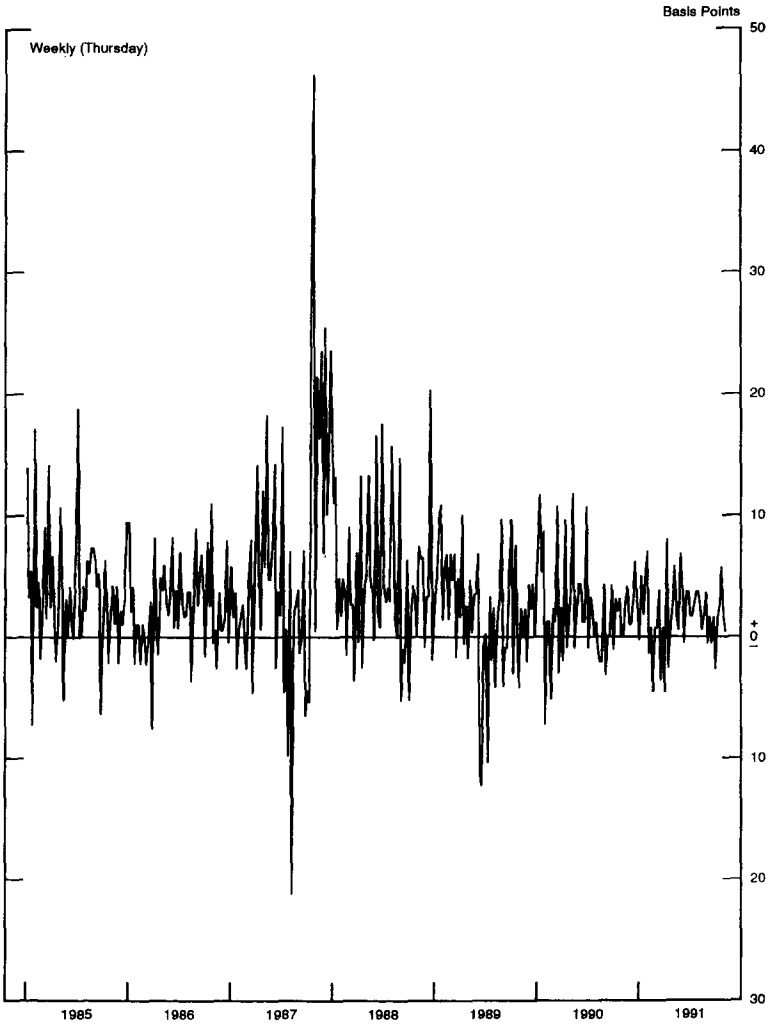

Fig. 2. Yield differentials between 13- and 12-week treasury bills.

maturing in a month. Because the yield spread between 13- and 12-week bills should be lower (higher) when the 13-week bill (12-week bill) matures during the last week of calendar months, the parameter estimate on this term should be negative.

In addition, a dummy variable, $DCMB_t^{13}$–$DCMB_t^{12}$, also is included in the model for the four Treasury bills in the sample whose supply is augmented by cash management bills.[7] When these cash management bills have 13-weeks (12-weeks) to maturity, the supplies of 13-week (12-week) bills are boosted. This dummy variable takes on the value one (minus one) when cash management bills have 13 weeks (12 weeks) to maturity. If the extra supply from cash management bills elevates their yields, the parameter estimate on this term should be significantly positive.[8]

2. The empirical results

The empirical results are presented in this section. Because of a few spikes in the autocorrelation function of the OLS residuals through lag 12, asymptotically valid standard errors are generated using the method developed by Hansen and Hodrick (1980) that allows non-zero autocorrelations through lag 12. This method is modified by the techniques developed by Newey and West (1987) and White (1980) that guarantee that the variance–covariance matrix is positive definite by downweighting the off-diagonal elements and corrects the standard errors for heteroskedasticity, respectively.

