THE JOURNAL OF FINANCE • VOL. LI, NO. 2 • JUNE 1996

Idiosyncratic Variation of Treasury Bill Yields

GREGORY R. DUFFEE*

ABSTRACT

I document a dramatic increase in the importance of two types of variation in Treasury bill yields beginning in the early 1980s. The first is idiosyncratic variation in individual short-maturity (less than three months) bill yields. The second is a common component in Treasury bill yields that is not shared by yields on other instruments, such as short-maturity privately-issued instruments or longer-maturity Treasury notes and bonds. Some evidence suggests the first type reflects increased market segmentation. These results have important implications for the calibration and testing of no-arbitrage term structure models and interpreting tests of the expectations hypothesis.

UNITED STATES TREASURY bill yields play a central role in economists' efforts to understand the behavior of financial markets. The focus on Treasury bills is driven by the belief that bill yields can be viewed as benchmarks from which yields on other debt instruments are derived.

For example, in no-arbitrage models of the default-free term structure, the stochastic properties of the (hypothetical) instantaneous interest rate determine bond prices. Researchers often construct and evaluate these models using short-maturity bill yields as proxies for instantaneous interest rates.[1] Similarly, bill yields are frequently used to test the expectations hypothesis of the term structure.[2]

Economists' standard pricing models for default-risky securities also view Treasury yields as building blocks. In such models, yields on default-risky securities depend, at least in part, on the yields of default-free securities and the underlying stochastic default process. Therefore, yields on Treasury bills have been used in studies of the effects of monetary policy on the business cycle—not because bills are intrinsically critical to the economy, but because

* Federal Reserve Board, Washington, DC. I thank Rob Bliss, Lee Crabbe, Mark Fisher, Steve Lumpkin, John Rea, Glenn Rudebusch, Dave Simon, René Stulz (the editor) and three anonymous referees for helpful comments. Valuable research assistance was provided by Yongshan Duanmu. All errors are my own. The analysis and conclusions of this article are those of the author and do not indicate concurrence by other members of the research staff, by the Board of Governors, or by the Federal Reserve Banks.

[1] Das (1995), Longstaff and Schwartz (1992), and Chan, Karolyi, Longstaff, and Sanders (1992) all use the one-month Treasury bill.

[2] Examples include Shiller, Campbell, and Schoenholtz (1983), Jones and Roley (1983), Mankiw and Summers (1984), Fama (1984), Mankiw and Miron (1986), Hardouvelis (1988), and Campbell and Shiller (1991).

changes in bill yields are presumably linked to changes in yields on all other debt instruments.[3]

This article argues that the links between Treasury bill yields and other yields have dramatically weakened over time. Since the early 1980s, bill yields have become increasingly irrelevant as a benchmark. This is not news to market participants; Stigum (1990, p. 667) makes the same point, based on interviews with traders. Although the argument is not new (but nonetheless likely a surprise to many academic economists), this article is the first to document extensively the changing relations among yields on bills and other instruments. It also discusses some possible explanations for this divergence and considers some implications for economic research.

I examine two types of variation in Treasury bill yields that have become increasingly important since the early 1980s. The first is idiosyncratic movements in yields on short bills; maturities of two months or less. Owing to this variation, the volatilities of short-maturity bill yields have jumped relative to those of longer-maturity bill yields; contemporaneous correlations between yields on short-maturity bills and yields on other instruments have fallen precipitously. For example, prior to 1983, the correlation between monthly changes in yields on one-month and six-month bills exceeded 0.70; over 1983–1994 this correlation fell to 0.30.

I conclude that these decreased correlations are not the result of increased measurement error, nor are they the result of quarter-end or year-end effects. I find evidence that they are the result of increased market segmentation, although this evidence should be regarded as preliminary. Because of the idiosyncratic behavior of short-maturity yields, I argue that researchers should not calibrate no-arbitrage models of the term structure with yields on one-month Treasury bills. I also argue that empirical tests of the "expectations hypothesis" of the term structure are likely to misinterpret idiosyncratic variation in bill yields as evidence of information in the term structure.

The second type of variation in Treasury bill yields highlighted here is common to bill yields of all maturities. It can be thought of as a movement in Treasury bill yields away from yields on both default-risky instruments and other Treasury securities. Principal components analysis indicates that this component is two to five times more important in explaining monthly changes in longer-maturity (at least three months) bill yields after 1982 than earlier. For example, in the post-1982 period it accounted for over one-fourth of the variance of monthly changes in the three-month bill yield. The economic interpretation of this component is unclear.

Section I of this article discusses some of the previous literature on Treasury bills. It also describes the data used in the remainder of the article. Section II discusses the increased idiosyncratic variability in short-maturity Treasury bills. Section III considers the links between longer-maturity Treasury bills and other instruments. The last section concludes.

[3] See, e.g., Litterman and Weiss (1985) and Bernanke and Blinder (1992).

I. Previous Research and Data Description

A. Previous Research

Previous researchers have produced evidence of market segmentation in Treasury bills. Park and Reinganum (1986) find that over 1959–1982, bills maturing at the end of calendar months had, on average, yields that are 6.9 basis points lower than yields on adjacent bills maturing at the beginning of the next calendar month. Ogden (1987) argues that this spread reflects the preference of corporations to pay their bills at the end of calendar months.

Simon (1991, 1994) finds that the supply of particular bills affected yields on those bills, but not those of adjacent bills. The earlier article documents that over 1980–1988, the announcement of cash management bills affected the yields of bills to be reopened, but not yields of adjacent bills. Announcements raised yields on affected bills relative to adjacent bills by an average of 20 basis points. The later article documents that variations in supply affected yields on 12-week and 13-week bills over January 1985 through October 1991. Bills in large supply (primarily those originally issued as 52-week bills) had on average, yields that were 4 basis points higher than adjacent bills.

These articles document deviations in the bill term structure that likely reflect supply and demand for individual bills. However, the sizes of these idiosyncratic deviations do not appear large relative to the total volatility of bill yields. Dybvig (1989) presents evidence indicating relatively little idiosyncratic volatility in Treasury bill prices. He uses principal components analysis to analyze monthly comovements in logs of Treasury bill prices with maturities ranging from one to nine months. He concludes that over the period June 1964 through December 1987, a single factor explained almost all (98 percent) of the total variation in log prices.

Knez, Litterman, and Scheinkman (KLS, 1994) come to a somewhat different conclusion. They use factor analysis to examine weekly comovements in yields (as well as log prices) in Treasury bill yields and equivalent-maturity privately-issued instruments over 1985–1988. They report two results that are related to this article. First, they find that the one-month Treasury bill yield had a large idiosyncratic component. Second, they describe three factors that determine the bulk of changes in yields on the instruments they examined: a level shift, a rotation (which they call steepness), and a "Treasury factor," which they describe as "characterized by the private issuer money market instruments moving uniformly away from the Treasury bill market." Later, I argue that this third factor is actually characterized by yields on Treasury bills moving away from both yields on privately-issued instruments and yields on Treasury notes and bonds.

B. Data Description

I use various sources for Treasury bill data. The first is month-end data from the Center for Research in Security Prices (CRSP). The CRSP data are primarily gathered from quote sheets constructed by the New York Federal

Reserve Bank (NY FRB), based on indicative quotes from a few primary dealers. These data cover February 1959 through December 1994. I also use month-end indicative quotes from Salomon Brothers, Bloomberg, and Bear Stearns; these datasets cover smaller time periods that are discussed later. Weekly (Thursday) Treasury bill data from December 1987 through December 1994 come from the NY FRB. More detailed information about the Treasury bill data is contained in the Appendix.

The Federal Reserve Board database is my source for yields on privately-issued instruments. These instruments include Fed funds (the effective overnight rate), Eurodollar deposits at highly rated banks (London Interbank Bid Rate, LIBID), prime commercial paper (an average yield across highly-rated issuers), and large-denomination CDs (an average yield across highly-rated New York banks.)

The construction of "month-end" yields requires a definition of the "month-end" day because some of these markets are closed (or have missing data for some other reason) on days when other markets are open. I selected the days used in the CRSP files. This choice resulted in missing Eurodollar yields for March 1975 and September 1976. In addition, there are no quotes for September 1987's six-month Treasury bill in the CRSP 6-month file (the relevant bill was trading when-issued), so I use Bloomberg quotes for this bill. All yields are expressed as continuously compounded 365-day year yields.

