THE MATURITY AMBIGUITY

A STUDY ON THE LIQUIDITY PREMIA IN US TREASURY SECURITIES

CASPAR RUNSTEN
JOHAN IVARSSON

Bachelor Thesis
Stockholm School of Economics
2024

The Maturity Ambiguity: A Study on The Liquidity Premia In US Treasury Securities

Abstract:

This thesis explores the impact of strict mutual fund maturity constraints on the liquidity premium of US Treasuries by examining the yield spreads between assets of varying maturities and liquidity. We find that there is different demand dynamics depending on maturity of T-bills. In addition, the existence of an on-the-run phenomenon within the T-bill market is assessed, with no clear evidence that a consistent liquidity premium between these highly liquid assets exist. The drivers behind the liquidity premium between T-bills and deposits is studied with the opportunity cost of money being a dominant driver over time, that in recent years have had the T-bill supply alongside it as a contributor to the liquidity premium of near-money assets.

Keywords:

Liquidity Premium, US Treasury Market, Mutual Fund Mandates, Maturity Mandates, Near-Money Assets, On-the-run, Off-the-run.

Authors:

Caspar Runsten (25316)
Johan Ivarsson (25530)

Tutor & examiner:

Adrien d'Avernas, Assistant Professor, Department of Finance

Bachelor Thesis
Bachelor Program in Business and Economics
Stockholm School of Economics

1.Introduction

1.1 Background

The liquidity premia hold significant relevance for monetary policy implementation and stability of financial systems. The control of assets with near-money properties, considered highly liquid, is essential for providing central-banks with the leverage needed to adjust short-term interest rates and to manage the liquidity available in the market. However, post the Great Financial Crisis shifts in regulatory frameworks aimed at increasing the resilience of financial institutions has inadvertently complicated this dynamic. As d'Avernas and Vandeweyer (2023) detail, the introduction of stringent liquidity requirements under the Basel III has constrained banks' ability to intermediate liquidity, leading to an environment where the liquidity across markets is inhibited. The regulatory mandates requiring banks to maintain a higher liquidity ratio has decreased their ability to distribute liquidity to other segments of the market. This effect complicates the central bank's ability to effectively manage monetary policy tools that rely on manipulating short-term interest rates.

Another similar effect of how mandates effect the liquidity premium is outlined by Bretscher, Schmid, and Ye (2023). They observe that mutual fund mandates that impose constraints on the maturity of fixed income assets in a portfolio inherently impacts market dynamics by shifting demand for assets meeting certain criteria. This shift results in a demand shock in the corporate bond market attributable to passive funds. As these funds adjust their portfolios around maturity cut-offs, it causes a disproportionate demand for certain maturities of assets. Specifically, they investigate 10-, 5- and 3-year cut-offs, where passive funds adjust their portfolios to align with their index mandates. This strategic realignment induces fluctuations in demand at these critical points intensifying the liquidity premium due to an artificial increased demand for certain maturity bonds.

Money market funds (MMF), particularly U.S. Government Money Market Funds, (GMMF) exemplify another aspect of how regulatory constraints influence market liquidity. Designed to maintain high liquidity and low risk, these funds face stringent regulatory mandates post the Great Financial Crisis to strengthen financial system resilience. GMMFs are subject to a constraint forcing them to hold short-maturity, highly liquid assets to comply with having an average dollar-weighted maturity not exceeding 60 days. Subsequently, they are prohibited from investing in instruments with more than 397 days to maturity and are required to maintain substantial proportions of highly liquid assets. Specifically, 10% of assets being able to be converted into cash within one day, 30% within five days, and max 5% held in securities requiring longer than one week (Electronic Code of Federal Regulations, 2024). Thus, GMMFs tend to hold treasury bills (T-bills) as noted by d'Avernas and Vandeweyer (2023), who also observe a demand shift for T-bills after the money market reform was implemented in 2016 with enhanced liquidity requirements.

Studies on the liquidity premium commonly analyze yield spreads between assets differing in liquidity. Mostly T-bills are utilized to understand the liquidity premium, its time variation and the underlying monetary policy in which the central bank has influence over the premium. Nagel (2016) analyzes the time variation using multiple yield spreads, controlling for the opportunity cost of money, supply of near-money assets, and flight-to-safety effects. He concludes that the short-term interest rate is a dominant driver of the liquidity premium between illiquid deposits and liquid T-bills, and hence the central bank is setting the liquidity premium through its interest rate policy. Other studies also outline liquidity premia persistent between Treasury securities themselves, but often fail to analyze the variation over a substantial period to determine the underlying factor controlling the premia. One of these premia are the premia between T-bills, often considered the most liquid, and T-notes (Nagel 2016; Amihud and Mendelson, 1991). Another is that between the most recently issued on-the-run security and their nearest off-the-run counterpart (Pasquariello and Vega 2009). Recent literature however has not thoroughly explored these liquidity premia in recent times. Given the previously outlined changes in market dynamics, this paper draws inspiration from Nagel (2016) to further explain these phenomena, and ultimately understand the research question "*Do mutual fund mandates have an impact on the liquidity premium of Treasury securities?"*.

This paper addresses a gap in current liquidity premia literature by assessing the persistence of liquidity premia between US Treasury securities over time, and during recent time. Drawing inspiration from Nagel (2016) we study underlying factors of the liquidity premia between Treasury securities, which are all considered highly liquid. We also examine how recent regulatory changes may have altered the foundation of these premia. If this dynamic has changed over time, we could find that new regulations are distorting the control the central bank has over the premia. The paper also explores lesser observed liquidity premia between longer maturity Treasury bills and notes. This further enlightens if implemented GMMF maturity mandates has distorted the premia for certain maturities of Treasury bills. We find that the liquidity premium landscape for US Treasuries differs distinctly depending on the maturity of the assets. This reinforces the theory that demand dynamics are influenced by stricter constraints on the maturities within portfolios of money market funds.

1.2 Literature Review

The liquidity premium is well-documented in financial literature. Previous research indicating that the liquidity characteristics of US Treasuries affects their price, deviating from predictions of a traditional asset pricing model include: Amihud and Mendelson (1991); Kamara (1994). Other literature study the time-variation of the liquidity premium by considering flight-to-safety effects and the supply of Treasuries. Longstaff (2004) analyzes the impact on the liquidity premium from the supply of Treasuries and the flight-to-liquidity that is related to consumer confidence, similar to Musto, Nini, and Schwarz (2014) who find that yield spreads become wider during crisis periods due to investors' preference for liquidity. Krishnamurthy and Vissing-Jorgensen (2012) report that a high US government debt-to-GDP ratio coincide with narrow yield spreads using a long sample period, similar to our study with debt-to-GDP as an explanatory variable for the liquidity premium. In Greenwood, Hanson, and Stein's (2015) model the T-bill supply drive changes in the liquidity premium.

Nagel (2016), similar to this thesis, studies the liquidity premium controlling for the supply of Treasuries and flight-to-safety effects, but unlike the papers mentioned above incorporates the opportunity cost of money into the analysis, finding that the Treasury supply has limited effect on the liquidity premium when controlling for the fed funds rate, indicating that deposits and T-bills are almost perfect substitutes, contrary to previous research. Li, Ma, and Zhao (2023) find that longer maturity Treasuries and deposits are imperfect substitutes. Similarly, Krishnamurthy and Li (2023) who replicate parts of Nagel's (2016) method also find them to be imperfect substitutes explained by T-bills providing collateral services that deposits are unable to, while deposits provide transaction services T-bills cannot do. d'Avernas and Vandeweyer (2023) indicate that T-bill supply explains the liquidity premium better than other monetary policy tools post the Global Financial Crisis, and that the money market reform entailed a demand shift for T-bills. He, Nagel, and Song (2022) examine the market for long-term Treasuries during Covid-19, finding that long-term Treasury yields increased in contrast to what is found for previous periods turbulent periods. He and Song (2022) find for agency mortgage-backed securities that the opportunity cost of money negatively correlates with the convenience premium for long-term securities, opposite of Nagel's (2016) theory. However, for short-term repos backed by long-term mortgage-backed securities the correlation is positive.

The literature indicates that there is a liquidity premium between on-the-run and off-the-run US Treasuries. Warga (1992) constructs portfolios of on-the-run treasury bonds and compare the returns with portfolios of off-the-run treasury bonds, using a short sample period of 7 years and concludes that there is a significant difference between the two that is partially driven by liquidity. Pasquariello and Vega (2009) identify a liquidity premium and analyze if it is caused by information heterogeneity and imperfect competition among informed traders. Goldreich, Hanke, Nath (2005) find a liquidity premium over the on-the-run and off-the-run cycle and concludes that it is driven by the amount of future liquidity. They follow the same treasury notes over time and identify that liquidity remains high during the on-the-run period before declining prior to the next issue, and then remains low for the rest of the asset's life. The yield spread between on-the-run and off-the-run becomes narrower over the cycle, and the method for constructing the on-the-run and off-the-run yield spread is to an extent utilized by Nagel (2016) and in this thesis. Moore and Winters (2014) note that the trading activity for T-bills follow a different pattern than T-notes over the on-the-run and off-the-run cycle, which is directly linked to the research in this thesis and validates further exploring the existence of a liquidity premium between on-the-run and off-the-run T-bills.