The results in Table 1 indicate that changes in relative supplies of 13- and 12-week bills have highly statistically significant effects on yield spreads between 13- and 12-week bills. The coefficient estimate of about .4 indicates that a $1 billion increase in the supply of 13-week bills relative to 12-week bills is associated with a 4/10 basis point increase in yield spreads. Because the average size of 52-week bill auctions over the sample period is about $9-1/2 billion, the supply of 13-week (12-week) bills that originate as 52-week

[7]The four cash management bills auctioned over the period with at least 13 weeks to maturity include a $7 billion issue that matured April 20, 1989, a $15 billion issue that matured April 19, 1990, a $6 billion issue that matured September 20, 1990, and a $12 billion issue that matured April 25, 1991. Because other cash management bills auctioned over the sample period had fewer than 12 weeks to maturity, they do not affect the supplies of 13- and 12-week bills.

[8]Twice during the sample period, auctions and settlements of 13-week bills were delayed beyond Thursday because the Treasury did not have room under the Treasury debt ceiling to issue securities. Because 13-week bills are already outstanding, 13-week bill yield quotes are available and the data set is constructed as if these auctions and settlements occurred on time. This is justified because a dummy variable for these postponed auctions and settlements entered the model insignificantly and did not qualitatively change the results. The tendency for the relative yields on these 13-week bills not to fall reflects the likelihood that these auctions were expected to take place as soon as Treasury debt ceiling constraints were lifted. In addition, because the Treasury's cash flows are fairly well anticipated by Fed watchers, there was little uncertainty concerning the approximate day on which Congress had to pass legislation to increase the debt ceiling to avoid defaults by the Treasury.

Table 1

The determinants of yield spreads between 13- and 12-week Treasury bills estimated by OLS with standard errors adjusted for heteroskedasticity and autocorrelation through the twelfth lag with weekly data from January 1985–October 1991

$$R_t^{13} - R_t^{12} = \underset{(0.547)}{-0.776} + \underset{(0.058)}{0.397}^{**}\,(S_t^{13} - S_t^{12}) + \underset{(0.008)}{0.045}^{**}\,(R_t^{26} - R_t^{5})$$
$$\underset{(0.356)}{-1.086}^{**}\,(\mathrm{DEOM}_t^{13} - \mathrm{DEOM}_t^{12}) + \underset{(1.148)}{5.959}^{**}\,(\mathrm{DCMB}_t^{13} - \mathrm{DCMB}_t^{12})$$

$\bar{R}^2 = 0.35$
SSE = 4.67
nobs = 354

[a]The dependent variable is the ask-side investment yield spread in basis points between 13- and 12-week bills. The independent variables in order are the differential between total supplies of 13- and 12-week bills (in $ billions), the slope of the yield curve between 26- and 5-week bills (in basis points), a dummy variable which takes on the value one (minus one) when 13-week (12-week) bills are the last bills maturing in calendar months, and a dummy variable which takes on the value one (minus one) when the supply of 13-week (12-week) bills is augmented by cash management bills. Standard errors are in parentheses and two asterisks denote statistical significance at the one percent level.

bills is on average $9-1/2 billion greater than the supply of 12-week (13-week) bills that do not originate as 52-week bills. As a result, 13-week (12-week) bills that originate as 52-week bills tend to have 4 basis point higher yields than 12-week (13-week) bills, ceteris paribus. The coefficient on the slope of the yield curve is also the expected sign and highly statistically significant. The coefficient estimate indicates that a 100 basis point steepening of the Treasury bill yield curve between 26- and 5-week maturities is associated with a 4-1/2 basis point increase in the yield spread between 13- and 12-week bills. The parameter estimate on the dummy variable for month-end maturity dates is the expected sign and statistically significant at the one percent level. The coefficient estimate indicates that yields on bills maturing during the last week of calender months are about 1 basis point lower than they otherwise would be. The parameter estimate on the dummy variable for cash management bills is statistically significant and indicates that yields on cash management bills are about 6 basis points higher than they otherwise would be. Overall, the equation explains 35 percent of the total variation in yield spreads.[9]

[9]Amihud and Mendelson (1991) demonstrate that investors in Treasury securities require higher yields to buy securities that have wider bid–ask spreads because of the associated higher transaction costs incurred if the securities are sold before maturity. These authors observe that seasoned coupon securities with exactly six months to maturity have higher bid–ask spreads and higher yields than 6-month bills. When bid–ask spread differentials between 13- and 12-week bills are included in the model, they enter with a statistically significant but wrong sign coefficient. This may reflect measurement error or the possibility that bid–ask spreads and yields are simultaneously determined. However, including bid–ask spread differentials in the model does not affect the coefficients on the other variables in the model.