II. An Analysis of Yields on Short-Maturity Bills

A. Empirical Analysis

Panel A of Table I reports the standard deviations and correlations among monthly changes in yields on Treasury bills with maturities ranging from one to six months. These yields are derived from data in the CRSP 6-month file, as described in the Appendix. The 1959–1994 period is broken up into subperiods roughly defined by the Federal Reserve's "monetarist experiment" that extended from October 1979 through late 1982. Table I documents the well-known fact that the volatilities of changes in bill yields were much higher during the 1979–1982 period than they were either before or after this period.

There are three points to take from Table I. First, all three points exhibit high correlations among bills with at least three months to maturity. All but one of these reported correlations exceeds 0.9. Fisher z-tests in Panel B indicate that these correlations are somewhat unstable (they are higher during the Fed experiment than either before or after). Nonetheless, this evidence indicates that, regardless of the Fed regime or the volatility of yields, yields on these bills largely move together.

Second, in both 1959–1978 and 1978–1982, yields on one-month and two-month bills also generally moved with yields on other bills, although the correlations are not as high as they are for the longer-maturity bills. Correlations involving the one-month yield averaged 0.78 in both periods, while those between the two-month yield and longer-maturity yields averaged 0.88 in the

Table I

Relations Among Monthly Changes in Treasury Bill Yields

The month-end yield on a Treasury bill with approximately i months to maturity is denoted Y_i. Yields are continuously compounded and expressed in percent/year. They are computed from the average bid and ask discount quotes from the Center for Research in Security Prices (CRSP) 6-month T-bill file.

Panel A: Standard Deviations and Correlations

			Correlation with:				
Period	Variable	Std. Dev.	ΔY_2	ΔY_3	ΔY_4	ΔY_5	ΔY_6
1959–1978	ΔY_1	0.480	0.811	0.792	0.784	0.744	0.745
	ΔY_2	0.439	—	0.865	0.873	0.881	0.882
	ΔY_3	0.435	—	—	0.927	0.872	0.903
	ΔY_4	0.411	—	—	—	0.917	0.921
	ΔY_5	0.427	—	—	—	—	0.939
	ΔY_6	0.411	—	—	—	—	—
1979–1982	ΔY_1	1.690	0.891	0.790	0.757	0.749	0.729
	ΔY_2	1.406	—	0.951	0.934	0.923	0.906
	ΔY_3	1.359	—	—	0.966	0.964	0.957
	ΔY_4	1.429	—	—	—	0.988	0.972
	ΔY_5	1.387	—	—	—	—	0.992
	ΔY_6	1.364	—	—	—	—	—
1983–1994	ΔY_1	0.697	0.441	0.419	0.423	0.293	0.301
	ΔY_2	0.377	—	0.816	0.789	0.745	0.734
	ΔY_3	0.339	—	—	0.927	0.921	0.929
	ΔY_4	0.332	—	—	—	0.912	0.931
	ΔY_5	0.351	—	—	—	—	0.970
	ΔY_6	0.349	—	—	—	—	—

Panel B: Significance Levels of Fisher z-Tests of Equality of Correlations Across Periods

		Correlation with:				
Periods	Variable	ΔY_2	ΔY_3	ΔY_4	ΔY_5	ΔY_6
1959–1978, 1979–1982	ΔY_1	0.068	0.906	0.770	0.845	0.940
	ΔY_2	—	0.001	0.035	0.159	0.472
	ΔY_3	—	—	0.018	0.000	0.009
	ΔY_4	—	—	—	0.000	0.001
	ΔY_5	—	—	—	—	0.000
1959–1978, 1983–1994	ΔY_1	0.000	0.000	0.000	0.000	0.000
	ΔY_2	—	0.115	0.010	0.000	0.000
	ΔY_3	—	—	0.997	0.019	0.132
	ΔY_4	—	—	—	0.781	0.520
	ΔY_5	—	—	—	—	0.001
1979–1982, 1983–1994	ΔY_1	0.000	0.000	0.001	0.000	0.000
	ΔY_2	—	0.000	0.000	0.000	0.001
	ΔY_3	—	—	0.024	0.018	0.125
	ΔY_4	—	—	—	0.000	0.008
	ΔY_5	—	—	—	—	0.000

earlier period and 0.93 in the later period. Panel B reports no strong evidence of instability in these correlations across the two periods.

Third, and most important, the post-1982 behavior of one-month and (to a lesser extent) two-month bills is dramatically different than earlier. The correlations involving the one-month bill averaged only 0.38, while the correlations of the two-month bill yield with the longer-maturity bill yields averaged 0.77. Panel B documents that the changes in these correlations over time are statistically significant. The volatility of these short-maturity bills also jumps relative to the volatilities of longer-maturity bills. For example, the three-month bill's standard deviation is less than half that of the one-month bill and less than 90 percent that of the two-month bill.

These results are consistent with those reported for 1985–1988 in KLS. Of course, because of the short time period they examine, KLS do not observe that this recent behavior of yields is markedly different from earlier behavior. If we focus on correlations, it appears that there was a fundamental change in the behavior of short-maturity bill yields in the early 1980s. However, we can put a different spin on Table I that suggests an earlier change. Consider regressing changes in the one-month bill yield on changes in the three-month bill yield. The results in Table I can be used to construct the standard error of this regression over the different time periods. This standard error is 29 basis points for 1959–1978, 103 basis points for 1978–1982, and 63 basis points for 1983–1994. Hence the idiosyncratic volatility of the one-month bill was much higher in both of the later two periods than in the earliest period. However, because the common component of yield changes was so volatile in the middle period, contemporaneous correlations were also high.

B. Possible Explanations

Why have correlations between short-maturity bill yields and longer-maturity bill yields fallen? I now consider four possibilities: Measurement error, month-end effects, variations in the precise maturities of the bonds used to construct short-maturity yields, and market segmentation.

B.1. Measurement Error

The Appendix notes that the manner in which the NY FRB constructs bill yields has changed over time. Accordingly, measurement error may have increased. I examine this possibility in two ways. First, I check whether there has been substantial measurement error in month-end bill yields over July 1987 through December 1994. I compare yields based on NY FRB data with yields from the *New York Times* (NYT). Beginning in July 1987, the NYT switched its source of Treasury bill data from the NY FRB to Bloomberg. Bloomberg quotes are averages (dropping high and low) of indicative quotes from many dealers. In April 1994, the NYT switched to Bear-Stearns indicative quotes.

To gauge the extent of measurement error in the quotes, I assume that there is some "true" average of bid and ask discount quotes on the maturity i bill at time t, which I denote by $Q_{i,t}$.[4] The average of bid and ask discount quotes from data source s is contaminated by measurement error (with perhaps a nonzero mean) that is independent through time and across data sources:

$$Q^s_{i,t} = Q_{i,t} + \varepsilon^s_{i,t}, \qquad s \in \{\text{CRSP, NYT}\}$$

Denote the difference between CRSP and *NYT* bid/ask average quotes on the same bill as $D_{i,t}$. We therefore have $\text{Var}(D_i) = \text{Var}(\varepsilon_i^{\text{CRSP}}) + \text{Var}(\varepsilon_i^{\text{NYT}})$ and $\text{Var}(\Delta Q_i^s) = \text{Var}(\Delta Q_i) + 2\ \text{Var}(\varepsilon_i^s)$. I then use the sample variances on the left-hand-sides of these equations to infer the variances of the unobserved components.

I find evidence of measurement error at the short end. The standard deviation of D_1 is 22.1 basis points, while the standard deviation of D_2 is 3.8 basis points. Corresponding standard deviations for maturities from three to six months are all less than 3.0 basis points. However, almost all of the measurement error in one-month bill quotes is in the NYT quotes. The implied standard deviations of $\varepsilon_1^{\text{CRSP}}$ and $\varepsilon_1^{\text{NYT}}$ are 6.0 and 21.3 basis points, respectively. The implied standard deviation of ΔQ_1 is 61.4 basis points, hence differenced CRSP quotes are very highly correlated with differenced "true" quotes: The implied correlation coefficient is 0.991.