This paper is also related to literature on the impact of fund mandates on demand for assets within a mandate. Koijen and Yogo (2019); Buffa and Hodor (2023) find that mutual fund mandates create inelastic demand that affect the price of securities allowed to be held by institutional investors subject to the mandate. Chaudhary, Fu, and Li (2023) study demand elasticities in the corporate bond market using mutual fund flows where mandates can create demand shocks for certain bonds and find that demand is inelastic short-term but more elastic long-term. Bretscher, Schmid, and Ye (2023) study maturity mandates, observing a change in demand when a corporate bond crosses a 10-, 5-, and 3-year time-to-maturity cutoff. A demand shock entailing reduced yield spreads and improved liquidity.

Our contribution to the literature is that we extend Nagel (2016) which is an extensive study of the time variation of the liquidity premium, which incorporates the opportunity cost of money as a driver of the liquidity premium, in addition to flight-to-safety effects and the supply of Treasuries included in research mentioned above. Nagel (2016) also examines the liquidity premium for on-the-run and off-the-run T-notes, examining the on-the-run phenomena but augments previous findings through controlling for the opportunity cost of money and the level of uncertainty in the market. On money market funds in particular we incorporate the theory of mutual fund maturity mandates' impact on market dynamics and price, where the funds are only allowed to hold assets with short maturities. We extend Bretscher, Schmid, and Ye (2023) with more pronounced focus on money market funds and US Treasuries instead of corporate bonds. Additionally, we analyze shorter maturity cutoff categories to see if mandates with shorter maturity periods impact the yield spreads similar to what Buffa and Hodor (2023) indicate for large institutional investors. We cover the periods that Nagel's (2016) study focused on and the specific period during Covid-19 He, Nagel, and Song (2022) do. Further we cover the period before and after Covid-19 which they do not do. This is a contribution since during this gap, there has been prominent economic periods such as the period with interest rates close to 0%.

To d'Avernas and Vandeweyer (2023) this thesis contribute insight into the observed demand shift for T-bills following stricter regulation, since the results in our study differ depending on the maturity left for the Treasuries employed. We further contribute by extending Nagel's (2016) analysis of on-the-run vs nearest off-the-run T-notes, providing a study on the existence and if so the magnitude of an on-the-run phenomena for T-bills which commonly is disregarded due to T-bills being considered highly liquid throughout their lifetime. To Pasquariello and Vega (2009) we contribute with additional drivers behind the on-the-run and off-the-run phenomenon as well as a longer study period.

1.3 disposition

The remainder of this thesis is divided into sections. Section 2 presents the method, data used, and where the data is sourced from, along with calculations and adjustments. Section 3 contains the empirical analysis with results for the liquidity premium, and the drivers behind it for various types of near money assets. Section 4 concludes the thesis, summarizing the key findings and their implications.

2. Method

2.1 Data

To examine the liquidity premiums inherent in Treasury securities under different market conditions and regulatory frameworks, the analysis leverages data covering a period as substantial as possible to capture economic cycles and structural changes. All data for rates is either monthly averages of daily rates or converted to a monthly average.

Treasury securities. Our main data source for Treasury securities comprises the Center for Research in Security prices (CRSP) daily Treasury Database. A comprehensive collection of daily price quotations, maturities, coupon rates, and issue dates, spanning from 1961 to the present for outstanding Treasury bonds, notes, and bills. We use data from January 1976 to December 2023 to create eight time series. To create a long time series beginning in 1920, we source rates on three-month T-bills from Federal Reserve Bank of St. Louis economic database (FRED). From January 1934 to December 2023 the data contains monthly averages of daily secondary market quotations for the most recently issued three-month T-bills and is based on the H.15 Selected Interest Rates report issued by the Board of Governors of the Federal Reserve System. We complement the series with monthly average daily quotes for three-to-six-month T-notes and certificates from January 1920 to December 1933. All FRED rates are quoted on a discount basis with a 360-day year.

Deposit rates. All three-month Banker's Acceptance and certificates of deposits rates are obtained from FRED. The original source for the Banker's Acceptance rates beginning from January 1941 to June 2000 is the G.13 Selected Interest Rates Release by The Board of Governors of The Federal Reserve. These are closing yields for acceptances of the highest rated money center banks quoted on a discount basis with 360-days day-count convention. 90-days Prime Banker's Acceptances for New York are used as a substitute from January 1920 to December 1939. Quotes for three-month certificates of deposits are averages of dealer bid rates on large denomination deposits of $1,000,000 or more. Large denomination deposits are not insured by the Federal Deposit Insurance Corporation (FDIC) and bear credit risk. From January 1976 the original source for daily CD rates is the H.15 Release. Rates are quoted on an investment basis using a 360-day year. The time series based on the H.15 Release was discontinued as of June 2013. To extend the series to December 2023, we collect a monthly series for three-month certificates of deposit rates onwards. The original source is the Organization for Economic Cooperation and Development (OECD) Main Economic Indicators database. The spread between three-month Treasury bills and three-month General Collateral Repo rates is from Stefan Nagel's website. Daily three-month GC repo rates from May 1991 to December 2011 are from Bloomberg and rates for three-month T-bills from CRSP. Nagel uses the midpoint between rates where dealers pay interest and rates where dealers receive interest to create a spread between GC repos and T-bills.

Treasury Securities supply. We retrieve an annual time series for U.S. government debt outstanding to GDP from Henning Bohn's website. The series is from 1791 to 2012 and is an updated version of the one originally featured in Bohn (2008). The debt-to-GDP ratio is fiscal year end public debt divided by the nominal GDP, and Bohn retrieves the data from the Budget of The United States and from National Income Accounts. We use the time series from 1920 until 2001. From March 2001 we create a monthly debt-to-GDP series. Monthly data on U.S. government public debt is published in the U.S. Department of the Treasury's fiscal database. Monthly GDP is from the US Monthly Nominal GDP Index available from S&P Global Market Intelligence. The index uses calculation and aggregation methods comparable to those used when calculating the official GDP, published by the U.S. Bureau of Economic Analysis (BEA).

Monthly data on outstanding Treasury bills is retrieved from the U.S. Department of the Treasury's fiscal database from January 2001 to December 2023. To create a T-bills outstanding to GDP ratio we follow Nagel (2016) and create a monthly GDP series by linearly interpolating quarterly nominal GDP to monthly values. Quarterly nominal GDP is from the Gross Domestic Product series available in FRED from 1947 onwards. The original source of this data is the U.S. Bureau of Economic Analysis Gross Domestic Product release. Our primary data set covers the period from January 2001 to the present. To extend our analysis back to January 1947, we integrate the supplementary data from Nagel (2016). He uses a GDP computation consistent with ours and retrieves data on T-bills outstanding further back from the CRSP monthly debt files. These files, subject to access restrictions, contain the outstanding face value of T-bills.

Federal funds rate and VIX. Data for the daily effective federal funds rate is retrieved from FRED. The original source of the data is the H.15 Selected Interest Rates report. This series is available from July 1954 to the present. To create a series from 1920 we utilize the Federal Reserve Bank of New York discount rate as a substitute. This time series is also from FRED. The daily Chicago Board Options Exchange (CBOE) S&P 500 Volatility Index (VIX) is obtained from the CBOE U.S. Index database via Wharton Research Data Services (WRDS) from January 1990 to the present. To obtain a time-series ranging from January 1920 to December 2023, we substitute the previous years with a VIX extension from Nagel's (2016) own research. He creates a time-series beginning in January 1920 by running a linear regression of the average monthly VIX on the monthly average squared daily returns of the S&P 500 from 1990 to 2011. He then applies the estimated projection coefficients backwards to calculate fitted values in earlier periods before 1990.

2.2 Model

The regression framework for our analysis of the driving factors behind different liquidity premiums can be defined as:

$$(1) \qquad i_t^{il} - i_t^{l} = \beta_o + \beta_1 \cdot r_t + \beta_2 \cdot \lambda_t + \beta_3 \cdot \log\left(\frac{D_t}{Y_t}\right) + \beta_4 \cdot \log\left(\frac{B_t}{Y_t}\right)$$

Equation (1) shows the relationship between our dependent variable and several key explanatory variables, where $i_t^{il} - i_t^{l}$ captures the liquidity premium between an illiquid asset i_t^{il}, and a liquid asset i_t^{l}.

The variable r_t is the short-term interest rate, reflecting the opportunity cost of holding a liquid asset. A high rate increases the opportunity cost of money and affects the premium of liquid assets. We capture this parameter by using the federal funds rate between July 1954 and December 2023. Before that we used the Federal Reserve Bank of New York discount rate since during that period banks regularly borrowed from the Federal Reserve at this discount rate making it an adequate proxy for the short-term rate.

