Do Traders Benefit from Riding the T-Bill Yield Curve?

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Grieves et al. [1999] and Bieri and Chincarini [2005] aptly represented a line of research that shows the trading strategy known as *riding the yield curve* has consistently provided higher returns than a matched-horizon buy-and-hold-to-maturity strategy.[1] These studies, like earlier ones, focused largely on whether 1) buying a U.S. Treasury bill (T-bill) with a maturity exceeding the investor's holding period and selling it at the end of the holding period before the T-bill matures, exceeds the return from 2) buying a T-bill with a maturity equal to the investor's holding period. The goal of riding the yield curve is to capture a term premium (when it exists) on the longer-term T-bill. It is possible that during the holding period yields rise sufficiently to cause a drop in the price of the longer-term T-bill that eliminates the higher return from riding the curve. This risk aside, studies have found that the higher returns to the riding strategy have been quite reliable.[2] Using three- and six-month constant-maturity rates from the Federal Reserve, Bieri and Chincarini [2005] found strong and consistent excess returns from riding the U.S. T-bill yield curve. Like other studies, Grieves et al. [1999] used end-of-day T-bill prices from dealer quotes. From 1987 through 1994, they found that every riding strategy they examined provided higher returns on average.[3]

Consistently profitable and easy-to-execute trading strategies, such as riding the yield curve, should be traded out of existence in efficient markets. In spite of this tenet, numerous studies have demonstrated the persistence and potential exploitability of the turn-of-the-year anomaly in stock markets that are believed to be relatively efficient.[4] Griffiths, Turnbull, and White [1999] provided convincing evidence that the answer to this puzzle lies in the difference between observed quotes and actual transactions. Using standard methods and observed quotes, they found strong evidence of the turn-of-the-year effect for stocks traded on the Toronto Stock Exchange. When the authors examined data on actual transactions, however, the transactions needed to capture the profits were not available. Eliminating market inefficiency as a possible explanation, this result suggests that the turn-of-the-year effect in equities persists because transaction costs (including institutional impediments to trading) exceed the available profits.

In this article, we will examine whether a similar explanation allows the simple trading strategy of riding the yield curve to consistently provide higher returns through time. Using daily interest rate data from the Federal Reserve on 91-day and 182-day T-bills, we found support for persistent positive returns from riding the yield curve in the period January 2001–September 2007. We extended prior studies by using actual cash market quotes and transaction prices (from GovPX). To our surprise, we found that there were no transactions (i.e., no trades were executed) in the interdealer broker market for 182-day T-bills on the dates necessary to complete the trading strategy.[5] Therefore, to complete the ride, we used a substitute transaction for the 182-day T-bills. Specifically, we assumed delivery of a 182-day T-bill with 91 days remaining until maturity against secondary market purchases of 91-day T-bills. Using the substitute transaction, we found support for persistent positive returns. The results from the substitute transaction suggest that in order to generate $1 million of annual gain from the average ride, $425 million of transactions—representing about 85% of the average total market volume on the days used to calculate the ride—would have been necessary. Thus, we conclude that riding the yield curve continues to appear beneficial across time, but market limitations prevent exploiting the strategy in an economically meaningful manner.

CAPTURING A LIQUIDITY PREMIUM

According to the pure expectations hypothesis of the term structure of interest rates, forward rates represent unbiased expectations of future spot rates.[6] Additionally, the rate on, say, a two-period security is the product of today's one-period spot rate and next period's forward rate. In contrast, the liquidity preference theory of the term structure of interest rates posits that investors will extend maturity only if they are compensated for the additional illiquidity risk (immunization motivations aside). Thus, forward rates will not only reflect pure expectations of future spot rates, but will also include a liquidity premium that increases with time to maturity.[7]

Riding the T-bill yield curve involves buying a T-bill with a maturity exceeding the investor's holding period and selling the T-bill at the end of the holding period before it matures, instead of simply buying a T-bill with a maturity equal to the investor's holding period. Because all T-bills pay par value at maturity with no intervening coupon payments, all T-bills with the same time to maturity have the same promised payment stream regardless of their original maturity. At any point in time, institutional and microstructure considerations aside, the price of the T-bill should reflect the current market yield for the remaining time to maturity. Thus, the goal of riding the yield curve is to capture a liquidity premium believed to be built into the yield on the longer-term bill.