As a further check that these results are not specific to NY FRB quotes, I constructed a subset of the results in Table I using month-end Salomon indicative bid-side quotes on one-month, three-month, and six-month bills from December 1963 through December 1994.[5] These results, which are available from the author on request, are quite similar to those in Table I. The correlations involving the one-month bill over 1983–1994 are somewhat higher using Salomon data than CRSP data ($\text{Cor}(\Delta Y_1, \Delta Y_3) = 0.53$ and $\text{Cor}(\Delta Y_1, \Delta Y_6) = 0.45$), but not high enough to affect the significance of the hypothesis tests of constant correlations over time. On balance, measurement error is an unlikely explanation for the low correlations in the post-1982 period.

B.2. Month-End Effects / Variations in Bill Maturity

So far we have focused on month-end data. It is well known that certain short-maturity instruments such as Fed funds and overnight repo are subject to potentially strong quarter-end and year-end effects. It is possible that, for some unspecified reason, short-maturity bills have become subject to such effects in recent years. If so, the low correlations among month-end bill yields since the early 1980s would simply reflect these effects, and would not be representative of relations among bill yields at times other than month-ends.

Another possible explanation for the low correlations during the 1983–1994 period is that there was a greater variation in the days-to-maturity of the bills

[4] For this exercise, the i-month bill at time t is defined as that used by CRSP in its 6-month file.

[5] I cannot match up CRSP quotes and Salomon quotes in the same way that I do with NYT quotes because Salomon does not identify the particular bill used as their one-month bill.

Table II

Relations Among Four-week Changes in Short-term Yields (Thursday to Thursday) December 1987 through December 1994

The Treasury bill yields are computed from bid-side composite quotes from the New York Federal Reserve Bank (NY FRB). The effective rate on Fed funds, the composite yield on one-month prime commercial paper, and the one-month Eurodollar deposit rate (LIBID) are from the Federal Reserve Board database. Treasury bills usually mature on Thursdays, hence the i-week bill here typically has $7i$–1 days to maturity as of its Friday delivery date. All yields are continuously compounded and expressed in percent/year.

		Correlation With Δ Yield on:						
Instrument	Std. Dev. of Δ Yield	One Month Eurodollar	One Month CP	4 Week T-bill	5 Week T-bill	9 Week T-bill	13 Week T-bill	26 Week T-bill
Fed funds	0.325	0.47	0.58	0.12	0.16	0.43	0.44	0.45
One month Euro	0.361	—	0.93	0.09	0.10	0.50	0.60	0.62
One month CP	0.354	—	—	0.04	0.08	0.50	0.59	0.63
4 week T-bill	0.509	—	—	—	0.66	0.53	0.39	0.28
5 week T-bill	0.423	—	—	—	—	0.63	0.53	0.42
9 week T-bill	0.246	—	—	—	—	—	0.89	0.79
13 week T-bill	0.231	—	—	—	—	—	—	0.92
26 week T-bill	0.259	—	—	—	—	—	—	—

used to construct the series of one-month and two-month yields. During the late 1960s and early 1970s, the Treasury issued one-year bills at the beginning of (almost) every month. Ten (eleven) months later, such a bill had a maturity of exactly two (one) months. Currently the Treasury issues bills every Thursday, resulting in a slightly greater variation in maturities on an 'i-month' bill.[6] (This issue is revisited in Section II.C.1.)

To simultaneously test these possibilities, I examine correlations among 28-day changes in yields on bills (Thursday to Thursday). Table II displays the standard deviations and correlations among four-week changes in bill yields from December 1987 through December 1994, which is the only period for which I have daily Treasury bill yields. Because the Treasury secondary market was closed on various Thursdays and a few other observations are missing, there are 328 valid observations of four-week differenced yields. (Table II also reports correlations involving other instruments; we consider them later.) Over this period the only source of variation in days-to-maturity was holidays that fell on Thursdays, pushing maturity back one day.

The correlations involving Treasury bills in Table II and those for 1983–1994 in Table I are very similar. For example, the correlation of the four-week changes in yields on the four-week bill and the 13-week bill that are respec-

[6] The standard deviation of the one-month bill's maturity from the CRSP 6-month file is 2.54 days during 1959–1978, 2.71 days during 1979–1982, and 2.83 days during 1983–1994. Standard deviations for the two-month bill's maturity are similar.

tively closest to one-month and three-month bills, is 0.39, while the correlation between four-week changes in yields on the four-week bill and the 26-week bill (closest to a six-month bill) is 0.28. These results indicate that the increased idiosyncratic volatility in short-maturity bill yields is not an artifact of varying days-to-maturity or month-end effects.

B.3. Segmented Markets

In order for these results to be explained by market segmentation, a number of conditions must be satisfied. First, there must be some group of investors for whom short-maturity, highly-rated privately-issued debt or longer-maturity Treasury bills are not good substitutes for short-maturity bills. Denote this group of investors as "inelastic" investors. Second, the importance of these inelastic investors must have risen over time. Third, these inelastic investors need to affect bill prices; there must be some periods during which these investors are at the margin.

Certain classes of investors can be viewed as inelastic investors. They include corporations who are funding specific liabilities that mature on a given date (Ogden (1987)) and money market mutual funds (Collins and Mack (1994), Cook and Duffield (1993)). Other investors who may not search out profit-making opportunities across the spectrum of Treasury bills are foreign central banks and individual direct purchasers of Treasury bills.

Stigum (1990) claims that the demand for bills on the part of these inelastic investors has risen over time. Her claim is consistent with the evidence of Cook and Duffield (1993), who note that state tax law changes caused money market mutual funds to sharply increase their holdings of Treasury bills in the latter half of the 1980s. In addition, Cook (1993) notes that foreign central banks doubled their holdings of bills from December 1985 to December 1988 because of exchange-rate interventions.

The demands of inelastic investors can move the yield of a given bill away from yields on nearby instruments if their demands are so large that they absorb the entire net supply of the bill. If so, the expected return to holding the given bill will fall below expected returns to holding nearby bills. Other investors (call them "speculators") would like to short the bill, in the sense that they would like to promise to deliver the cash flow associated with this bill at maturity. In other words, speculators would like to issue their own Treasury bills. However, only the Treasury can issue Treasury bills—therefore speculators cannot take advantage of this relatively low-yielding bill.[7] This point has also been made by Rowe, Lawler, and Cook (1986).

[7] Short positions in the Treasury market are achieved through a combination of reverse repos (simultaneously buying a bill and selling it forward) and selling the bill acquired through the reverse repo. If the expected return to holding a particular bill is lower than the general collateral rate, the bill will be on special in the repo market. Therefore, speculators taking short positions in the bill will be unable to profit from its relatively low yield. For a discussion of special repo rates, see Duffie (1996).

If the increased idiosyncratic variability in short-maturity bill yields is the result of an increase in demand on the part of inelastic investors, exogenous fluctuations in the supply of short-maturity bills should be positively associated with idiosyncratic fluctuations in expected returns. I test this hypothesis for one-month, two-month, and three-month bills. There are two major problems in testing this hypothesis. First, fluctuations in supply are not truly exogenous, but are determined by the Treasury. Second, expected returns are unobserved.

The working assumption here is that changes in supply cause idiosyncratic changes in expected returns, but causality could easily go the other way. For example, if the Treasury were to issue additional three-month bills whenever it perceives an increase in current or future demand for such bills, any positive relation between supply and expected returns that is induced by inelastic investors could be mitigated or even reversed by the Treasury's reaction function.[8]

I use yields as a proxy for expected returns. The problems this proxy causes in interpreting the results are discussed below. I define the idiosyncratic component of the month-i bill yield as the residual from a regression of the bill's differenced yield on the differenced yields of bills with maturities ranging from four to six months. The resulting idiosyncratic component for the month-i bill is then regressed on the change in the log supply of the month-i bill. The results are displayed in Table III.