Table 2

The determinants of yield spreads between 13- and 12-week treasury bills with separate variables for supply originating from 52-, 26- and 13-week bill auctions estimated by OLS with standard errors adjusted for heteroskedasticity and autocorrelation through the twelfth lag with weekly data from January 1985–October 1991

$$
\begin{aligned}
R_t^{13}-R_t^{12}= & -0.775 + 1.639^{**}(S_t^{13,13}-S_t^{12,13}) + 2.461\,(S_t^{13,26}-S_t^{12,26}) \\
& (0.728)\quad (0.443) \qquad\qquad (1.686) \\
& +.390^{**}(S_t^{13,52}-S_t^{12,52}) + 0.056^{**}\,(R_t^{26}-R_t^{5}) \\
& (0.052) \qquad\qquad (0.012) \\
& -0.916^{**}\mathrm{DEOM}_t^{13}-\mathrm{DEOM}_t^{12}) + 6.407^{**}\,(\mathrm{DCMB}_t^{13}-\mathrm{DCMB}_t^{12}) \\
& (0.352) \qquad\qquad (1.015)
\end{aligned}
$$

$\bar{R}^2=0.39$ SSE = 4.78 nobs = 354

[a]The dependent variable is the ask-side investment yield spread in basis points between 13- and 12-week bills. In order, the independent variables are the differential between the supplies (in $ billions) of 13- and 12-week bills from 13-week bill auctions, from 26-week bill auctions and from 52-week bill auctions, the slope of the yield curve between 26- and 5-week bills (in basis points), a dummy variable which takes on the value one (minus one) when 13-week (12-week) bills are the last bills maturing in calendar months, and a dummy variable which takes on the value one (minus one) when the supply of 13- week (12-week) bills is augmented by cash management bills. Standard errors are in parentheses and two asterisks denote statistical significance at the one percent level.

Because the majority of weekly fluctuations in relative supplies of 13- and 12-week bills owes to whether or not one of the bills originate as a 52-week bill, I now examine whether the finding of significant supply effects owes primarily to large swings in supplies from 52-week bill auctions. The model is re-estimated with separate variables for relative supplies from 13-week bill auctions, from 26-week bill auctions, and from 52-week bill auctions. The estimated model is now,

$$
\begin{aligned}
R_t^{13}-R_t^{12} = & \beta_0+\beta_1(S_t^{13,13}-S_t^{12,13})+\beta_2(S_t^{13,26}-S_t^{12,26}) \\
& +\beta_3(S_t^{13,52}-S_t^{12,52})+\beta_4(R_t^{26}-R_t^{5}) \\
& +\beta_5(\mathrm{DEOM}_t^{13}-\mathrm{DEOM}_t^{12}) \\
& +\beta_6(\mathrm{DCMB}_t^{13}-\mathrm{DCMB}_t^{12})+u_t, \qquad (2)
\end{aligned}
$$

The supply terms in order are the difference between 13- and 12-week bill supplies originating from 13-week bill auctions, 26-week bill auctions and 52-week bill auctions, respectively, where $S^{i,j}$ is the supply of i-week bills originating from j-week bill auctions, again in billions of dollars. The same procedure outlined above is used to re-estimate the model.

The results in Table 2 indicate that the previous finding that relative

supplies affect bill rates owes primarily to supply differentials owing to 52-week bill auctions. The coefficient on the term for relative supplies from 52-week bill auctions is little changed from the previous estimate on overall relative supplies at 0.39 and is again highly statistically significant. The parameter estimate on the term for relative supplies from 13-week bill auctions is also highly statistically significant, but is not economically significant in view of the typical weekly changes in 13-week bill auction sizes. The coefficient estimate of 1.6 indicates that yield spreads between 13- and 12-week bills increase 1-6/10 basis points when the difference in the supplies of 13- and 12-week bills from 13-week bill auctions increases by $1 billion. However, the typical effect is very small because the supply of 13-week bills rarely jumps more than $200 million in a particular week. The estimated coefficient on the relative supplies of 13- and 12-week bills from 26-week bill auctions is not statistically significant. Decomposing the supply variable has little effect on other variables in the model. The coefficients on the slope of the yield curve and the dummy variables for cash management bills and bills that mature during the last week of calendar months are again statistically significant and the expected sign.