Subsequently, λ_t represents market volatility. We use this parameter to see the effects on our liquidity premiums under periods of high uncertainty in financial markets. During these periods a flight-to-safety effect could occur where preferences for liquid assets increase relative to illiquid deposits. The parameter captures this effect, and subsequently its effect on the liquidity premium. In the regressions, this parameter is captured by the CBOE index of implied volatility from 1990 to 2023 and before that we use a projection of the VIX based on monthly average squared returns of the S&P 500.

D_t and B_t are represented by public U.S. government debt outstanding and outstanding U.S. T-bills respectively. Y_t represents U.S. nominal GDP. We use the debt-to-GDP and T-bill supply-to-GDP to understand the effects of the supply of Treasury securities on the liquidity premium. The public debt-to-GDP acts as a proxy for total supply of liquid government securities. We use an annual time series for public debt-to-GDP from January 1920 to February 2001, and a monthly time series from March 2001. The T-bill supply-to-GDP visualizes the supply of near-money liquid government securities. Data for T-bill supply is available from January 1947 onwards. We use GDP ratios to normalize the supply by the size of the economy for better comparison across different periods and different economic contexts. We use the natural logarithm to create linear relationships and avoid heteroscedastic issues that could distort the results. Figure 1 plots the explanatory variables. For visualization, all variables have been demeaned and standardized to unit standardization. Further, Debt-to-GDP and T-bills-to-GDP have been signed switched to visualize that a positive value in theory imply a higher yield spread between liquid and illiquid assets.

To ensure the robustness of our regressions results, and consistency with the original framework in Nagel (2016), we adjust for potential autocorrelation and heteroskedasticity in the error terms of our time series data by using Newey-West standard error, 12 lags. The method provides consistent estimates of the standard errors even in the presence of autocorrelation and heteroskedasticity.

2.3 Yield spreads

All variables used to create the time series for rates consist of monthly averages of daily annualized effective yields.

Liquidity premium between Deposits and T-bills
One main discussion in financial literature on liquidity premiums has been to determine the source of the liquidity premium, and to determine to what extent near-money assets are substitutes to deposits. Nagel (2016) suggests deposits and T-bills have a high elasticity of substitution given that he finds the dominant driver of the liquidity premium to be the short-term interest rate. He argues that since the premium is not driven by the supply of near-money assets, but by interest-rates, this implies that the opportunity cost of money is explaining the liquidity premia, and people are willing to pay a greater premium when this cost is high as the necessity for liquidity increases in value, and thus these near-money assets are in fact substitutes.

Panel A Panel B

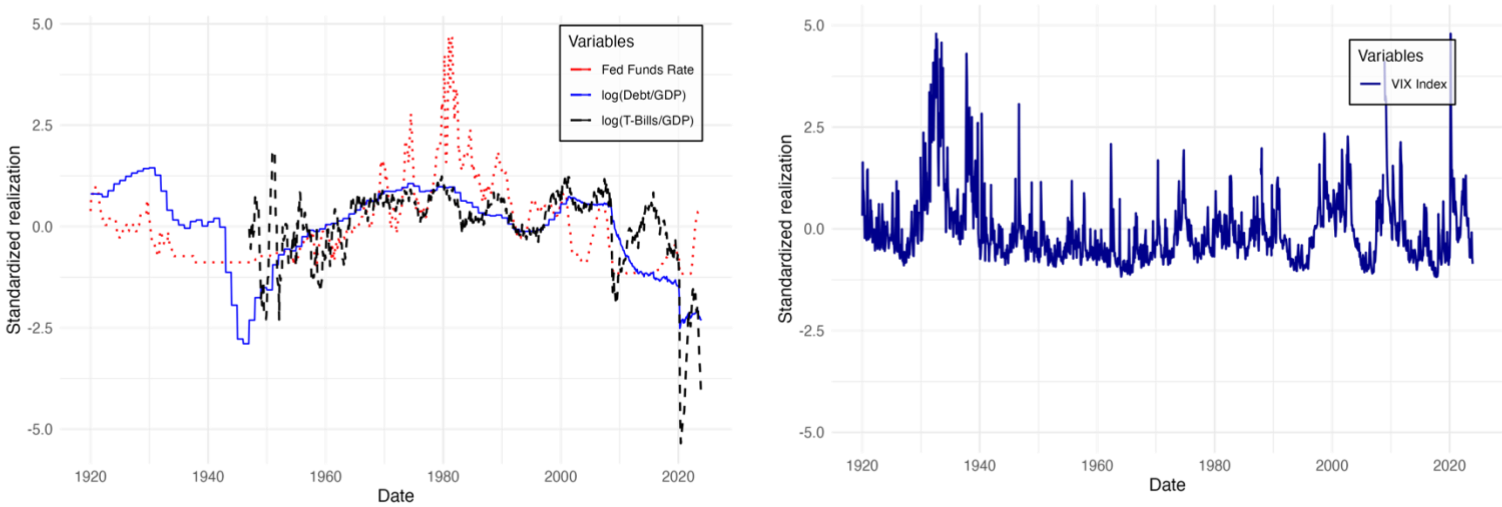


Figure 1: Standardized Explanatory Variables. The explanatory variables in the regression framework are plotted from 1920 to 2023. For consistency all variables have been demeaned and standardized to unit standardization. Subsequently, the T-bills/GDP and Debt/GDP variables in Panel A have been signed switch so that an increase in the plot visualizes a theoretical increase in the liquidity premia.

To understand whether this conclusion holds over time, we create two time-series. A long from 1920 to 2023 and a shorter from 1976 to 2023. The regression framework then determines the dominant driver of the spread. The highly liquid asset is represented by three-month T-bills, matched with the illiquid rates available that have similar risk and maturity. Thus, we isolate the liquidity premium as the difference between these rates.

For illiquid assets, to create the long series we combine three different rates of illiquid assets. The most similar asset to T-bills in terms of safety and maturity is the three-month GC Repo spread, available from May 1991 to December 2011. Before this period, the three-month Banker's Acceptance rate is used, and post 2011 the three-month Certificate of Deposit rate. For further perspective, we create a shorter time-series with the CD rate continuously used as the illiquid asset to see if the results hold for a shorter period with one continuous asset as the illiquid one. The rates are expressed using different day-count conventions and yields in different formats. We normalize all yields to effective annual yields with a 365.25-day year. For any quotes on a discount basis, we follow Amihud and Mendelson (1991) to convert the discount yield to a price which then is used to obtain an effective annual yield. Otherwise, we convert rates to a 365.25-day basis before calculating the effective annual yield.

If Nagel's (2016) findings still hold, we will find that the explanatory effects of the supply variables diminish once we account for the federal funds rate. Then the opportunity cost of capital sets the liquidity premia. If we find that the explanatory effects differ over time between these assets, it could indicate that other variables not included in the model distort the theory that liquidity premia are driven by the opportunity cost of capital.

Liquidity premium between Treasury Securities

Other liquidity premia often discussed in financial literature are the premia between on-the-run Treasuries and off-the-run Treasuries (Goldreich, Hanke and Nath, 2005), and that between T-bills and T-notes (Amihud and Mendelson, 1991). The framework is used to study different maturities of these liquidity premiums and determine the differences between them, in terms of magnitude and underlying drivers. This will identify which liquidity premia are existent in the US Treasury market, and their variation over time. Further, discrepancies between these premia in terms of magnitude or underlying explanatory variable could identify if there are other causes affecting the liquidity premium of these assets.

On-the-run and nearest off-the-run

To construct the spread between on-the-run securities and their nearest off-the-run counterpart we follow Goldreich, Hanke and Nath (2005). We construct two spreads from January 1976 to December 2023. The spreads are the difference in yields between the on-the-run and nearest off-the-run two-year T-Notes, and an equal spread between the on-the-run and nearest off-the-run one-year T-bill. The purpose of this is to determine if the liquidity premia differ between on-the-run and off-the-run T-notes and on-the-run and off-the-run T-bills.

The process of constructing the spreads consists of matching the most recently issued security, with the security issued one auction earlier. To do this we isolate all notes with a two-year maturity, and all bills with a one-year maturity. We then observe every day the most recently issued security and compare it to the one with the second highest maturity. To ensure continuously comparing the on-the-run and nearest off-the-run securities we filter out days when either the on-the-run or off-the-run security might not have traded or are missing. Both two-year T-notes and one-year T-bills are issued on a monthly auction cycle which helps us observe the premium without irregular seasonal effects.

For calculating the yields of any T-note with coupon payments left, we calculate the effective annual yield to maturity, extracting the nominal price, accrued interest, payments, and days to each payment. Then we iterate to find the effective annual rate that sets the present value of the payments equal to the price + accrued interest. For any zero-coupon bond we calculate the effective annual yield in a similar fashion. Given that zero-coupon bonds do not pay coupons the formula simplifies, and the effective yield can be found by solving for the rate that sets the face value of the bill equal to the price, in line with Amihud and Mendelson (1991). To ensure that yields are comparable we adjust for difference in maturity, and for notes also the difference in coupon. We follow Nagel (2016) and value the cash-flows of the on-the-run and off-the-run notes and bills using the off-the-run zero-coupon yield curve. This value is used to estimate the yield of two synthetic securities, one that is equal to the on-the-run security in terms of maturity, and coupon for the notes, and one that is equal to the off-the-run security in terms of maturity, and coupon for the notes. The difference between these synthetic securities is added to the yield of the off-the-run security. This adjustment accounts for the difference in maturity, and for the notes also the difference in coupon rates.