Table III indicates that during 1959–1978, changes in bill supply had no significant effect, either economically or statistically, on yields. During 1979–1982, only the three-month yield was significantly associated with changes in bill supply. However, the sign is wrong (greater supply corresponded to lower yields). By contrast, during 1983–1994, changes in supply were strongly positively associated with idiosyncratic changes in yields on both the one-month bill and the two-month bill. Changes in supply explained (in an R^2 sense) 17 percent of the idiosyncratic variation in one-month yields and 9 percent in two-month yields.

Table III tells us that over 1983–1994, supply affected yields on one-month and two-month bills. Although this is consistent with a model of segmented markets with inelastic investors, such a model is not a necessary implication of these empirical results. Moreover, even if this model were true, these results do not imply that inelastic investors are the marginal holders of one-month and two-month bills, because yields are not equivalent to expected returns.

For example, the observed positive relation between supply and the two-month yield could be driven by the asset demands of speculators who are aware of the positive relation between supply and the one-month yield. To fix ideas, assume that the supply of the two-month bill today is low. Then

[8] As of this writing, the Treasury does not adjust the size of its auctions in response to such perceived fluctuations, but it is not clear what the Treasury's behavior was in earlier years because its policies are unpublished.

Table III

The Effect of Treasury Bill Supply on Bill Yields

Idiosyncratic components of monthly changes in yields on one-month, two-month, and three-month Treasury bills are constructed by regressing these changes on contemporaneous changes in yields on bills with maturities ranging from four to six months. Yields are computed from average bid and ask discount quotes from the Center for Research in Security Prices (CRSP) 6-month T-bill file; they are continuously compounded and expressed in percent/year.

$$\Delta Y_{i,t} = \alpha_0 + \sum_{j=1}^{3} a_j Y_{j+3,t} + \eta_{i,t}, \qquad i = 1, 2, 3$$

Then for each maturity i, the idiosyncratic component $\eta_{i,t}$ is regressed on the change in the log of the supply of the i-month bill, denoted $\Delta S_{i,t}$.

$$\eta_{i,t} = b_0 + b_1 \Delta S_{i,t} + e_{i,t}$$

Results of the latter regressions are displayed below, with Newey-West t-statistics (2 lags) in parentheses.

Period	Maturity (i)	Var(η_i)	b_1	R^2
1959–1978	1	0.088	0.059	0.011
			(1.68)	
	2	0.036	0.015	0.002
			(0.78)	
	3	0.024	0.009	0.001
			(0.34)	
1979–1982	1	1.176	0.534	0.020
			(0.88)	
	2	0.250	−0.112	0.004
			(0.74)	
	3	0.112	−0.298	0.082
			(2.38)	
1983–1994	1	0.366	1.012	0.171
			(6.57)	
	2	0.052	0.256	0.086
			(2.93)	
	3	0.012	−0.012	0.001
			(0.35)	

the supply of next month's one-month bill will also be low (since it is the same bill). This means that next month's one-month bill is likely to have a low yield, or equivalently a high price. Speculators will then increase their demand for today's two-month bill, with the intent of selling it prior to maturity. Therefore the equilibrium yield of the two-month bill will fall when the supply of the two-month bill falls. At maturity, the net supply of the bill will presumably be held entirely by inelastic investors, but the results in Table III do not allow us to know at what point speculators sell their bill holdings.

C. Implications

The following discussion is not meant as an exhaustive list of the implications of idiosyncratic components in short-maturity bill yields. The most important message to take from this discussion is that these components can have important implications for typical empirical tests. If these implications are ignored, empirical results can easily be misinterpreted.

C.1. Parameterizing Term Structure Models

Das (1995) and Longstaff and Schwartz (1992) calibrate their respective models of the default-free term structure with the instantaneous default-free interest rate proxied by the one-month Treasury bill yield. Chan, Karolyi, Longstaff, and Sanders (1992) investigate the properties of the one-month Treasury bill yield for the express purpose of choosing among term structure models.

There is, however, no compelling reason to use a Treasury bill yield as a proxy for the instantaneous default-free rate. No-arbitrage term structure models are not models of yields on Treasury securities. Interest rates in these models are rates at which agents can both borrow and lend without credit risk, but agents cannot commit to default-free borrowing at Treasury yields. In addition, Grinblatt (1995) argues that Treasury securities have a liquidity advantage over privately-issued instruments because Treasuries are the desired mechanism for hedging interest rate risk. Hence owners of Treasury securities receive a convenience yield in addition to dividends and price appreciation. (This argument is more relevant to yields on three-month bills, which are heavily traded, than one-month bills, which are infrequently traded.)

Of course, models of default-free term structures are not models of yields on privately-issued instruments either. However, short-term instruments issued by highly-rated firms have a negligible probability of default and have no short-sale constraints. Hence the theoretical r_t of these term structure models is likely closer to the London Inter Bank Offered Rate (LIBOR) or LIBID than it is to some Treasury bill yield.

A simple way to check whether a particular short-maturity yield is a reasonable proxy for the instantaneous default-free rate is to look at the correlations of that yield with default-free yields at other maturities. In one-factor term structure models, the instantaneous default-free rate is perfectly instantaneously correlated with all other default-free yields. In two-factor models, this perfect correlation is relaxed. However, with typical two-factor models such as Brennan and Schwartz (1979) or Longstaff and Schwartz (1992), the second factor primarily affects longer-maturity yields, hence the instantaneous default-free rate is highly correlated with other short-maturity yields.

By this metric, the one-month Eurodollar yield is superior to the one-month Treasury bill yield. Recall Table II, which reports correlations of four-week differenced yields among Fed funds, one-month Eurodollars, and various Treasury bills. Yields on three-month (13-week) and six-month (26-week) Treasury bills are more closely correlated with the one-month Eurodollar yield than they are with either the four-week or the five-week bill yield. These results are consistent with those in KLS. Moreover, the overnight Fed funds rate is more closely correlated with the one-month Eurodollar yield than with either the four-week or the five-week bill yield.

There is also a practical reason for calibrating such models with a one-month Eurodollar yield instead of a one-month Treasury bill yield.[9] The stochastic properties of one-month Treasury bill yields critically depend on the precise construction of the time series of yields. Recall that during the 1983–1994 period, all Treasury bills matured on Thursdays (unless a holiday intervened). For example, at the end of month t there could be a bill with 27 days to maturity and a bill with 34 days to maturity. Therefore construction of a time series of one-month Treasury bills requires a decision rule, but there is no obviously "right" rule. Unfortunately, the choice of rule matters. For example, Table II documents that 4-week and 5-week bill yields were not strongly correlated and had very different standard deviations.

Here I illustrate some of the differences in the stochastic properties of three commonly used one-month Treasury bill yield series that are constructed by CRSP using different decision rules. The first is from the CRSP Risk Free Rates file, which uses the bill closest to 30 days to maturity. The other two series are "built by selecting for each month the bill closest to either 6 months to maturity or 12 months to maturity, then following that bill to maturity" (CRSP (1995), p. 19). The one-month yield used earlier in this paper was taken from the CRSP 6-month file.

I denote the one-month yield from the Risk Free file as CRSP-RF, the one-month yield from the six-month file as CRSP-6, and the one-month yield from the twelve-month file as CRSP-12. Panel A of Table IV reports the standard deviations and contemporaneous correlations of monthly yield changes among these various one-month bill yields, as well as the one-month Eurodollar deposit rate. The time period examined is 1983–1994.

The correlation between CRSP-RF and CRSP-6 is high (0.88). By contrast, the correlations of these series with CRSP-12 are 0.59 and 0.55, respectively. The standard deviation of CRSP-12 is substantially smaller than the standard deviations of CRSP-RF and CRSP-6.[10] None of these yields is closely correlated with the Eurodollar yield.

[9] An alternative is to use longer-maturity bond prices to infer the properties of the instantaneous default-free interest rate.

[10] I have no good explanations for the lower volatility of CRSP-12. In particular, it is not a consequence of the greater volatility in the supply of bills composing the CRSP-6 and CRSP-RF series. (CRSP-12 bills are all 12-month bills that are reopened as six-month bills and three-month bills. The CRSP-RF and CRSP-6 bills are sometimes original six-month bills and sometimes original twelve-month bills. Therefore, these latter series exhibit greater variability in the total supply of bills outstanding.) For each series, I regressed changes in yields on changes in log supply, but the volatility of the CRSP-12 residuals remained substantially lower than the volatility of the residuals from the other two series.