Capturing the apparent higher return seems reasonable because investors need only sell T-bills at market prices in a secondary market that is known to be large and active. However, transacting could be difficult because the T-bill market has three trading segments: 1) when-issued trading, 2) on-the-run trading, and 3) off-the-run trading. When-issued trading is trading in forward contracts for new T-bills and covers the time from Treasury auction announcement through the issuance of new bills. On-the-run trading covers the time from the issuance of a bill until the next new bill is issued. With the issuance of a new bill, the previous bill goes off the run and remains off the run until maturity.

Fleming [2003] noted that 71% of Treasury securities trading occurs on the run. Barclay, Hendershott, and Kotz [2006] found that Treasury note volume declines by more than 90% when T-notes go off the run and that the market share of electronic trading falls from 81% for on-the-run securities to 12% for off-the-run securities. They concluded that human interaction is needed to match traders in the thinly traded off-the-run market. Riding the T-bill yield curve requires selling off-the-run T-bills.

Given the lack of off-the-run trading activity, it is reasonable to question whether an investor can trade at quoted market prices and capture the positive benefits from riding the yield curve that have been suggested in prior studies. Accordingly, this uncertainty motivated our reexamination of the T-bill trading strategies of Grieves et al. [1999] and Bieri and Chincarini [2005] to determine if higher returns are available using transaction data.

DATA AND METHODS

In this section, we will describe the data used in our study and the methodology used to compute ride returns.

Data Description

GovPX provides price and transaction (tick-by-tick) data for Treasury securities reported by six of the seven major Treasury security brokers for interdealer activity.[8] To generate our sample, we used the GovPX database and paired all 91-day and 182-day T-bills having the same issue date. From these data, we identified every 91-day T-bill that had complete price data and quotes series from issuance to maturity. We then paired each 91-day T-bill that had a complete price and quote series with the 182-day T-bill of the same issue date that also had a complete price series from issuance to the maturity date of the paired 91-day T-bill. This process identified 326 potential

91-day T-bills. The pairing of the 182-day T-bills resulted in a loss of 23 of the potential bills due to holidays and nontrading Thursdays, leaving a final sample of 303 paired 91-day and 182-day T-bills distributed throughout the sample period. We then collected all tick-based transaction data for the paired T-bills for the issuance day (Thursdays only) and the maturity day of the 91-day T-bill 91 days later (Thursdays only).[9] For these same days, we also collected daily price/yield information from the Federal Reserve Bank of St. Louis FRED database for 91-day and 182-day T-bills (see the following discussion).

Grieves et al. [1999] used daily closing prices from HSBC to represent the prevailing market price at which participants could have transacted.[10] To provide comparability with Grieves et al. we used daily 91-day and 182-day T-bill yields from FRED. FRED provides daily T-bill yields that the Federal Reserve Bank of New York has determined are representative of the prevailing market yield. FRED data are not closing data, but are near-end-of-day quotes (at 3:30 p.m.) for on-the-run T-bills. We collected daily secondary market data for the most recently auctioned T-bills for each maturity tranche.[11]

Our sample period is January 4, 2001, through September 27, 2007, which corresponds to the dates for which GovPX data is available. Because Grieves et al. [1999] analyzed data from January 2, 1984, through April 20, 1997, we were able to determine if the higher returns observed in previous studies persist into a more recent time period.[12] The sample period is interesting because of the economic shocks and alternative interest rate environments it spans. For example, during the first half of the sample period, the Federal Open Market Committee (FOMC) was lowering the Fed funds target rate to an historic low of 1%, coupled with the market turbulence associated with the unwinding of the Internet bubble and the events of September 11. Rates remained virtually flat for approximately 18 months during 2003 and 2004, followed by a "measured" increase in the target rate to 5.25% through August 2007.

Computation of Ride Returns

We define *riding returns* as the annualized 91-day holding-period return (HPR) on every 182-day T-bill minus the annualized 91-day HPR on the paired 91-day T-bill. Riding returns are not excess returns because there is no attempt to control for risk in calculating these returns; this is common practice in this body of literature. Riding returns are not ex ante. Instead, our study is an ex post analysis of the returns available from riding the yield curve.