One final issue persists, and that is that the Treasury ceased auctions of the one-year Treasury bills at the end of February 2001, and then reintroduced them at the beginning of June 2008. To best fill these missing values, we follow a similar approach to how Nagel (2016) filled the missing values of the VIX index. For this purpose, we also take out the yield of the on-the-run and adjusted yield of the nearest off-the-run six-month T-bills. The spread between these is however excluded from the main analysis. This is done in the same fashion described above. Then we estimate two projection coefficients, one for the on-the-run yield of one-year Treasury bills, and one for the adjusted off-the-run yield for one-year T-bills. For the on-the-run yield, we estimate the coefficient by running a linear regression on the on-the-run yield for two-year T-notes, and six-month T-bills for the period where all bills are available. Similarly, we estimate the coefficient for the adjusted off-the-run yield by running a regression on the same off-the-run spreads. We then apply these estimated coefficients to calculate synthetic on-the-run and off-the-run yields for one-year T-bills in the missing period. Then we calculate the spread between these two yields.

The validity of this approach is discussed in appendix 1, where we also present why the six-month on-the-run nearest off-the-run spread is excluded. The results of the spread between on-the-run and nearest off-the-run six-month securities is presented in appendix 3.

Ultimately, if we see substantial differences between these two spreads in our framework, we should be able to conclude if there is an on-the-run premium for T-bills. We should also be able to determine if the premia differ between T-bills and T-notes, and see what is the underlying reason for this difference.

Liquidity premium between T-notes and T-bills
When constructing the spread between T-notes and T-bills we follow Amihud and Mendelson (1991). We use this spread to see if we can find a similar liquidity premium for T-bills as others have found. To also widen the analysis, we further construct three different spreads between T-bills and two-year T-notes. We do this to observe if different maturities of T-bills hold different liquidity premiums when compared to the same less liquid asset. The three spreads are created with three-month, six-month and one-year T-bills respectively, and we compare them to a two-year T-note with a maturity left equal to that of the bill.

To construct these spreads, we look each day for three T-notes with a remaining maturity closest to 91, 182 and 365 days respectively. We then identify two T-bills that straddle the respective maturities. The spread is then calculated by subtracting the linear interpolation of the two T-bill yields from the respective two-year notes. Calculating the yield for the notes differs depending on whether they have coupon payments left. If a note has coupon payments left, we calculate the effective yield to maturity as described above. If they do not, we calculate the effective annual yield similar to how it is calculated for zero-coupon bonds, in line with Amihud and Mendelson (1991). The formula simplifies and the effective yield can be found by solving for the rate that sets the face value and the one coupon payment left of the note equal to the price plus accrued interest. All yields for treasury bills are calculated as above, which aligns with Amihud and Mendelson's approach (1991) and is further motivated as the appropriate way to compare coupon notes with zero-coupon bills according to Glasgo, Landes and Thompson (1982).

Once again, we encounter the issue that the Treasury ceased auctions of one-year T-bills from February 2001 to June 2008. We solve this issue with a similar approach to how we filled the missing values for on-the-run and nearest off-the-run one-year bills. We still have the yield for two-year treasury notes with a maturity closest to 365-days. Thus, the approach simplifies slightly since we must only create one synthetic yield, the interpolated one-year T-bill yield. We do this by estimating a projection coefficient by running a linear regression on the interpolated yield of one-year T-bills on two-year T-notes with a maturity closest to 365-days. We also control for the interpolated yield of the other two Treasury bills we have selected, and their relation to their respective two-year T-notes with a maturity closest to 91-days and 182-days. Then we apply the projection coefficients on the missing period to synthetize a one-year yield interpolated to the two-year note's maturity. This approach is further discussed in appendix 2.

With this we intend to figure out if the liquidity premium differs for different maturities of bills and notes, to visualize to what extent these bills provide liquidity services. Further, we aim to find out if the spreads differ significantly, or the underlying factors driving the liquidity premium differs between maturities. If we fail to find coherent results, it could indicate that other factors might be distorting the liquidity premium for longer maturity bills.

Process

The ultimate analysis follows a three-step approach to capture the entirety of the described regression framework. Initially, we analyze the existence of the selected liquidity premiums over time. We extend this analysis by analyzing their variation during different periods. Secondly, we run regressions on the federal funds rate and VIX index to observe if the federal funds rate has explanatory value for the premiums, and whether this effect holds for different time-periods. Finally, we run six regressions on all our liquidity premiums. One controlling for each explanatory variable individually (we include VIX in all regressions to account for flight-to-safety), and then two subsequent regressions where we view the individual supply effects of debt-to-GDP and T-bills-to-GDP. Then we control for the federal funds rate, to finally land in one full regression for each liquidity premium using the entire above specified framework. This to see which variables remain explanatory when all conditions are controlled for. The final regressions are all run using the entire sample, since the supply variables need sufficient observations to gain explanatory effects.

3. Empirical Analysis

In the analysis below we measure the liquidity premium of near-money assets between deposits and T-bills. Furthermore, an analysis of yield spreads between liquid Treasury assets of different maturities and payment structures is provided. Subsequently, for comparisons between T-bills and T-notes, two-year T-notes who are generally viewed as highly liquid are used. All interest rates and yields employed in the empirical analysis are monthly averages of daily annualized effective yields.

3.1 Measurement of Liquidity Premium

Table 1 presents the means of the individual liquidity spreads during different time periods. To measure the yield spread between illiquid- and highly liquid near-money assets, we match 3-month T-bills with illiquid assets of similar maturity and risk characteristics. As illiquid assets, the GC repo is employed between May 1991 to December 2011, BA rates January 1920 to April 1991, and CD rates January 2012 to December 2023. The credit risk components for BAs and CDs are important to consider in the analysis, as the impact of liquidity characteristics on the yields is more difficult to isolate. Collectively these three assets form the long spread covering the period from January 1920 to December 2023 displayed in Panel A, column (9). It will henceforth be referred to as long. The mean of the individual spreads in the long series are also presented for their respective time periods. The spread for the GC repo, BA and CD are available in columns (1), (2), and (3) respectively.

During the period 1991-2011 the average yield spread between GC repo and 3-month T-bills was 23.65 basis points (bp), in concurrence with the quoted bid-ask spreads for T-bills (0.4 bps) and GC repo (7.0 bps) in Panel B, underscoring their liquidity difference. The bid-ask spreads generally act as an indicator for an assets liquidity and low values signify high trading volumes. During the same period as for the GC repo, the CD/T-bill spread was 44.42 bps, nearly double the magnitude of the GC repo spread, attributed to the credit risk associated with CDs. Notably, the CD/T-bill spread was higher between January 1976 and December 1990, averaging 84.30 bps, further enlightening the credit risk component of the CDs as the fed funds rate reached levels above 19% and financial turmoil ensued stemming from the savings and loan crisis. Post 2011 the CD/T-bill spread narrowed significantly to 18.24 bps. 2012-2023 compared to previous periods was characterized by greater stability and lower interest rates, motivating the lower spread. Interestingly, the CD/T-bill spread for this period is still lower than the GC/Repo spread the period before by 5.41 basis points. This strengthens the CD/T-bill spread as an adequate

Table I
Summary Statistics: Liquidity Premia and Bid-Ask Spreads

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Period	Repo/ 3m T-bill	BAAcc/ 3m T-bill	CD/ 3m T-bill	2y off/ on run	1y off/ on run	T-note/ 3m T-bill	T-note/ 6m T-bill	T-note/ 1y T-bill	Long
Panel A: Mean and standard deviation of yield spreads (basis points)									
1976–2023			50.34	1.75	-0.10	7.16	3.02	4.99	
(std. dev.)			(50.21)	(3.96)	(3.80)	(13.21)	(9.49)	(10.14)	
1976–2011			61.04	1.95	0.55	9.14	3.74	5.41	
(std. dev.)			(53.33)	(4.51)	(3.91)	(14.46)	(10.62)	(11.54)	
1976–1990			84.30	3.13	1.32	14.93	3.40	2.27	
(std. dev.)			(58.02)	(6.44)	(4.44)	(19.08)	(14.35)	(15.10)	
1991–2011	23.65		44.42	1.10	0.00	5.01	3.99	7.66	
(std. dev.)	(18.19)		(42.63)	(1.92)	(3.39)	(7.61)	(6.84)	(7.33)	
2012–2023			18.24	1.16	-2.07	1.23	0.83	3.72	
(std. dev.)			(13.54)	(1.06)	(2.58)	(4.94)	(3.90)	(3.17)	
1920–2000		44.56							
(std. dev.)		(50.88)							
1920–2023									37.72
(std. dev.)									(46.49)
Panel B: Typical quoted bid-ask spreads (basis points of yield)									
1990s-2000s	7.0/4.0		5.0/0.4	1.0/0.4		> 1.0/0.4			
1970s-1980s		(10.0/1.3)	(10.0/1.3)						

Notes: Means for yield spreads in basis points are created with monthly averages of daily effective annual rates. Long comprises the spread between three different illiquid assets and three-month T-bills. From January 1920 to April 1991 the illiquid asset is the three-month Bankers' Acceptance rate. From April 1991 to December 2011, the illiquid asset is the three-month General Collateral Repo rate, and from January 2012 to December 2023 it is the three-month certificate of deposit rate. Typically quoted bid-ask spreads reported in Panel B are obtained from Nagel (2016).

measure to assess the liquidity premium outside of periods of financial turmoil. During the long period BA-rates are available, the BA/T-bill spread averages 44.56 bps, which is consistent with the quoted bid-ask spread in Panel B, which for BA is 10.0 bps compared to 1.3 bps for T-bills. In column 9 the long spread for 1920-2023 is 37.72 bps, indicating that there is a liquidity premium present over a long period, and through analysis across subperiods and various financial instruments, this conclusion is reinforced further.