Table IV

A Comparison of Various One-month Yields, 1983–1994

This table reports some statistical properties of monthly changes in yields on one-month Eurodollar deposits and yields on "one-month" Treasury bills. Three different time series of one-month Treasury bill yields are considered; all are constructed by the Center for Research in Security Prices (CRSP). The yield derived from the CRSP Riskfree Rates file is denoted CRSP-RF; the yield from the CRSP 6-month file is denoted CRSP-6; and the yield from the CRSP 12-month file is denoted CRSP-12. All bill yields are based on average bid/ask discount quotes reported in the CRSP files. All yields are continuously compounded and expressed in percent/year. T-statistics are in parentheses.

Panel A. Summary Statistics

Instrument	Std. Dev. of Δ Yield	Correlation With Δ Yield on: CRSP-6	CRSP-12	Eurodollar
CRSP-RF	0.744	0.876	0.595	0.265
CRSP-6	0.697	—	0.549	0.253
CRSP-12	0.558	—	—	0.333
Eurodollar	0.427	—	—	—

Panel B. Maximum Likelihood Estimates of an ARCH(1) Model

$$\Delta r_{t+1} = (\beta_0 + \beta_1 r_t)\Delta t + \epsilon_{t+1}, \quad \sigma^2_{\epsilon_{t+1}} = \alpha_0 + \alpha_1 \epsilon_t^2$$

Yield	β_0	β_1	α_0	α_1
CRSP-RF	3.219	−0.595	0.459	0.125
	(1.27)	(1.55)	(10.75)	(1.69)
CRSP-6	2.608	−0.519	0.373	0.215
	(1.145)	(1.53)	(10.62)	(1.71)
CRSP-12	1.667	−0.365	0.214	0.280
	(0.84)	(1.26)	(8.56)	(2.50)
Eurodollar	−0.796	−0.099	0.125	0.288
	(0.61)	(0.57)	(7.31)	(2.30)

Panel C. GMM Estimates of the Level—Volatility Relationship

$$\Delta r_{t+1} = (\beta_0 + \beta_1 r_t)\Delta t + \epsilon_{t+1}, \quad \sigma^2_{\epsilon_{t+1}} = r_t^{2\gamma} V \Delta t$$

Yield	β_0	β_1	V	γ	p-values of χ^2 (1) Test: $\gamma = 0.00$	$\gamma = 0.5$	$\gamma = 1.0$
CRSP-RF	4.112	−0.769	4.712	0.089	0.711	0.204	0.036
	(1.97)	(2.23)	(1.05)	(0.35)			
CRSP-6	3.738	−0.702	2.965	0.185	0.460	0.341	0.066
	(1.79)	(1.99)	(0.95)	(0.68)			
CRSP-12	2.330	−0.435	0.457	0.572	0.046	0.762	0.107
	(1.69)	(1.75)	(1.13)	(2.41)			
Eurodollar	1.308	−0.223	0.557	0.349	0.086	0.501	0.025
	(1.06)	(1.24)	(1.17)	(1.65)			

These yields also differ in the time series properties of their respective volatilities. First consider the persistence of volatility. I fit the one-month yields to the ARCH(1) model in equation (1):

$$\Delta r_{t+1} = (\beta_0 + \beta_1 r_t)\Delta t + \varepsilon_{t+1}, \qquad \sigma^2_{\varepsilon_{t+1}} = \alpha_0 + \alpha_1 \varepsilon_t^2 \tag{1}$$

Panel B of Table IV reports the results of maximum likelihood estimation of equation (1). The t-statistics do not allow us to reject, at the 5 percent level, the hypothesis of no persistence in volatility for CRSP-RF or CRSP-6. By contrast, both CRSP-12 and the Eurodollar yield exhibit statistically significant volatility persistence.

Now consider the relation between the level of the yield and the volatility of the yield, as summarized by the coefficient γ in equation (2):

$$\Delta r_{t+1} = (\beta_0 + \beta_1 r_t)\Delta t + \varepsilon_{t+1}, \qquad \sigma^2_{\varepsilon_{t+1}} = r_t^{2\gamma} V \Delta t. \tag{2}$$

Commonly used theoretical models include $\gamma = 0$ (Vasicek (1977)), $\gamma = 0.5$ (Cox, Ingersoll, and Ross (1985); CIR), and $\gamma = 1.0$ (Brennan and Schwartz (1980)). Chan et al. estimate equation (2) with Generalized Method of Moments (GMM) over July 1964 through December 1989 with CRSP-12 and find $\gamma = 1.5$. I use their GMM technique to estimate equation (2) over January 1983 through December 1994 with CRSP-RF, CRSP-6, CRSP-12, and the Eurodollar yield. The results are reported in Panel C of Table IV.

If we were to use the estimates in Panel C to choose among competing models of the term structure, we would make different choices depending on the series examined. For example, with CRSP-RF, the most appropriate model is Vasicek; Brennan-Schwartz is easily rejected. However, with CRSP-12, Vasicek is rejected in favor of CIR, or perhaps Brennan-Schwartz. The fact that slight differences in the definition of a "one-month" bill yield can have such large effects on its time series properties is further evidence that these yields should not be used to calibrate term structure models.

C.2. Interpreting Tests of the Expectations Hypothesis

One version of the expectations hypothesis of interest rates is that long-maturity yields are an average of expected future short-term yields. A modified form of this hypothesis allows a constant maturity premium in long yields. This hypothesis is frequently tested by regressing the future change in a one-period yield on the current spread between two-period and one-period yields.

$$Y_{1,t+1} - Y_{1,t} = b_0 + 2b_1(Y_{2,t} - Y_{1,t}) + e_{t+1}. \tag{3}$$

This hypothesis implies $b_1 = 1$, which is almost always strongly rejected with Treasury bill data. The overwhelming rejections have led to the evolution of this empirical literature away from tests of the expectation hypothesis to tests of "information" in the term structure (is b_1 different from zero?). For example, Fama (1984) estimates equation (3) with one-month and two-month Treasury bill yields over February 1959 through July 1982. He finds $b_1 = 0.55$, with an R^2 of 0.17. He interprets this as implying that the two-month yield contains information about the future one-month yield.

If markets for short-maturity bills are segmented, the primary mechanism that underlies the expectations hypothesis—speculators keep expected returns on Treasury bills approximately equal across the spectrum of bills—is not operative. Paradoxically, however, the increased idiosyncratic variability in one-month yields since the early 1980s can lead us to conclude that the amount of information in the two-month yield about next month's one-month yield has *increased* over time.

To fix ideas, assume that the current one-month yield has fallen because of a temporary increase in idiosyncratic demand. The two-month yield will not respond to this increase in demand, therefore the spread between the two-month yield and the one-month yield will increase. Because the increased idiosyncratic demand is temporary, it is likely that next month's one-month yield will be higher than the current one-month yield. Therefore, the positive spread today will correspond to a future increase in one-month yields, which is the qualitative result predicted by the expectations hypothesis.

An examination of equation (3) reveals that the presence of a component in the one-period yield that is independent of other current or future yields will bias both b_1 and the regression's R^2 toward 0.5. In fact, these are almost precisely the results of estimating equation (3) with one-month and two-month bill yields over January 1983 through December 1994. (The yields are from the CRSP 6-month file.) The estimated regression coefficient is 0.51 with a heteroskedasticity-consistent standard error of 0.05. The R^2 is 0.444. Of course, this regression coefficient does not necessarily reflect the presence of noise: Fama's estimated coefficient, based on pre-1983 data, is almost identical. However, recall that Fama's R^2 is only 0.17.

The high R^2 in the later period is unique to Treasury bills. An estimate of equation (3) using yields on 30-day and 60-day commercial paper (the only other instrument for which I have a two-month yield) over January 1983 through December 1994 has an R^2 of 0.261. Roberds, Runkle, and Whiteman (1994) estimate equation (3) over February 1984 through July 1991 using yields on 30-day and 60-day term Fed funds and repo. They find an R^2 of 0.152 for Fed funds and an R^2 of 0.150 for repo. I therefore conclude that the high R^2 for bill yields is further evidence of segmentation in the markets for individual Treasury bills instead of evidence of a very informative two-month yield.