Grieves et al. [1999] calculated returns to 91-day rides on a Thursday-to-Thursday basis because newly issued T-bills become available on Thursdays. We followed their approach and conducted our primary analysis using Thursday price/yield data, followed by robustness checks using non-Thursday data. The method of calculating the HPR with FRED data follows. First, given the quoted discount rate on the 182-day T-bill on its issue date, we calculate its price. A new 91-day T-bill is issued 91 days later, so we obtain its discount rate on that day and calculate the price of the 182-day T-bill, now having 91 days to mature, based on this rate. On-the-run versus off-the-run issues aside, this computed price should reflect the price at which the 182-day T-bill could be sold. Finally, we use the two prices to calculate the 91-day HPRs on the 182-day T-bill. HPRs from GovPX data are calculated in a similar manner, but without the need to calculate prices from yields as GovPX provides price data directly.

For example, the discount rate from FRED on the 91-day T-bill issued on January 4, 2001, was quoted at 5.37%. The discount rate quote on the paired 182-day T-bill was 5.00%, which results in a purchase price of 97.472% of par value.[13] The January 4, 2001, 91-day T-bill matures on April 5, 2001, which leaves 91-days remaining until maturity for the 182-day T-bill. FRED provides information for the on-the-run security only. Hence, its use invokes a no-arbitrage argument that a 182-day T-bill with 91-days remaining should sell at the price of a 91-day T-bill issued on that same day.[14] Thus, we use the issue price of the new 91-day T-bill issued on April 5, 2001, as the April 5, 2001, selling price of the 182-day T-bill issued on January 4, 2001. On April 5, 2001, we observe a discount rate quote of 4.01% on the new 91-day T-bill, which translates to a price of 98.986361% of par. Using the two prices provides a raw return of 1.553% over the 91-day period, or an annualized HPR of 6.23%. Thus, riding the yield curve in this instance provides an annualized riding return of 0.86% (6.23% minus 5.37%). Using the GovPX data, we computed HPRs in the same manner.

RESULTS

In this section, we will discuss the results of our analysis using data from FRED and from GOVPX.

Results from FRED Data

Exhibit 1 presents the riding returns for 91-day rides reported by Grieves et al. [1999] and from our use of FRED data for 91-day rides. The first row shows the Grieves et al. average riding return of 1.483% from January 1987 through April 1997. For our full sample, we found the average ride provides an annualized return of 0.216%. In addition, 244 of the 303 rides (80.5%) generate positive riding returns. Clearly, our sample period provided substantially lower returns than the Grieves et al. sample period.

A year-by-year breakdown shows that riding returns and the success of the rides vary substantially through time. In each year from 2001 to 2003 and in 2007, riding the yield curve consistently provided higher returns using daily representative prices. This result is perhaps not surprising as these years also coincided with expansionary Fed policy that lowered short-term policy rates. Exhibit 2 demonstrates this fact and also shows that this period includes the largest term spreads in our sample period; Boyd and Mercer [2009] provided evidence showing this period's influence on other fixed-income trading strategies. In contrast, when the Fed was tightening in its "measured" fashion from 2004 to 2006 and term spreads were lower, 182-day T-bill rides proved unprofitable a significant portion of the time. An additional consideration is that the minimum bid–ask spread on a round-trip transaction in T-bills is two basis points (bps), and spreads of four to eight bps are not uncommon for off-the-run T-bills. Therefore, the average riding returns in 2004, 2005, and 2006 were well within the bid–ask spread, which would clearly eliminate any benefits to riding the curve.[15]

Results from GovPX Data

We next turn to an analysis of riding returns using secondary-market tick data. The use of tick data, rather than FRED data, more directly represents prices at which traders could have transacted. Our results on riding returns from the GovPX tick data are divided into four subsections: 1) rides using secondary-market sales of 182-day T-bills, 2) a discussion of a substitute transaction, 3) rides based on the substitute transaction, and 4) rides using when-issued market volume.

Secondary-market sales of 182-day T-bills. Given that there are clear benefits to riding the yield curve over more than half of our sample period and in over 80% of potential rides, coupled with consistent benefits found by others in earlier periods, we examined whether evidence exists that traders have taken advantage of the strategy. In other words, did actual secondary-market transactions take place that would have allowed an investor to capture the returns to 91-day rides on 182-day T-bills shown in

EXHIBIT 1

Holding-Period Return Statistics for Ride Strategies Using 182-Day T-Bills

	Number of Rides	Max Annualized Ride Return (%)	Min Annualized Ride Return (%)	Mean Annualized Ride Return (%)	Median Ride Return	Std. Dev.	Number of Winners (%)	Number of Losers (%)
GMMR 1987–1997	**518**			**1.483**	**1.467**	**0.444**		
Full Sample—MMW	303	1.546	−0.267	0.216	0.153	0.325	244 (80.5%)	59 (19.5%)
2001 Data	47	1.546	0.000	0.707	0.720	0.476	47 (100%)	0
2002 Data	48	0.720	0.018	0.293	0.241	0.156	48 (100%)	0
2003 Data	47	0.380	−0.138	0.155	0.171	0.091	45 (95.7%)	2 (4.3%)
2004 Data	48	0.356	−0.267	0.023	0.023	0.169	25 (52.1%)	23 (47.9%)

Source: Federal Reserve Bank of St. Louis FRED data.