3. Potential yield-pickup owing to relative supplies

I next examine the magnitude of the effects of differences in supplies on yield spreads between 13- and 12-week bills, relative to transactions costs. The solid lines in fig. 3 trace the yield spread between 13- and 12-week bills owing to relative bill supplies when 13-week bills originate as 52-week bills (the upper panel) and the yield spread between the 12- and 13-week bills owing to relative supplies when 12-week bills originate as 52-week bills (the lower panel). Yield spreads owing to relative supplies are equal to the estimated coefficient on the differences in total supplies from the first model, .40, times the relative supplies when one of the bills originates as a 52-week bill. Because investors placing new funds in the bill market buy either bill at the ask side of the market and because the yield data are ask-side quotes, the solid line in the upper (lower) panel represents the yield pickup available to investors who purchase 13-week (12-week) bills rather than 12-week (13-week) bills when 13-week (12-week) bills originate as 52-week bills. The figure shows that for these investors, the yield pickup due to increased supplies from 52-week bills typically is about 4 basis points over the sample period. This represents an extra return of roughly $100 on a $1 million investment. Brokerage costs, which are paid by the side initiating transactions, generally amount to 1/4 basis point on a discount rate basis or $6.25 on a $1 million one-way transaction in 3-month bills. Because this fee would

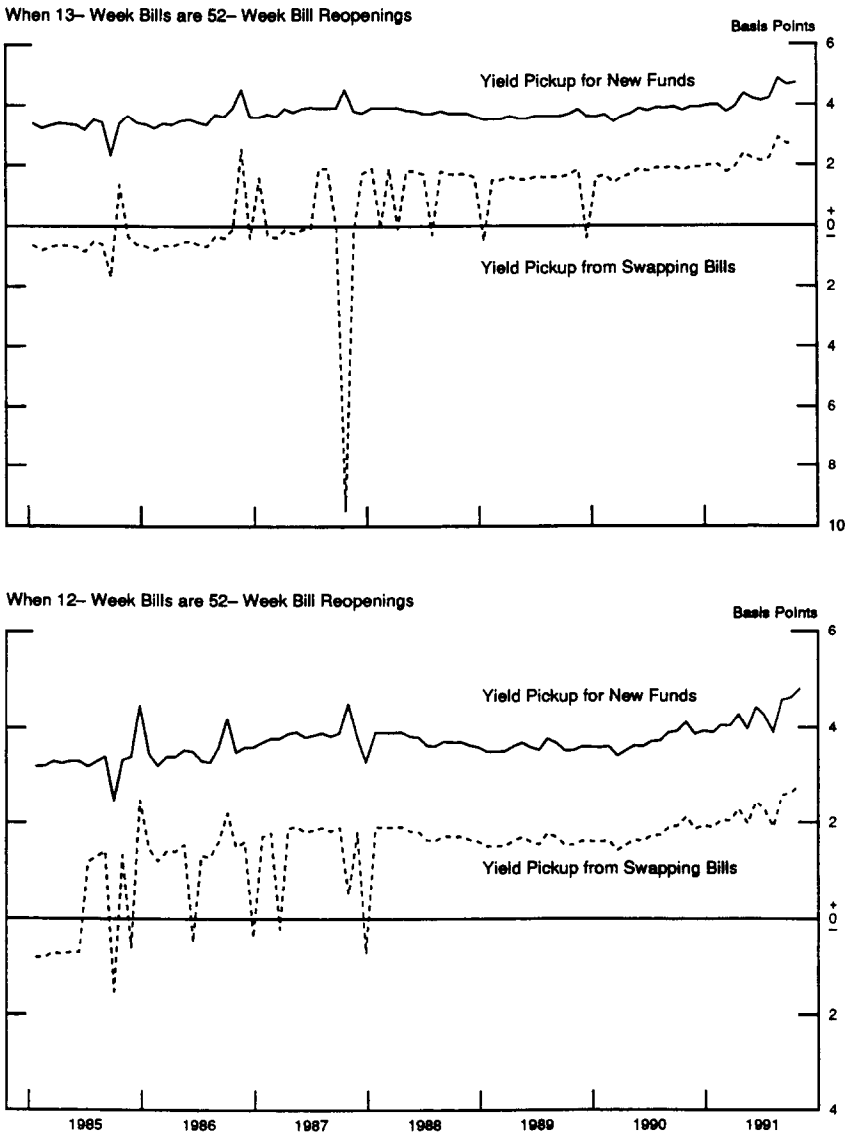

Fig. 3. Yield pickup net of transaction costs.