III. An Analysis of Common Movements in Bill Yields

As mentioned above, yields on Treasury bills with three or more months to maturity largely move together. This section examines whether they also move in sync with other yields, such as yields on short-maturity privately-issued instruments and longer-maturity Treasury notes and bonds.

A. Empirical Results

The approach in this section differs from that taken in the prior section in two ways. First, here I focus on principal components instead of standard deviations and correlations (although of course the information content is identical).[11]

Second, I examine only the post-1974 period. The private-issuer markets that I consider in this section (Eurodollars, commercial paper, and bank CDs) underwent substantial changes in the early 1970s in response to the collapse of Bankhaus I.D. Herstatt and the problems at Franklin National Bank. These events caused substantial volatility in yields on such privately-issued instruments. After 1974 the markets settled down. Because of the relatively short time period examined, I consider only two subperiods here: 1975–1982 and 1983–1994. The volatility of yields during the earlier time period is concentrated during the 1979–1982 Fed monetarist experiment.

I consider three-month and six-month Treasury bills, Eurodollars, commercial paper, and bank CDs, as well as CRSP-constructed zero-coupon Treasury bonds with maturities from one to five years. For each subperiod, a single principal components decomposition is used to construct the 13 principal components associated with monthly changes in yields on these 13 instruments. Figure 1 displays the first three principal components for 1975–1982, while Figure 2 displays the first three components for 1983–1994. Although I have yields on one-month instruments for all four types of instruments, I do not include these yields in the calculation of principal components because the one-month bill yield drastically contaminates the results.[12] However, the figures include the projections of the one-month yields on the principal components in order to show the effect that these components have on very short-maturity yields. Table V reports, for each yield, the fraction of variance explained by each of the first three components.

As is typical in decompositions of yield movements (Dybvig (1989), Litterman and Scheinkman (1991), and Abken (1993)), in both periods the first component is the dominant component and is a roughly parallel movement in yields. This component accounts for 92.2 percent of the total variation in the earlier period and 87.8 percent of the total variation in the later period.

The second component can be called a "twist" in the term structure. It accounts for 4.2 percent of the total variation in the earlier period and 6.7 percent in the later period. In both periods, the default-risky instruments appear to twist more than do Treasury bills. However, as Table V indicates, this component is much more important in explaining variations in the longer-

[11] A principal components analysis of the Treasury bill yields examined in the prior section is uninteresting. For 1983–1994, the first component is a roughly parallel movement in yields, the second is a movement in the one-month yield, and the third is a movement in the two-month yield.

[12] For 1983–1994, the second component of such a decomposition is essentially an idiosyncratic one-month Treasury bill component. The component accounts for 90 percent of the variation in this yield, but accounts for no more than 4.5 percent of the variation in any other yield.

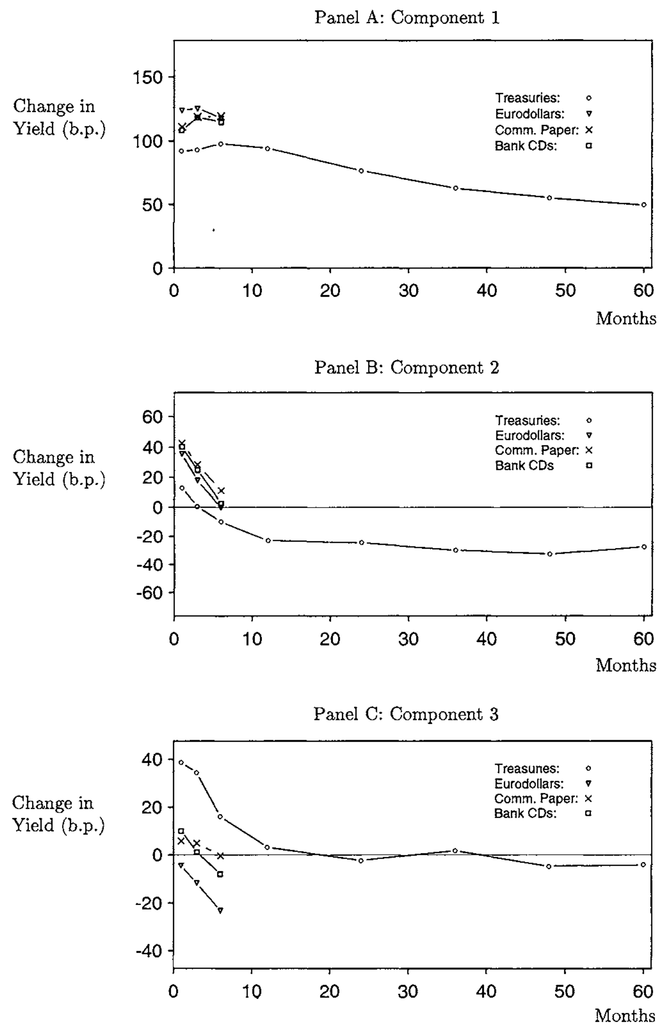

Figure 1. Principal components decomposition of yields, 1975–1982. Panels A, B, and C display the first three principal components of monthly changes in continuously-compounded annualized yields on various zero-coupon instruments. The graph of each component represents the change, in basis points, associated with a one standard deviation shock to that component.

maturity Treasury instruments than in the shorter-maturity instruments, so I do not focus on it here.

Of much more interest is the third component. Although this component explains only 1.6 percent of the total variation in the earlier period and only 3.0 percent in the later period, it has a large impact on Treasury bills. I follow KLS in calling this component a "Treasury bill" component, although this term is slightly misleading in the earlier period. Unlike KLS, however, I cannot interpret this component as a movement of default-risky instruments away from Treasuries. Instead, I interpret it as a movement of Treasury bills away

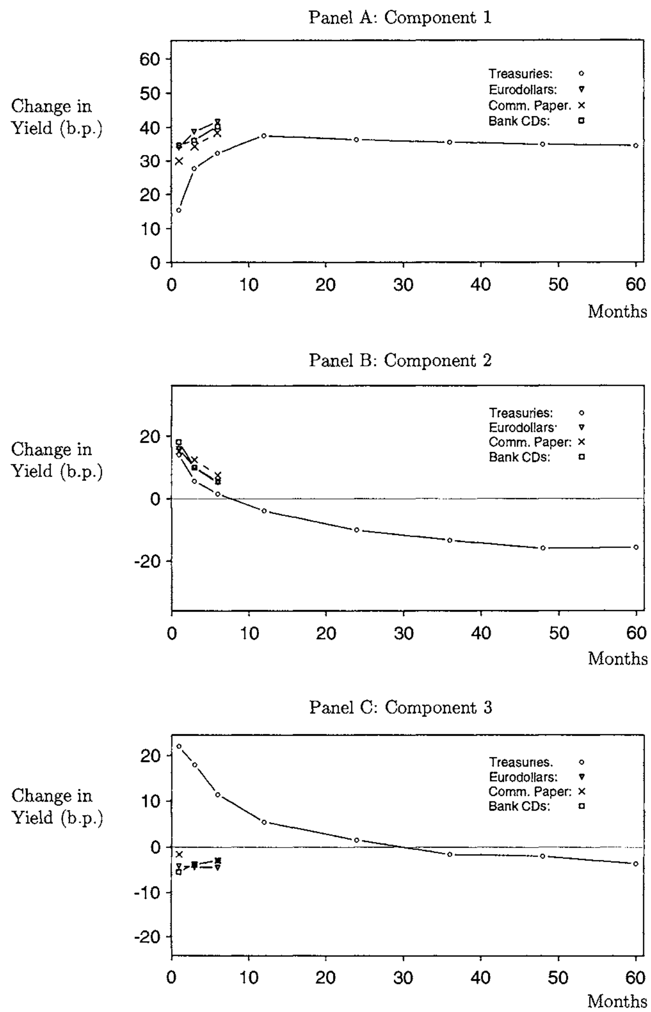

Figure 2. Principal components decomposition of yields, 1983–1994. Panels A, B, and C display the first three principal components of monthly changes in continuously-compounded annualized yields on various zero-coupon instruments. The graph of each component represents the change, in basis points, associated with a one standard deviation shock to that component.

from both default-risky instruments and other Treasury securities. This component consists of large changes in Treasury bill yields, with much smaller changes in yields on all other instruments.