EXHIBIT 2

Rates, Spreads, and 91-Day T-Bill Ride Returns, January 2001–September 2007

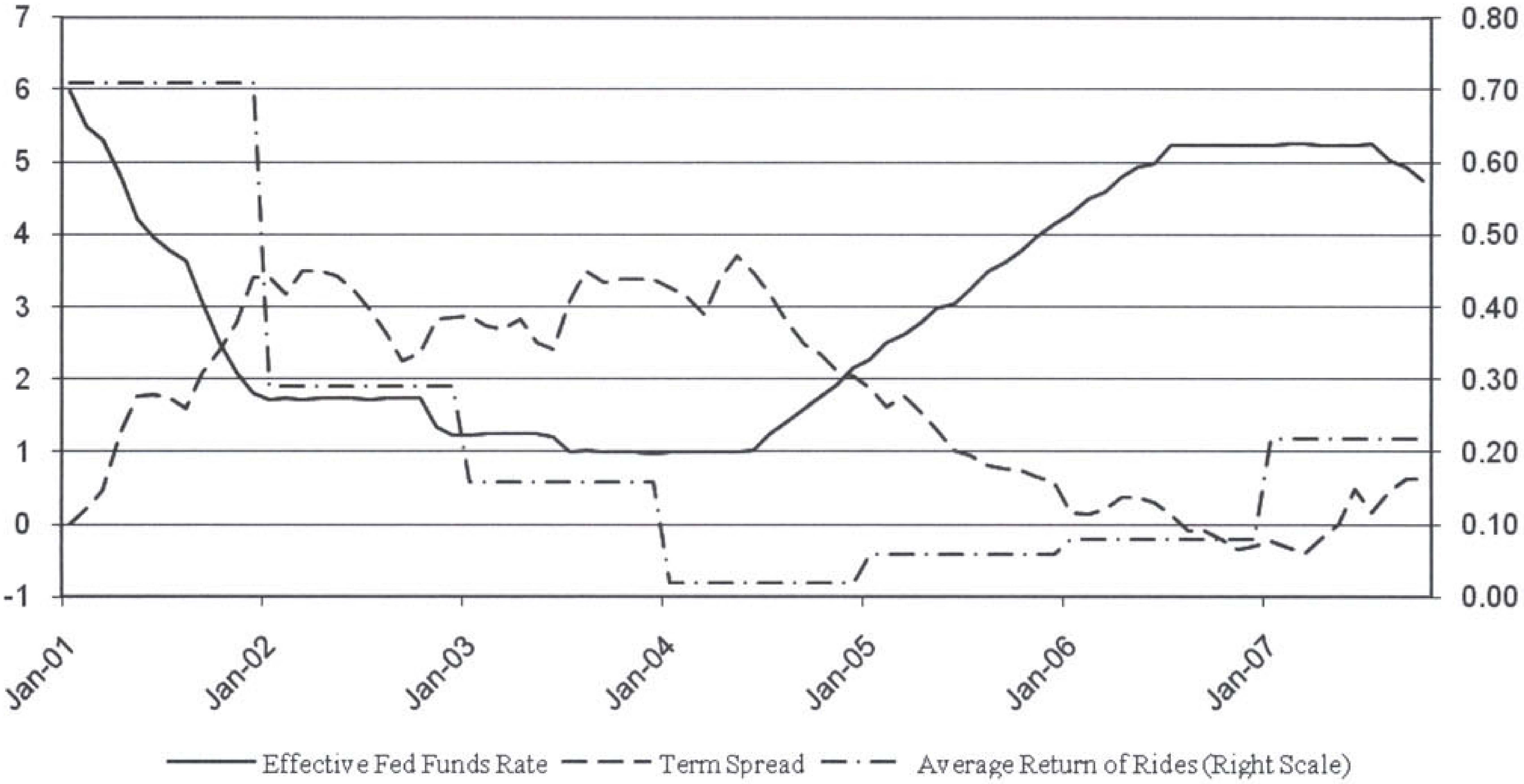

Exhibit 1? To this end, we analyzed GovPX tick data for each of the 303 rides examined in Exhibit 1.