For the spread between two-year T-notes on-the-run nearest off-the-run there is a liquidity premium of small magnitude between 1.10-3.13, depending on the observed period, which is consistent with their different bid-ask spreads. Surprisingly, the premium was larger by a small amount, 0.06 bps, during 2012-2023 when compared to 1991-2011. 2012-2023 is a period with lower interest rates and less volatility and should thus imply a lower premium. For the one-year T-bills on-the-run and nearest off-the-run the spread shows a premium during 1976-1990 where rates were high and there was much turmoil, however in recent time the spread is instead negative. Overtime, the spread is -0.10 bps, and thus we cannot consistently conclude that there is a liquidity premium persistent over time. This is in line with Moore and Winters (2014), who find that T-bills' trading activity differs from that of T-notes, and T-bills not exhibiting the same pronounced off-the-run period as T-notes. During 1976-1990, we observe a yield spread of 1.32 bps, but during 2012-2023 it is negative by -2.07 bps. The implication of this shift suggests a substantial preference for off-the-run one-year-bills. Even though they are adjusted to be equal in terms of maturity to the on-the-run bill, they still display an opposite liquidity premium to the expected one in theory during recent time periods. This could indicate that maturity mandates are skewing the preferences, where the off-the-run bill fits the average dollar-weighted maturity mandates better.

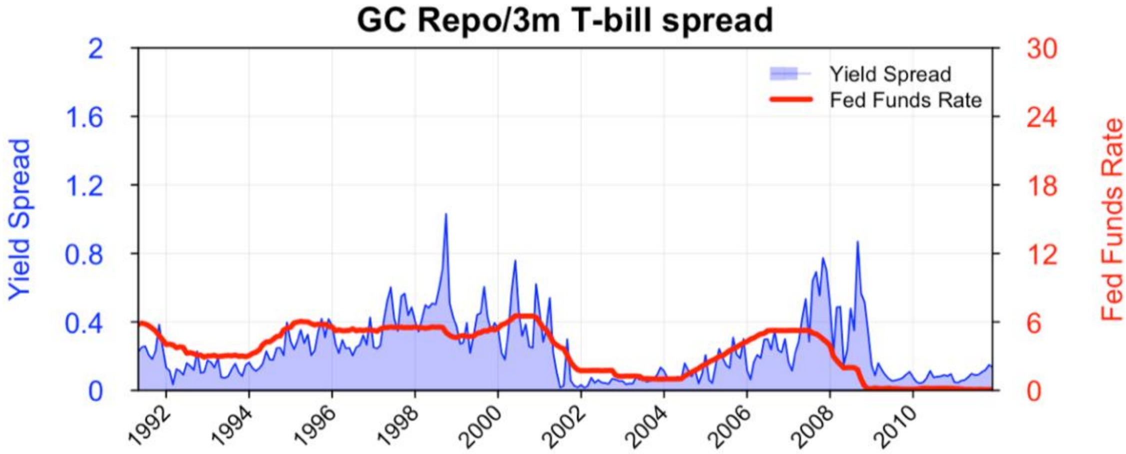
Finally, the spreads between off-the-run T-notes and T-bills of maturities three-months, six-months and one-year are observed in columns (6), (7) and (8) respectively. We observe consistent positive yield spreads for all maturities and analyzed periods. Thus, we can confirm that there is an inherent liquidity premium between T-notes and T-bills. The highest spread is between three-month T-bills and the two-year notes with three-months left to maturity, averaging 7.16 bps over the entire period. The period between 1976-1990 this spread (14.93) is substantially higher than for the other two maturities. The explanation presumably lies in the liquidity preference for shorter maturity assets since they are considered the most liquid, and the interest rate volatility during this period. Interestingly however this dynamic changes in recent periods where the premia between one-year T-bills compared to T-notes exceeds the shorter maturities. This could be an effect of T-bills issued with a maturity of one-year immediately being within the mandates for GMMFs, whereas the T-notes are just coming into the time frame for GMMFs to trade them. However, the ambiguity of that conclusion, means we cannot certainly claim this. It can also be speculated that the stricter liquidity and maturity regulations implemented in recent years have increased the demand for even shorter maturity Treasuries, hence the lower yield spread for three-month Treasuries as both the T-bills and the T-notes with that maturity are subject to higher demand.

3.2 Opportunity Cost of Money and Flight-to-safety Effects

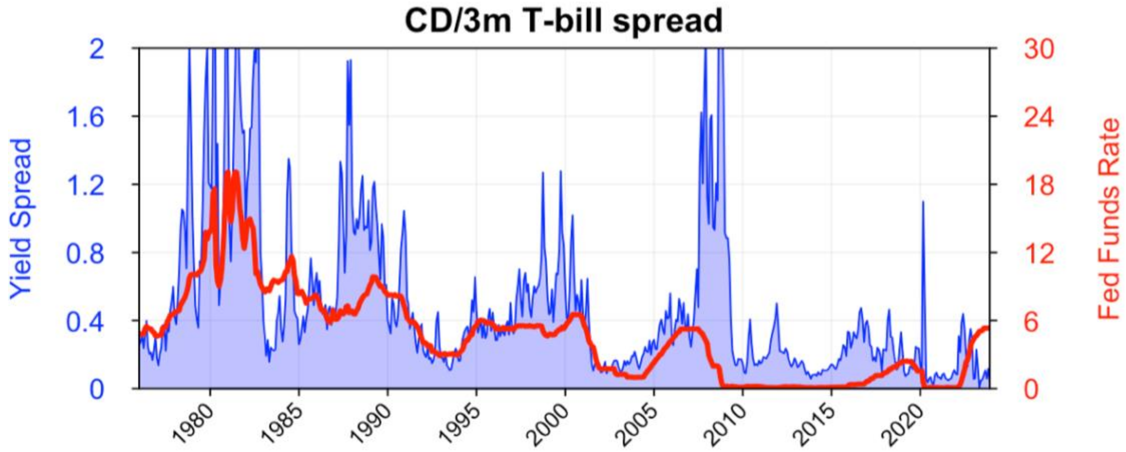
To illustrate the time-variation in the liquidity premium between T-bills and deposits, Figure 2 presents a time series plot of the GC repo/T-bill, CD/T-bill and long spread for the time periods for which data is available for the respective deposit rates. Additionally, the plots display the federal funds rate from July 1954 and the Federal Reserve Bank of New York's discount rate between January 1920 to June 1954. The model implies that a potential liquidity premium is anticipated to exhibit a positive correlation with the fed funds rate. The results indicate that large yield spreads between illiquid deposits and liquid T-bills throughout the time series tend to occur simultaneously as high interest rates. However, during turbulent periods the magnitude of the change in the liquidity premium for the spreads with BAs and CDs is larger than for GC repo, due to the credit risk associated with those assets. Apart from this the federal funds rate and the three different spreads move together in a similar way. For the long sample period 1920-2023 we can see the shock of the Covid-19 pandemic, but ultimately the spread between illiquid deposits and liquid T-bills tend to follow the rate.

Figure 3 plots the various spreads for different maturities of T-bill/T-note with the federal funds rate. Generally, the spreads move similarly in relation to one another, and in relation to the federal funds rate. However, the spreads between one-year treasury securities and six-month treasury securities plummet in the early 1980s, while the spread for three-month securities increased. Two underlying arguments could explain this distortion. One, three-month T-bills are considered the most liquid out of all the securities, and given rising interest rates and substantial economic turbulence, the demand for short-term liquid assets would increase the most. However, an opposing effect can be seen in 2023, where rates rise while the spread between one-year securities rise, and the spreads for the lower maturities decrease. This once again indicates that the demand for longer maturity T-bills has more of a preference to their two-year note counterparts, which indicates a distinguishable change in maturity preferences.