Table V reports that, as a fraction of the total variance of Treasury bill yields, the importance of this component is much greater in the later period than in the earlier period. In the earlier period, it explains 11.8 (2.5) percent of the total variance of the three-month (six-month) bill. This fraction increases to 28.0 (10.8) percent in the later period. In other words, in 1983–1994, over

Table V

Principal Components of Monthly Changes in Yields

Monthly changes in yields on various instruments are decomposed into their principal components. The table reports the variances of these monthly changes and the fractions of these variances that are explained by the first three components. Within each panel, these components are given by a single decomposition that includes all of the instruments. The instruments are three-month and six-month Eurodollar deposits, prime commercial paper, bank CDs, and Treasury bills, as well as artificially-constructed (by CRSP) zero-coupon Treasury bonds with maturities ranging from one to five years. Yields are continuously compounded and expressed in percent/year.

		Percent of Total Variance Accounted for by:		
Instrument	Total Variance	Factor 1	Factor 2	Factor 3
Panel A: 1975–1982				
3 mon Eurodollar	1.659	95.7	1.9	0.9
6 mon Eurodollar	1.481	94.6	0.0	3.7
3 mon Comm Paper	1.522	93.2	5.3	0.2
6 mon Comm Paper	1.491	96.7	0.8	0.0
3 mon Bank CD	1.488	94.8	5.1	0.0
6 mon Bank CD	1.359	97.9	0.0	0.5
3 mon Treasury bill	1.002	86.8	0.0	11.8
6 mon Treasury bill	1.034	93.8	0.1	2.5
1 yr Treasury zero	0.975	91.9	5.5	0.0
2 yr Treasury zero	0.664	88.8	9.2	0.1
3 yr Treasury zero	0.502	79.0	17.9	0.1
4 yr Treasury zero	0.440	70.0	24.2	0.5
5 yr Treasury zero	0.345	72.3	21.8	0.5
Panel B: 1983–1994				
3 mon Eurodollar	0.168	90.1	5.9	1.2
6 mon Eurodollar	0.185	94.3	1.4	1.1
3 mon Comm Paper	0.143	83.2	10.9	1.1
6 mon Comm Paper	0.159	94.0	3.5	0.6
3 mon Bank CD	0.146	90.5	6.7	1.0
6 mon Bank CD	0.170	96.1	1.8	0.5
3 mon Treasury bill	0.115	67.2	2.8	28.0
6 mon Treasury bill	0.122	86.4	0.2	10.8
1 yr Treasury zero	0.153	92.9	1.1	1.9
2 yr Treasury zero	0.147	90.5	7.1	0.1
3 yr Treasury zero	0.148	85.9	12.3	0.2
4 yr Treasury zero	0.152	80.5	16.9	0.3
5 yr Treasury zero	0.149	80.2	16.6	0.9

one-fourth of the total variance of the three-month bill is accounted for by this component.

Given the increased importance of this component in the later period, it is not surprising that all correlations between the three-month or six-month Treasury bill yields and nonbill yields were lower in 1983–1994 than they were in 1975–1982.[13] For example, the correlation between the three-month bill yield and the three-year zero-coupon Treasury yield fell from 0.83 in the earlier period to 0.68 in the later period. Fisher z-tests of the changes in these correlations over time are all significant at the 10 percent level, and all but two are significant at the 5 percent level. By contrast, no correlation between the yield on a privately-issued instrument and the yield on a longer-term Treasury instrument (a maturity of at least one year) changed significantly (at the 5 percent level) from 1975–1982 to 1983–1994. Because of the increased importance of the third component, during 1983–1994 the zero-coupon Treasury bond yields were more closely correlated with yields on the three privately-issued three-month instruments than they were with the yield on the three-month bill.

In recent years, yields on overnight lending have also been more highly correlated with three-month and six-month privately-issued instrument yields than with three-month and six-month Treasury yields. For example, Table II documents that from December 1987 through December 1994, the correlation between four-week changes in yields on Fed funds and contemporaneous changes in yields on three-month Treasury bills was 0.44. Over the same period, the mean correlation between four-week changes in yields on Fed funds and changes in yields on three-month privately-issued instruments was 0.51.

These empirical results immediately bring to mind two questions. First, is there some economic interpretation of this third component? Second, why is this component more important in the later period than in the earlier period?

B. Interpretations

Here I mention a few possible interpretations of this third component; a full investigation is beyond the scope of the article. This component could be a very transitory shock to required expected returns that is negatively associated with an increase in default risk of the same magnitude. Hence yields on Treasury bills change but yields on equivalent-maturity privately-issued instruments as well as yields on long-maturity Treasury instruments are unchanged. A problem with this interpretation is that the default risk of the privately-issued instruments considered here is negligible, because the instruments' maturities are short and the issuing firm is highly rated.

Alternatively, this component may reflect variations in what Grinblatt calls the "convenience yield" of Treasury bills. He argues that because of the liquidity of the bill market, bills are used by large investors to adjust their interest rate risk exposure. Presumably, this convenience yield is higher when interest rate risk is higher. If so, the third component may be the response in the bill market to an increase in interest rate risk that is uncorrelated with yields on other instruments. Testing this hypothesis is left for future work.

[13] Owing to space considerations these correlations are not reported in any table, but are available on request.

Future work will also be required to determine why the third component is more important in 1983–1994 than in 1975–1982. It is possible that the increased importance is just a consequence of the lower volatility of yields in the later period. A cursory look at the scales of the vertical axes in Figures 1 and 2 reveals that the volatilities of all three components fell from the earlier period to the later period, although the first component's volatility fell further (in percentage terms). Perhaps the relatively high volatility of the first component during 1975–1982 was an artifact of the Fed's experiment. Alternatively, perhaps the convenience yield of Treasury bills was more variable in the later period. The increased importance of the "Treasury bill" component remains an open question.

IV. Conclusions

Since 1983, the correlations of monthly changes in Treasury bills yields with contemporaneous changes in yields on other instruments have significantly declined. This article distinguishes between two types of idiosyncratic variability in bill yields that underlie these falling correlations.

The first type of variation is movements in yields on individual bills that are unrelated to movements in yields on any other instrument. This idiosyncratic variation affects bills with no more than two months to maturity, and its importance rises as maturity falls. The fact that this variation is related to variations in bill supply suggests that it is a consequence of increased market segmentation over time, although this evidence is not definitive.

Researchers often use the stochastic behavior of one-month bill yields to calibrate models of default-free term structures. I argue that Eurodollars should be used for this purpose instead of Treasury bills, because the idiosyncratic volatility of Treasury bill yields makes them poor proxies for the instantaneous default-free interest rate. Moreover, I find that the stochastic behavior of the one-month Treasury bill yield critically depends on the definition of a "one month" yield. I also argue that tests of the expectations hypothesis of the term structure that use one-month and two-month bills will be biased (in both the estimated coefficient and R^2) toward finding "information" in the term structure, even if the two-month yield is unrelated to forecasts of next month's one-month yield.

The second type of variation is a common movement in Treasury bill yields that is unrelated to movement in yields on other instruments, such as longer-maturity Treasury notes and bonds and privately-issued instruments. I can only speculate about the economic interpretation of this component. It may be the result of time-variation in the convenience yield to holding Treasury bills. If so, because the convenience yield should be tied to special repo rates, an analysis of the variability of these rates could be illuminating. This issue, like many others discussed here, awaits future research.

Appendix

This appendix provides more detail about Treasury yield data. There are two basic sources for yields on Treasury securities: dealers and brokers. Dealers' quote sheets contain indicative bid and ask prices for all Treasuries; these quotes reflect their sense of where the market is. Firm quotes from specific dealers are typically available only over the phone, although at least one dealer has a screen on Bloomberg through which customers can buy or sell notes and bonds at firm prices. Brokers have inside (firm) bid and ask prices from dealers, although at any point in time a broker may have no live bid or ask price for a given security. This is especially true for bills with less than two months to maturity, which are traded infrequently.