We examined the tick-by-tick transaction data for each of the 303 Thursday pairs for which a purchase or sale of the 182-day T-bill would have been necessary in order to conduct the riding strategy. We found many opportunities, on each of the 303 Thursdays that start a ride, to buy the 182-day T-bill. To our surprise, however, we found *zero* transacted volume in any of the 182-day T-bills on the day we would need to sell the bill to complete the ride; that is, none of the 182-day T-bills that we would need to sell at the end of the ride had a single sale on those Thursdays. Furthermore, only 2 of the 303 182-day T-bills in our sample had any unfilled bid–ask quote activity.

For robustness, we also examined whether there were any transactions on the day before the close of the ride (Wednesday). Across the 303 possible rides, we found a total of only eight transactions executed that would complete the ride, and the transactions were confined to two contracts. It is thus clear that during our sample period traders were not actively trading to complete the ride and capture the potential benefits.

If the GovPX database had limited coverage of T-bills, it could explain our lack of transactions and quotes. Fleming [2003] discussed the coverage of Treasury securities in GovPX and pointed out that any limitations are concentrated in notes and bonds for which GovPX coverage declines through time. Fleming found that GovPX coverage of T-bills is about 90% of the market and that the coverage is consistent across time, suggesting that we did not miss any significant segment of the market covered by GovPX. It is important, however, to clearly define the market covered by GovPX.

GovPX was created in 1991 as a joint venture between primary dealers and interdealer brokers to provide the public better access to Treasury securities prices (see Fleming [1997] and Fleming and Remolona [1999] for discussions of the development of GovPX). Accordingly, GovPX captures and reports Treasury securities activity in the interdealer broker market. Fleming [1997] noted that brokers collect and post dealer quotes and execute trades between dealers while providing dealers anonymity. Thus, Fleming's [2003] statement that GovPX covers about 90% of the market means that GovPX covers 90% of the brokered market for trading between primary dealers. Additionally, Fleming [1997] noted that although over 1,700 brokers and dealers trade in the secondary market for Treasury securities, the primary dealers (numbering 39 in Fleming [1997], but only 20 at the end of our sample period) account for the majority of Treasury securities trading volume. The primary result from our analysis of secondary-market sales of 182-day T-bills is that we find zero sales of 182-day T-bills with 91 days remaining to maturity in the interdealer broker market, which accounts for the majority of the trading volume in T-bills.

Substitute transaction. Clearly, the lack of sales in 182-day T-bills with 91 days remaining until maturity suggests that traders are not directly selling 182-day T-bills in the interdealer broker market in order to complete the riding strategy. Traders can, however, complete the riding strategy by delivering a 182-day T-bill with 91 days to maturity against a secondary market purchase of a 91-day T-bill. This section describes this substitute transaction and how it relates to our data.

During our sample period, all regular 91-day T-bills were issued as a re-opening of a previously issued 182-day T-bill. In other words, on the issuance date of a new 91-day T-bill, the 91-day T-bill is identical to a previously issued 182-day T-bill with 91 days until maturity. In fact, the new 91-day T-bill is issued under the same CUSIP as the 182-day T-bill it re-opens. Accordingly, a trader wishing to ride the yield curve could exit the 182-day T-bill by delivering the 182-day T-bill into secondary-market purchases of the 91-day T-bill that re-opens the 182-day T-bill the trader holds.[16] The trader can do this either in the when-issued or on-the-run market for the new 91-day T-bill.

Having identified this substitute transaction, how would it be reported in GovPX if it were to occur? Specifically, we need to determine how the transaction would be reported when an investor buys a 91-day T-bill and the seller delivers a 182-day T-bill with 91 days to maturity. The investor would post a bid for a 91-day T-bill that the seller would fill with a bill that is identical to the one the investor wants to buy. It is reasonable that this transaction could be reported as the purchase of a 91-day T-bill and thus not appear in our data as a transaction in the original-issue 182-day T-bill. But GovPX identifies all new T-bills by CUSIP as well as an alias that identifies the initial maturity, so when the bill moves across the interdealer broker network it should be identified as a 182-day T-bill with 91 days until maturity. Accordingly, our methods in the previous section would have picked up these trades as sales of 182-day T-bills, yet our analysis found no trades of 182-day T-bills with 91-days until maturity.