Panel A



Panel B



Panel C

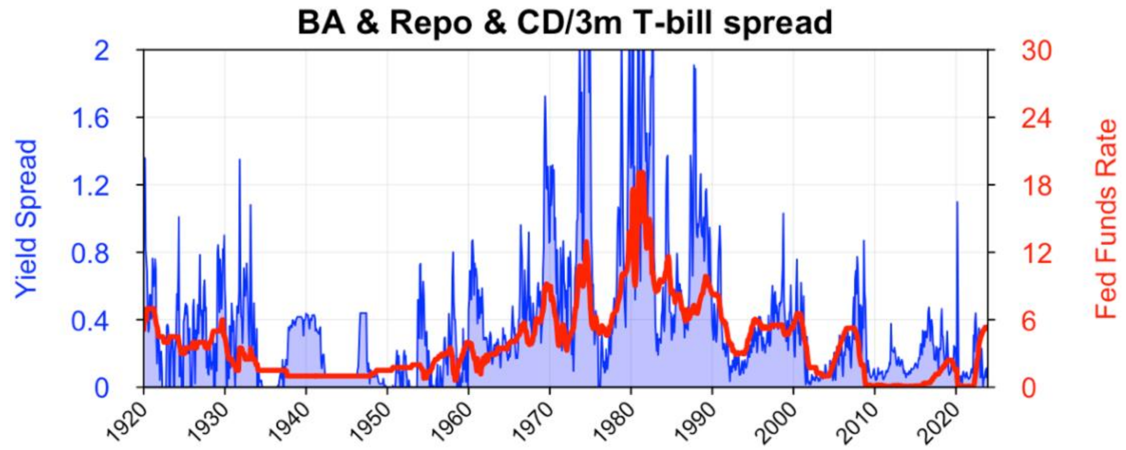
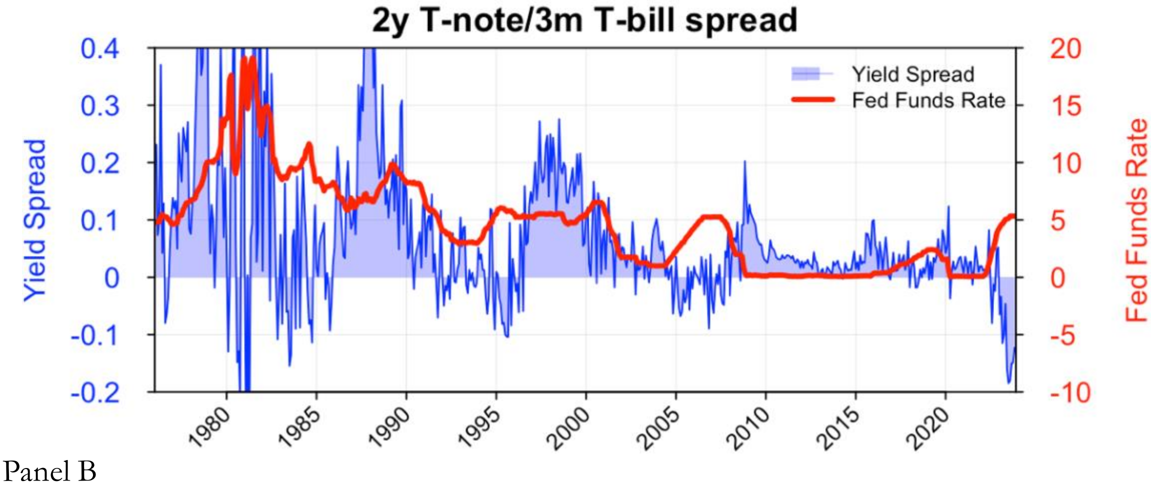
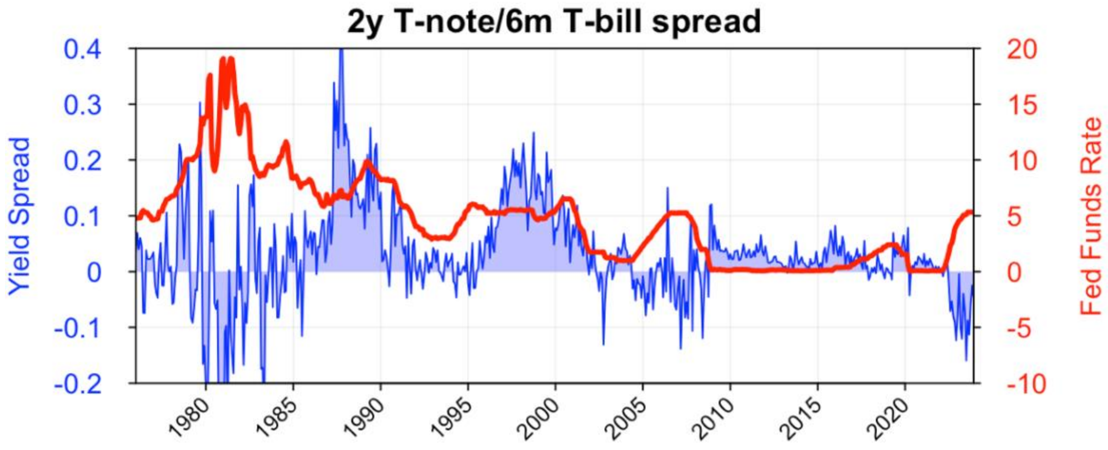


Figure 2 – Time Variation in Yield Spreads Between Three-Month Deposits and T-bills, and the Level of Short-Term Interest Rates. The yield spreads in basis points are shown as the shaded areas with the corresponding axis to the left; the level of the federal funds rate, and the Federal Reserve Bank of New York discount rate prior to July 1954 is shown as the solid line with the corresponding axis to the right.

Panel A



Panel B



Panel C

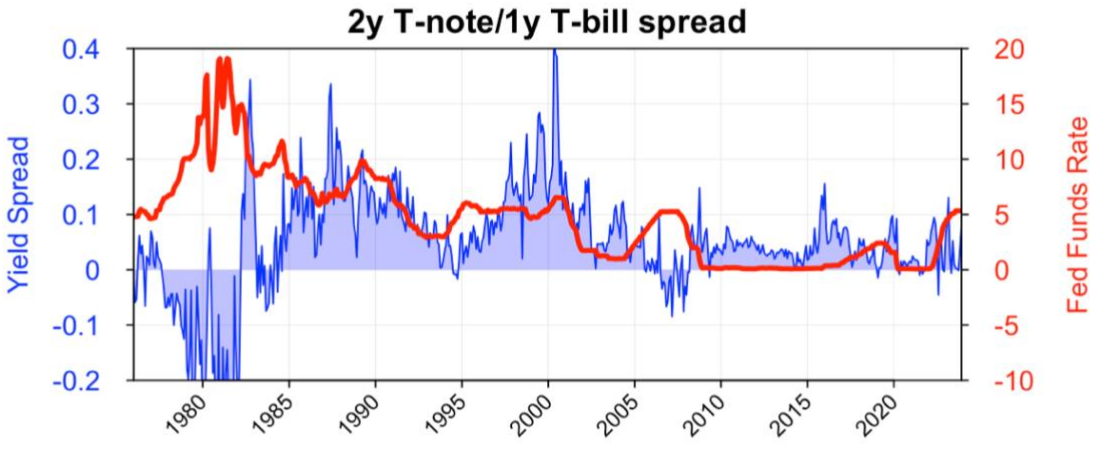
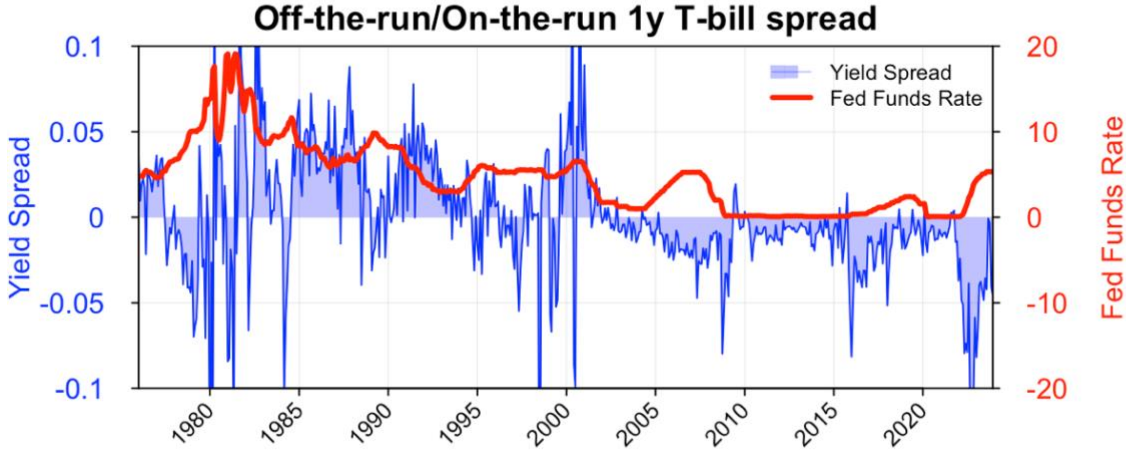


Figure 3 – Time Variation in Yield Spreads Between T-bills and T-notes of equal maturity, and the Level of Short-Term Interest Rates. The yield spreads in basis points are shown as the shaded areas with the corresponding axis to the left; the level of the federal funds rate, and the Federal Reserve Bank of New York discount rate prior to July 1954 is shown as the solid line with the corresponding axis to the right.