be paid regardless of the bill purchased, it would not affect the yield pickup.[10]

The dotted lines in the figure show the yield pickup owing to relative supplies available to investors swapping out of 12-week bills into 13-week bills when the latter originate as 52-week bills (the upper panel) and vice versa (the lower panel). An investor swapping into 13-week (12-week) bills and out of 12-week (13-week) bills would sell 12-week (13-week) bills at the bid-side of the market and again would purchase 13-week (12-week) bills at the ask-side of the market. Hence, the difference in yield pickup for investors placing new funds into the bill market and for those swapping bills is the bid-ask spread of the bill that is being swapped out of and the 1/2 basis point brokerage fee. The figure shows that from 1985 through 1987, positive yield pickups often are unavailable to investors swapping into bills that originate as 52-week bills.[11] From 1987 through 1991, the yield pickup from swapping bills typically is about 1-1/2 basis points, largely reflecting narrower bid-ask spreads. This yield pickup would represent an extra return of $37.50 on a $1 million swap. Of course, these arbitrage opportunities need not exist on average to be important; investors would swap bills only if it is profitable to do so.[12]

4. Conclusions

This paper demonstrates that differentials in relative supplies of 13- and 12-week bills have highly statistically significant effects on their yield spreads. Yields on bills that originate as 52-week bills are about 4 basis points higher than they otherwise would be. Abstracting from other factors affecting the yields on these bills, investors placing new funds into the bill market would buy either bill at the ask-side of the market and typically would be able to pick up 4 basis points by investing in 13-week (12-week) bills rather than in 12-week (13-week) bills when the former originate as 52-week bills. This yield pickup would represent an extra return of about $100 per $1 million investment. For investors swapping out of 12-week (13-week) bills into 13-week (12-week) bills when 12-week (13-week) bills originate as 52-week bills,

[10]Stigum (1989) states that brokerage costs for a $1 million transaction in 3-month Treasury bills are 1/4 of one basis point on a discount rate basis, which amounts to $12.50 per $1 million. However, brokerage fees of 1/4 basis point on 3-month bills (which traders at the Federal Reserve Bank of New York verify) amount to $6.25 on one-way and $12.50 on round-trip $1 million transactions.

[11]This is particularly true for investors swapping out of 12-week bills into 13-week bills because bid-ask spreads on 12-week bills are often wider than those on 13-week bills.

[12]A potential caveat to these results is that investors may face wider bid–ask spreads than those reported by surveyed dealers to the Federal Reserve Bank of New York and used in this paper. While this possibility would not necessarily reduce the yield pickup available to investors placing new funds into the bill market, it would lower the yield pickup from swapping bills because investors would incur the higher costs associated with wider bid–ask spreads.

bid-ask spreads and brokerage fees typically would have wiped out potential gains from 1985 through 1987. However, from 1988 through October 1991 as bid-ask spreads narrow, yield pickups to investors swapping bills are about 1-1/2 basis points, which represent an extra return of $37.50 on a $1 million swap. Therefore, although investors already owning one of the bills did not have an incentive to swap bills until the latter half of the sample, investors placing new funds in the bill market had a fairly strong incentive to purchase bills that are additional supplies of previously auctioned 52-week bills. It is surprising that this latter class of investors do not arbitrage away these yield spreads because with large quantities of bills maturing every week, there is no shortage of investors placing new funds in the bill market.

The finding that investors do not modify investment patterns to arbitrage away these yield spreads along this highly liquid area of the yield curve indicates that segmentation in the Treasury bill market is more pervasive than previously documented. Investor demand curves for particular securities are downward sloping, and as a result, investors require higher yields to hold greater quantities of particular bills. The results are also consistent with the findings of Park and Reinganum (1986) and Ogden (1987), who demonstrate that bills that mature during the last week of calender months have lower yields than adjacent maturity bills and Simon (1991), who shows that yields on bills that are reopened as cash management bills have higher yields than adjacent maturity bills.

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