Every afternoon, the Federal Reserve Bank of New York (NY FRB) obtains indicative prices on all Treasury securities from a small sample of dealers. In the case of bills, these "prices" are quoted as discount yields. The NY FRB then creates "Composite" prices in a subjective manner (they throw out quotes that look suspicious).

Academic work has relied almost exclusively on these NY FRB quotes, largely because CRSP uses them to construct its bond files. However, quote sheets from particular dealers have been used (e.g., Amihud and Mendelson (1991)), especially Salomon Brothers quotes (Salomon Brothers (1995)). Brokers' inside quotes have also been used (e.g., Simon (1994)). Other publicly available sources of Treasury bill data include composite quotes from Bloomberg. (Bloomberg throws out the high and low, then averages the remaining indicative dealer quotes.)

The NY FRB used to collect both bid and ask prices, but currently collects only bids. The precise date at which they switched is no longer in the institutional memory of the NY FRB's trading room. Some evidence suggests that they collected ask-quotes intermittently in the early 1980s, then stopped collecting them altogether. A maturity-dependent spread is used to construct asks. The NY FRB's current policy is to use the same "spread curve" every day.

The standard practice in the Treasury market is to quote prices for next-day delivery. In other words, this secondary market is a market for forward contracts in Treasury instruments, with delivery in one business day. The CRSP Bond File guide incorrectly states that the NY FRB quotes are for two-day delivery. This confusion is understandable given the wording of the composite quote sheets. DeGennaro and Moser (1990) explain the quote sheet reporting conventions.

This standard practice breaks down with 'when-issued' (WI) quotes. The Treasury auctions three-month bills by reopening the bill that, 13 weeks earlier, had been auctioned as a six-month bill. Similarly, every fourth six-month bill auction is a reopening of a prior one-year bill. Before the additional bill supplies are issued by the Treasury, there are two markets for the reopened bill: A market for next-day delivery and a market for WI delivery. Prices in the two markets can differ, but dealers' quote sheets usually report only one price for the bill. Because the WI market is more active than the next-day market, the WI price is usually reported.

The Treasury bill yields used in this paper were computed assuming next-business-day delivery, at a price determined by the average of bid and ask discount quotes. Hence, when I use CRSP data in this article, I am not using the yields calculated by CRSP (which assume same-day delivery, notwithstanding their belief that the quotes are for two-day delivery). Instead, I use the CRSP data to back out bid and ask discount quotes, then recalculate the yields. Because I use next-business-day delivery, the yields that I calculate using WI discount quotes are slightly wrong, but the errors are minimal (less than a basis point).

REFERENCES

Abken, Peter A., 1993, Generalized methods of moments tests of forward rate processes, Working paper, Federal Reserve Bank of Atlanta.

Amihud, Yakov, and Haim Mendelson, 1991, Liquidity, maturity, and the yields on U.S. Treasury securities, *Journal of Finance* 46, 1411–1425.

Bernanke, Ben S., and Alan S. Blinder, 1992, The federal funds rate and the channels of monetary transmission, *American Economic Review* 82, 901–921.

Brennan, Michael J., and Eduardo S. Schwartz, 1979, A continuous time approach to the pricing of bonds, *Journal of Banking and Finance* 3, 133–155.

Brennan, Michael J., and Eduardo S. Schwartz, 1980, Analyzing convertible bonds, *Journal of Financial and Quantitative Analysis* 15, 907–929.

Campbell, John Y., and Robert J. Shiller, 1991, Yield spreads and interest rate movements: A bird's eye view, *Review of Economic Studies* 58, 495–514.

Center for Research in Security Prices, 1995, *Bond Files Guide,* Graduate School of Business, University of Chicago.

Chan, K. C., G. Andrew Karolyi, Francis A. Longstaff, and Anthony B. Sanders, 1992, An empirical comparison of alternative models of the short-term interest rate, *Journal of Finance* 47, 1209–1227.

Collins, Sean S., and Phillip R. Mack, 1994, Avoiding runs in money market mutual funds: Have regulatory reforms reduced the potential for a crash, Working paper, Federal Reserve Board.

Cook, Timothy Q., 1993, Treasury bills, *Instruments of the Money Market,* 7th Ed., (Federal Reserve Bank of Richmond), 75–88.

Cook, Timothy Q., and Jeremy G. Duffield, 1993, Money market mutual funds and other short-term investment pools, *Instruments of the Money Market,* 7th Ed., (Federal Reserve Bank of Richmond), 156–172.

Cox, John C., Jonathan Ingersoll, and Stephen Ross, 1985, A theory of the term structure of interest rates, *Econometrica* 53, 385–407.

Das, Sanjiv, 1995, Jump-diffusion processes and the bond markets, Working paper, Harvard Business School.

DeGennaro, Ramon P., and James T. Moser, 1990, Failed delivery and daily Treasury bill returns, *Journal of Financial Services Research* 4, 203–222.

Duffie, J. Darrell, 1996, Special repo rates, *Journal of Finance* 51, 493–526.

Dybvig, Philip H., 1989, Bond and bond option pricing based on the current term structure, Working paper, Washington University.

Fama, Eugene F., 1984, The information in the term structure, *Journal of Financial Economics* 13, 509–528.

Grinblatt, Mark, 1995, An analytical solution for interest rate swap spreads, Working paper, UCLA.

Hardouvelis, Gikas A., 1988, The predictive power of the term structure during recent monetary regimes, *Journal of Finance* 43, 339–356.

Jones, David S., and V. Vance Roley, 1983, Rational expectations and the expectations model of the term structure, *Journal of Monetary Economics* 12, 453–465.

Knez, Peter, Robert Litterman, and Jose Scheinkman, 1994, Explorations into factors explaining money market returns, *Journal of Finance* 49, 1861–1882.

Litterman, Robert, and Jose Scheinkman, 1991, Common factors affecting bond returns, *Journal of Fixed Income* 1, 54–61.

Litterman, Robert, and Laurence Weiss, 1985, Money, real interest rates, and output: A reinterpretation of postwar U.S. data, *Econometrica* 53, 129–156.

Longstaff, Francis A., and Eduardo S. Schwartz, 1992, Interest rate volatility and the term structure: A two-factor general equilibrium model, *Journal of Finance* 47, 1259–1282.

Mankiw, N. Gregory, and Jeffrey A. Miron, 1986, The changing behavior of the term structure of interest rates, *Quarterly Journal of Economics* 51, 211–228.

Mankiw, N. Gregory, and Lawrence H. Summers, 1984, Do long-term interest rates overreact to short-term interest rates, *Brookings Papers on Economic Activity,* 223–242.

Ogden, Joseph P., 1987, The end of the month as a preferred habitat: A test of operational efficiency in the money market, *Journal of Financial and Quantitative Analysis* 22, 329–343.

Park, Sang Yong, and Marc R. Reinganum, 1986, The puzzling price behavior of Treasury bills that mature at the turn of calendar months, *Journal of Financial Economics* 16, 267–283.

Roberds, William, David Runkle, and Charles H. Whiteman, 1994, Resurrecting the term structure: A daily view of yield spreads and short-term interest rate movements, Working paper, Federal Reserve Bank of Atlanta.

Rowe, Timothy D., Thomas A. Lawler, and Timothy Q. Cook, 1986, Treasury bill versus private money market yield curves, *Federal Reserve Bank of Richmond Economic Review,* July/August, 3–12.

Salomon Brothers, 1995, *Analytical Record of Yields and Yield Spreads,* (Salomon Brothers Inc., New York, New York).

Shiller, Robert J., John Y. Campbell, and Kermit L. Schoenholtz, 1983, Forward rates and future policy: Interpreting the term structure of interest rates, *Brookings Papers on Economic Activity,* 173–217.

Simon, David P., 1991, Segmentation in the Treasury bill market: Evidence from cash management bills, *Journal of Financial and Quantitative Analysis* 26, 97–108.

Simon, David P., 1994, Further evidence on segmentation in the Treasury bill market, *Journal of Banking and Finance* 18, 139–151.

Stigum, Marcia, 1990, *The Money Market,* 3rd edition, (Dow Jones-Irwin, Homewood, Illinois).

Vasicek, Oldrich A., 1977, An equilibrium characterization of the term structure, *Journal of Financial Economics* 5, 177–188.