Because no transactions are occurring across the interdealer broker market to complete the ride, the obvious question is why not? In the next two subsections, we will examine, using tick data, whether positive returns from riding the yield curve are available for the substitute transaction and whether sufficient volume exists in these transactions to make riding the yield curve economically attractive.

We recognize that two traders transacting with the same dealer to deliver 182-day T-bills with 91 days to maturity against a bid for a 91-day T-bill would not appear in the GovPX data. Consequently, we cannot rule out the existence of this type of trade and, in fact, are confident that this type of trade does exist. We will discuss the economic viability of these transactions to capture riding returns in the following subsections.

Riding returns from prices on the substitute transaction. In the previous subsection, we discussed completing the ride by delivering a 182-day T-bill with 91 days to maturity to an investor who is bidding to buy a 91-day T-bill. Although these trades do not appear in our sample, the GovPX tick data do provide the price and volume information to calculate riding returns and potential dollar gains from the substitute transaction. This subsection presents our analysis of the substitute transaction.

To maintain consistency with our previous results, our analysis of the substitute transaction uses only Thursday data. We calculated the riding returns using on-the-run secondary-market data from GovPX for the new 91-day T-bill on the day that each 182-day T-bill in the sample had 91 days remaining to maturity. Our sample size for this analysis is 237 T-bill pairs.[17]

Because we calculated riding returns using secondary-market transaction prices (on Thursdays) and the transactions occurred at many different prices, we needed to identify which prices to use in the HPR calculations. We investigated three alternative approaches: 1) a best-case scenario, 2) a worst-case scenario, and 3) a volume-weighted average. The best-case scenario uses prices that maximize each riding return and the worst-case scenario uses prices that minimize each riding return. The volume-weighted average uses volume-weighted prices to calculate the riding returns. Summary statistics for riding returns under each method are reported in Exhibit 3.

The volume-weighted results suggest an average riding return of 23.6 bps with 82% of the available rides being winners. These results are similar to the FRED results (21.6 bps and 80.5% winners) and continue to suggest

EXHIBIT 3
Holding-Period Return Statistics for Ride Strategies Using 182-Day T-Bills

	Mean	Max	Min	Winners	Losers
Volume-Weighted Average					
HPR	0.236%	1.538%	–0.236%	195 (82%)	42 (18%)
Volume	$501 mil.	$1,626 mil.	$105 mil.		
Best-Case Scenario					
HPR	0.286%	1.636%	–0.227%	205 (87%)	32 (13%)
Volume	$60 mil.	$460 mil.	$5 mil.		
Worst-Case Scenario					
HPR	0.178%	1.444%	–0.983%	177 (75%)	60 (25%)
Volume	$57 mil.	$767 mil.	$3 mil.		

Note: Alternative delivery method using GovPX data.

positive riding returns. In addition, the volume statistics show the average daily volume used to weight the transactions is $501 million. An annualized return of 23.6 bps on $501 million represents a potential annual gain of $1,182,360.

The best-case scenario riding returns were computed as follows: 1) calculate the 91-day HPR on each 182-day T-bill using the lowest possible issuance-day purchase price for the 182-day T-bill and using the highest possible selling price for the new 91-day T-bill 91 days later (the substitute transaction), and 2) then subtract the 91-day (buy-and-hold) HPR on the 91-day T-bill using the highest possible price on the day that begins the ride. The mean riding return from this process is 28.6 bps with 87% of the rides being winners. Clearly, the best-case scenario should provide higher returns than the average, and it does, but the improvement is only 5 bps. We say *only* because we believe that outliers (a best case) generally should be substantially above the mean. The trading strategy we examined on T-bills, however, has little uncertainty. Accordingly, an improvement of 5 bps is reasonable. The average volume available for the best-case scenario is $60 million, which provides annual profits of $171,600 for a trader who always picks off the best prices.

The worst-case scenario riding returns were computed as follows: 1) calculate the 91-day HPR on each 182-day T-bill using the highest possible issuance-day purchase price for the 182-day T-bill and using the lowest possible selling price for the new 91-day T-bill 91 days later, and 2) then subtract the 91-day (buy-and-hold) HPR on the 91-day T-bill using lowest possible price on the day that begins the ride. The worst case provides an average riding return of 17.8 bps with 75% of the rides being winners. This approach produces lower riding returns and fewer winners, but the results still suggest that it is an attractive trading strategy. With average volume of $57 million, the worst-case scenario provides annual profits of $101,460.