Panel A



Panel B

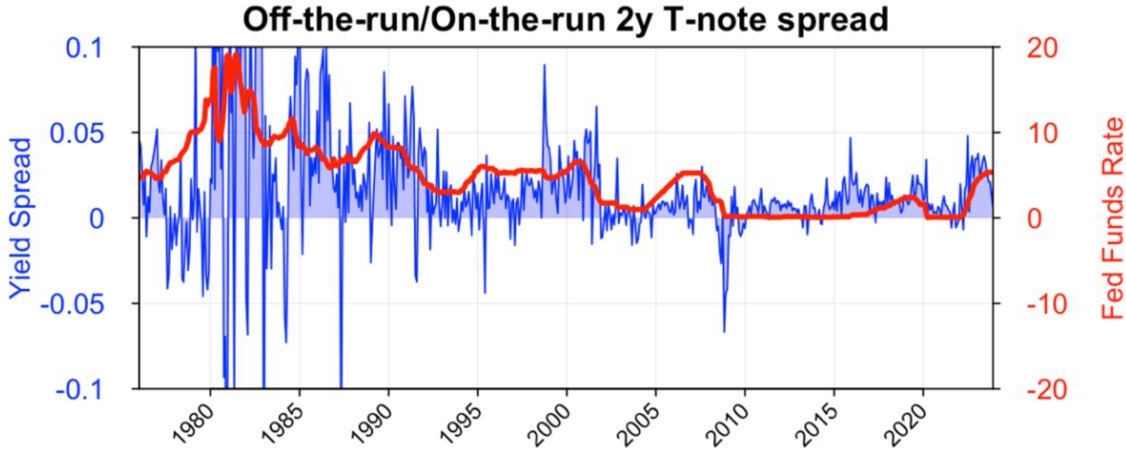


Figure 4 – Time Variation in Yield Spreads Between On-The-Run and Nearest Off-The-Run Treasury Securities Issued with Equal Maturity, and the Level of Short-Term Interest Rates. The yield spreads in basis points are shown as the shaded areas with the corresponding axis to the left; the level of the federal funds rate, and the Federal Reserve Bank of New York discount rate prior to July 1954 is shown as the solid line with the corresponding axis to the right.

Figure 4 plots the relationship between the on-the-run/off-the-run spreads and the federal funds rate. As we can see, while the relationship is volatile, both one-year T-bills and two-year T-notes display a co-movement with the federal funds rate in earlier periods. However, the relationship for one-year T-bills changes drastically in later time, where the premia reverts to being almost constantly negative. This is interesting, since if on-the-run bills were preferred as more liquid, these would trade at a premium. Our results however show that off-the-run bills are more preferred. Given that the off-the-run bill, while adjusted to be equal in maturity, trades at a premium to the on the-run-bill the liquidity premium displayed is opposite to the expected one in theory during recent time periods. This could indicate that the preference has been distorted, and the off-the-run bill fits the maturity mandates better.

Table 2 summarizes the initial regressions with the federal funds rate and VIX to illustrate any initial correlation of the spreads to the federal funds rate. The VIX index is employed to incorporate flight-to-safety effects. The GC repo/T-bill spread demonstrates a strong relationship with the fed funds rate. There are also significant results for a correlation with the

Table II

Liquiditiy Premia and The Opportunity Cost of Money: Baseline Specification

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Repo/3m T-bill	CD/3m T-bill	2y off/on run	1y off/on run	T-note/3m T-bill	T-note/6m T-bill	T-note/1y T-bill
Panel A: January 1976-December 2023							
Fed funds rate		8.22 ***	0.27 **	0.17 *	1.13 ***	-0.22	-0.63
		(0.84)	(0.09)	(0.09)	(0.25)	(0.39)	(0.46)
VIX		2.71 ***	0.03	0.01	0.47 ***	0.31 *	0.26 *
		(0.74)	(0.04)	(0.05)	(0.14)	(0.13)	(0.12)
Intercept		-40.35 ***	-0.06	-1.20	-7.18 **	-1.90	2.94
		(12.16)	(0.75)	(0.87)	(2.69)	(2.74)	(2.52)
Adj. R^2 (%)		54.10	7.24	3.02	16.64	6.15	9.60
#Obs.		576	576	576	576	576	576
Panel B: January 1976-December 2011							
Fed funds rate		8.97 ***	0.31 **	0.07	1.19 ***	-0.40	-0.99 .
		(0.95)	(0.11)	(0.10)	(0.28)	(0.49)	(0.52)
VIX		3.23 ***	0.04	0.02	0.55 ***	0.34 *	0.24
		(0.79)	(0.05)	(0.06)	(0.16)	(0.17)	(0.15)
Intercept		-55.70 ***	-0.61	-0.29	-8.69 *	-0.74	6.39 .
		(12.59)	(1.07)	(1.24)	(3.39)	(4.10)	(3.73)
Adj. R^2 (%)		51.69	6.56	0.13	14.35	8.46	14.73
#Obs.		432	432	432	432	432	432
Panel C: May 1991-December 2011							
Fed funds rate	6.50 ***	7.03 ***	0.39 ***	0.26	1.06 *	1.44 **	1.45 *
	(0.62)	(1.46)	(0.08)	(0.19)	(0.53)	(0.50)	(0.58)
VIX	0.96 ***	3.13 **	0.02	-0.02	0.50 ***	0.37 **	0.33 *
	(0.18)	(1.02)	(0.04)	(0.05)	(0.11)	(0.12)	(0.13)
Intercept	-18.38 ***	-43.92 *	-0.73	-0.55	-8.91 **	-8.62 **	-4.20
	(4.11)	(16.98)	(0.86)	(1.35)	(3.00)	(3.05)	(3.49)
Adj. R^2 (%)	52.35	33.56	15.95	2.30	26.32	25.44	20.13
#Obs.	248	248	248	248	248	248	248
Panel D: January 1976-December 1999							
Fed funds rate		10.73 ***	0.21	-0.19	0.62 .	-1.60 **	-2.22 ***
		(0.80)	(0.16)	(0.12)	(0.35)	(0.49)	(0.46)
VIX		2.60 ***	0.12	0.12 *	0.93 ***	0.90 ***	0.75 ***
		(0.30)	(0.08)	(0.05)	(0.21)	(0.08)	(0.17)
Intercept		-60.81 ***	-1.27	0.27	-10.15 *	-0.03	7.84
		(8.17)	(1.66)	(1.07)	(4.16)	(4.32)	(4.80)
Adj. R^2 (%)		61.96	3.33	3.77	12.58	32.59	39.28
#Obs.		288	288	288	288	288	288
Panel E: January 2000-December 2023							
Fed funds rate		6.13 **	0.29 **	0.16	-0.56	-0.39	0.66
		(2.36)	(0.09)	(0.30)	(0.52)	(0.55)	(0.82)
VIX		2.54 *	-0.02	-0.01	0.25 ***	0.10 .	0.14 *
		(1.08)	(0.03)	(0.05)	(0.05)	(0.06)	(0.07)
Intercept		-29.71	0.72	-1.34	-1.55	-0.07	0.86
		(19.23)	(0.61)	(1.04)	(1.24)	(1.43)	(1.96)
Adj. R^2 (%)		30.17	16.16	0.69	21.51	6.01	7.17
#Obs.		288	288	288	288	288	288

*p<0.05, ** p<0.01, *** p<0.001

Notes. The table summarizes linear regressions of yield spreads between assets of differing liquidity, consisting of monthly averages of daily rates. The dependent variables are yield-spreads expressed in basis points. The explanatory variable is the short-term interest rate in percent. The short-term interest rate is the federal funds rate from July 1954 to December 2023, and Federal Reserve Bank of New York discount rate before that. VIX is the CBOE S&P500 implied volatility index from 1990 to 2023. Before that the VIX variable comprises a linear projection of the VIX index on the of the daily squared returns on the S&P 500. Newey-West standard errors (12 lags) are shown in parentheses.

uncertainty in the market (VIX), with a high R^2 value. The CD/T-bill spread in column 2 displays similar results for the rate, consistent over multiple time periods with strong explanatory power, but the VIX coefficient is higher which reflects the credit risk associated with CDs. Between 2000 and 2023, the relationship however weakens compared to earlier periods. The result is interesting as it indicates that the explanatory effect of the federal funds rate is distorted in more recent time. Further, given that the period 1991-2011 displays higher significance than the lower significance viewed in the 2000-2023 period, the decrease in the federal funds rates explanatory power is presumably due to changes close to or post 2011. This is coherent with the period for the implementation of the stricter constraints on GMMFs. However, given the continuously low federal funds rates during the subsequent period, the result seen could also be a consequence of that.