All three scenarios provide benefits, suggesting a potentially attractive trading strategy. For our sample period, however, the gains generated from the best and worst cases were likely not sizable enough to attract the attention of the dealers in a position to implement this trading strategy. The $1.1 million potential gain for the volume-weighted average might be large enough to attract some attention, but the gain requires capturing all of the available volume without moving prices. It is unlikely that a trader wishing to ride the yield curve could capture all the daily market volume and do so without moving prices. Because we analyzed only the issuance-day volume on the 91-day T-bill, and the bill trades forward in the when-issued market, we then investigated whether the when-issued market provides sufficient volume to provide the opportunity to exploit this trading strategy.

When-issued market volume. All T-bills have a when-issued market in which forward contracts trade for delivery of the next new T-bill issued. A T-bill trades on a when-issued basis from the time the Treasury announces the auction (on a Thursday) until the bill from that auction is issued (the following Thursday). The when-issued market has two segments—one existing before the Treasury's announcement of the auction results at 1:00 p.m. on the Monday between the two Thursdays, and the other existing after the 1:00 p.m. Monday announcement when all T-bill primary dealers know their allotment from the auction. Given this timing, we chose to use Tuesday's and Wednesday's when-issued volume to determine if sufficient additional volume exists to ride the yield curve in an economically meaningful manner.[18]

The average when-issued volume in 91-day T-bills in our sample period was $830 million on Tuesdays and $748 million on Wednesdays. Combining this volume with the average $501 million secondary-market volume on Thursdays results in total available average volume of $2.079 billion. At the average riding return of 23.6 bps, a trader would need to capture about 20% of the total volume on these days to create a position capable of generating an annual riding gain of $1 million; that is, a trader would need to capture 20% of the market volume every week without moving prices to generate an annual gain of $1 million.

CONCLUSIONS

In efficient markets, consistently profitable trading strategies should not remain profitable through time. Prior studies and our analysis using more-recent data show, however, that riding the T-bill yield curve appears to consistently provide benefits in the form of enhanced returns above a buy-and-hold-to-maturity alternative.

Using daily representative prices (from secondary market quotes), we found benefits to 91-day rides on 182-day T-bills from January 2001–September 2007. We found similar results using actual secondary market prices from GovPX when delivering 182-day T-bills with 91 days to maturity against purchases of new 91-day T-bills. These benefits and the consistency of these benefits vary through time and appear to be loosely related to the wide swings in monetary policy's impact on short-term interest rates.

Using tick-by-tick transaction data from the inter-dealer broker market to investigate the extent of cash market trading, we found that no transactions took place at the times necessary to complete the trading strategy and capture the potential benefits. Assuming that investors are rational and this market is efficient, the answer must lie in the available activity. Using volume-weighted average prices of market activity for our alternative delivery of 182-day T-bills to close the rides, we found 23.6 bps of return on $501 million of daily activity, resulting in $1,182,360 of average annual profits. Clearly, any trader or trading firm would be interested in additional annual profits of over $1 million. But to create this additional $1 million in gain would require capturing, on average, almost all of the available transactions for the ride on each Thursday. Specifically, to have generated $1 million of gain from the average ride, $425 million of transactions—representing about 85% of the average total market volume on days when the rides were completed—would have been necessary. Thus, we conclude that riding the yield curve continues to appear beneficial across time, but market limitations prevent exploiting the strategy in an economically meaningful way.

Our results suggest that the available volume in the interdealer broker market also substantially limits the viability of riding the yield curve in a meaningful way. Our data do not allow us to make a definitive statement about whether any traders attempt to ride the yield curve because we do not have access to trades completed within a single dealer's book. Trades among investors working with a single dealer should be smaller in size than trades across dealers. We conclude that the volume in the interdealer broker market limits the viability of riding the yield curve in an economically meaning manner.

ENDNOTES

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[1]Early studies focusing on U.S. T-bills include Dyl and Joehnk [1981], Osteryoung, McCarty, and Roberts [1981], and Grieves and Marcus [1992]. Ang, Alles, and Allen [1998] studied international data out to one-year maturities.

[2]Like prior studies in this area, we did not control for risk. Instead, we compared riding strategies against matched-horizon buy-and-hold alternatives. The interesting question of whether a risk premium is predictable is beyond the scope of this study and left to future research.

[3]Grieves et al. [1999] noted that previous studies used implied prices, and that their closing prices approximate the market prices available to traders. We note that caution should be used when interpreting results using closing T-bill prices. Hughes, Smith, and Winters [2007] examined on-the-run intraday T-bill yields and found that intraday volatility in T-bill yields follows the U-shaped volatility pattern observed in the market microstructure literature. The high end-of-day volatility suggests that closing prices may not be representative of prices available to traders throughout the trading day.

[4]See Banz [1981], Reinganum [1981], and Keim [1983].

[5]In addition, there are virtually no quotes for the needed trades.

[6]Term structure theories receive a fairly standard treatment in leading textbooks. Lucid discussions are provided in Fabozzi [2004] and more recently in Blackwell, Griffiths, and Winters [2007].

[7]Although forward rates in most term structure models also include a convexity bias term, we did not consider it in this study because the convexity bias is negligible at the short end of the term structure. See Ilmanen [2005] for a discussion of forward rate decomposition. Ilmanen also explains that convexity is negligible in T-bills.

[8]See Elton and Green [1998] for a discussion of the superiority of GovPX data over data collected by the Federal Reserve System.

[9]The normal T-bill cycle (91-day and 182-day bills) involves a Thursday issuance and a Thursday maturity, 91 or

182 days later. For legal holidays that occur on Thursdays, such as Thanksgiving, the appropriate issuance or maturity date is deferred to the subsequent Friday. The adjustment in the process for holidays can affect days to maturity on bills. To avoid any problems with holidays we omit these bills from consideration by deleting "holiday issuances" from our sample.

[10]Daily closing prices were from quotes and were drawn from Streetsoft Software.

[11]We use the DTB3 and DTB6 secondary-market series for the 91-day and 182-day T-bills, respectively. These market quotations are on a bank discount-rate basis and are taken at approximately 3:30 PM (EST) each business day by the Federal Reserve Bank of New York.

[12]The ending date of Bieri and Chincarini's [2005] sample for U.S. T-bill data appears to be 2003, although it is not made entirely clear in their study.

[13]The following formula is used to calculate price: $P = 100 * (1 - \frac{(Q/TTM)}{360})$ where P is the price (stated as a percentage of the maturity value and quoted to the sixth decimal place), Q is the discount quote rate, and TTM is the number of days remaining to maturity (either 91 or 182).

[14]This assumption is inherent in the Grieves et al. [1999] analysis. In our sample, all new 91-day bills are re-openings of previously issued 182-day T-bills. A more complete discussion of bill re-openings is in the results section of the article.

[15]For example, the average annualized ride return of 0.077% in 2006, when "de-annualized," is below 0.02%, and therefore less than the minimum two-basis-point round-trip transaction cost.

[16]Some transactions that appear viable do not occur due to market impediments. A former Wall Street fixed-income executive indicated to us that this transaction is viable.

[17]GovPX provides a set of data items for each Treasury security and creates a new tick of data every time any data item changes. Accordingly, there are many ticks of data that do not constitute a new transaction, so the time series of transactions must be extracted from the overall data. We are comfortable that we were able to identify the vast majority of trades. For situations in which we were not confident we could correctly identify transactions, we removed these days from further analysis. To readers familiar with GovPX this statement may be puzzling because GovPX has a data item labeled aggregate volume, which increments when a trade occurs, but this item is not fully populated in the T-bill data. In fact, it is only available in T-bills for a few contracts at the beginning of our sample period. Thus, we created an algorithm to extract transactions for the time series of tick data and test the algorithm on the contracts with cumulative volume. The algorithm correctly identified over 90% of the actual trades. We then applied it to the remainder of our sample to identify trades. Because we cannot know whether we perfectly identified all trades, we reviewed the volume for each Thursday and removed any day for which the volume was not reasonably similar to days with known volume. The result is a sample of 237 T-bill pairs.

[18]When-issued trading is trading in a forward contract for delivery of T-bills on issue day. Because the deviation from the average ride return is only 5 bps in the best case and 6 bps in the worst case, we assumed that the average ride return of 23.6 bps is a reasonable proxy for the ride returns from trading on when-issued days and focused this discussion on the available volume.

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