In column 3 the two-year T-notes on-the-run/off-the-run spread indicates that there is no significant relationship with the VIX index for this liquidity premia. However, a significant but small relationship with the fed funds rate persists over time. The only period where the significance disappears is if we look at January 1976 to December 1999. This is inconsistent with the other Treasury spreads who instead lose any significance held if looking at the period afterwards. This result is interesting as it displays that the federal funds rate holds explanatory value for longer maturities in a more recent period, and further that the on-the-run and nearest off-the-run two-year notes do not display similar shifts as shorter maturity spreads do.

The on-the-run/off-the-run spread for one-year T-bills in column 4 has a weaker significant relationship of small magnitude with the fed funds rate for the entire period in Panel A. For the subperiods in Panel B and Panel C the fed funds rate loses this significance as a driver behind the spread, further evidenced by low R^2 values. This is indicative of the lacking liquidity premia between these bills that was previously observed in Table 1. The absence of explanatory value across all subperiods makes it hard to draw any conclusion about what is affecting this spread, which is indicative for the lacking spread over time and the negative spread in recent time observed graphically in figure 4, panel A.

In column 5 the T-note/T-bill spread for 3-month maturity indicates a highly significant positive relationship between this liquidity premium and the fed funds rate as well as the VIX index for the long period and the subperiods in Panel B and C. Although there is a weaker significance on the fed funds rate for the period 1991-2011. This contrasts with the other two maturity spreads who only gains significance in the short period in Panel C and in the first period in Panel D. In column 6 and 7 the T-note/T-bill spread for six-month and one-year maturity indicates a negative but insignificant correlation with the fed funds rate during the long period in Panel A, and a lower significant positive relation with the VIX index. However, for the period in Panel C there is a positive and significant relationship with the fed funds rate, in clear contrast to the negative and insignificant relationship observed for the longer period. The R^2 value is also improved a lot for that period. Following, in Panel D the same result can be found, but with a negative coefficient for the federal funds rate. In contrast though, in Panel E the results disappear when looking at the most recent time period, potentially due to the fed funds rate being close to 0% during parts of this period. The significance for the VIX index is lower post 2000 for the 6-month and one-year maturity spreads, and their R^2 values deteriorates, while for the 3-month maturity spread the VIX index maintains significance, while exhibiting an improved R^2 value. Post 2000 we conclude that there potentially are other variables, as opposed to the federal funds rate, that drive changes in the liquidity premium for Treasuries with varying maturitie

Table III

Liquidity Premia and The Opportunity Cost of Money: Including Near-Money Asset Supply

	(1)	(2)	(3)	(4)	(5)	(6)
		1920-2023			1947-2023	
Panel A: Long BA-GC-CD/3m T-bill						
Fed funds rate	10.30 ***		10.58 ***		10.07 ***	10.32 ***
	(1.09)		(1.19)		(1.14)	(1.15)
VIX	1.13 ***	0.63 *	1.16 ***	1.84 **	1.49 ***	1.50 ***
	(0.21)	(0.30)	(0.22)	(0.66)	(0.42)	(0.41)
log(Debt/GDP)		-39.51 ***	3.84			4.69
		(8.66)	(4.35)			(9.04)
log(T-bill/GDP)				-77.42 ***	-11.97	-14.95
				(17.59)	(8.77)	(10.38)
Intercept	-24.22 ***	-8.55	-22.70 ***	-179.27 ***	-57.81 *	-62.59 *
	(6.86)	(7.81)	(6.84)	(46.65)	(24.32)	(25.37)
Adj. R^2 (%)	54.03	16.24	54.08	18.97	56.54	56.54
#Obs.	1248	1248	1248	924	924	924
			1976-2023			
Panel B: CD spread/3m T-bill						
Fed funds rate	8.22 ***		7.79 ***		7.28 ***	8.04 ***
	(0.84)		(1.39)		(1.05)	(1.35)
VIX	2.71 ***	2.32 ***	2.68 ***	2.85 ***	2.84 ***	2.98 ***
	(0.74)	(0.67)	(0.71)	(0.79)	(0.79)	(0.75)
log(Debt/GDP)		-61.04 ***	-6.65			19.43
		(12.61)	(13.51)			(14.65)
log(T-bill/GDP)				-81.45 ***	-30.22 *	-46.32 **
				(16.00)	(12.47)	(14.27)
Intercept	-40.35 ***	-42.78 **	-43.11 **	-202.18 ***	-111.69 **	-141.65 ***
	(12.16)	(15.28)	(15.55)	(42.55)	(34.35)	(30.46)
Adj. R^2 (%)	54.10	33.20	54.16	29.91	56.01	56.58
#Obs.	576	576	576	576	576	576

*p<0.05, ** p<0.01, *** p<0.001

Notes: The dependent variable in Panel A is the spread, in basis points, between the three-month banker's acceptance rate and the three-month T-bill yield from January 1920 until April 1991, and the spread between three-month GC repo and three-month T-bill from May 1991 to December 2011. Subsequently the spread between three-month Certificates of Deposits and three-month T-bill is used to 2023 in Panel A, and the entire period in Panel B. The interest rate data consist of monthly averages of daily or weekly rates. VIX refers to the CBOE S&P500 implied volatility index. From January 1990 onward, the data are the monthly average of the daily VIX index. Prior to 1990, the VIX variable refers to the linear projection of the monthly average VIX index on the monthly average of daily squared returns on the S&P500. The other explanatory variables are the federal funds rate and Federal Reserve Bank of New York's discount rate before 1953, expressed in percent. The log government debt/GDP ratio, and the log of outstanding amounts of Treasury bills to GDP from 1947. Newey-West standard errors (12 lags) are shown in parentheses.

3.3 Supply Effects

Krishnamurthy and Vissing-Jorgensen (2012) and Greenwood, Hanson, and Stein (2015) indicate that changes in supply variables impact the liquidity premium. Nagel (2016) opposes this view by including the federal funds rate as an explanatory variable, and argues that the supply effect diminishes if the rate is controlled for. To check if what is observed by Nagel (2016) still holds, and that the opportunity cost of money is the main driver behind the liquidity premium, table 3 summaries regressions off the supply variables on the spreads of illiquid deposits and liquid treasury bills over a long time period.

For the long sample period in Panel A, the liquidity premium cannot be explained by changes in supply. In column 2, there is a significant negative relationship between debt/GDP that is eliminated when incorporating the fed funds rate in column 3. The R^2 value also improves from 16.24 to 54.08, further validating the significant explanatory effect of the federal funds rate. The same is observed in column 4-6 for the T-bill/GDP supply variable which has a significant negative correlation with this liquidity premium until the fed funds rate is incorporated. These results are in line with those of Nagel (2016). Over time, the main driver of the liquidity premium between deposits and T-bills is the opportunity cost of money. In Panel B, a similar result is found when doing the exercise on solely the CD/T-bill spread during a shorter time period. However, when regressing on the T-bill supply to GDP in columns (4), (5) and (6), this variable remains significant with a strongly negative coefficient of -46.32 even when controlling for the federal funds rate. While the federal funds rate increases the explanatory value in column (5) and (6), the persistence of the significance of T-bills supply is contrary to Nagel's conclusion. It does signify that supply of near-money assets holds significant explanatory effect for the liquidity premium. This result also indicates a shift in the drivers behind the liquidity premium in recent time, where the federal funds rate is no longer the sole explanatory variable for the premium.

Table 4 presents the same process for on-the-run/off-the-run liquidity premia. In Panel A, the 2-year T-note on-the-run/off-the-run liquidity premium displays a significant relationship with the federal funds rate consistently through the regressions. Furthermore, the supply variables hold very small significant value, with very low R^2. Any significant effects deteriorate once the federal funds rate is controlled for. This is similar to the results Nagel obtains for deposits and T-bills. In panel B, a contrast is observed. The federal funds rate initially holds significance for the on-the-run/nearest-off-the run one-year bill spread, but with a very low R^2 . When we control for the debt to GDP, this effect disappears. Ultimately, in the final regression in column (6), only the debt to GDP holds significant explanatory value. This contrast once again enlightens the two differences in the liquidity between on-the-run/off-the-run T-bills and T-notes. The T-note spread has a distinct relation to the opportunity cost of capital, whereas the T-bill spread has supply as the main factor explaining the spread. This further strengthens the conclusion that other variables are distorting the premium between on-the-run/off-the-run one-year T-bills.

Moving on to the relation between different maturities, table 5 conducts the same analysis with the varying maturity yield spreads between off-the-run T-notes and T-bills with an equal maturity left. In panel A, the spread between 3-month maturities has a significant relationship to the federal funds rate consistently. Interestingly though, when controlling for supply variables the significance of the rate decreases which is opposite to what Nagel (2016) observed, where the rate instead increased in significance. Whereas initially debt-to-GDP holds highly significant value when controlling for no other variables it loses its explanatory effect completely once the federal funds rate is controlled for which is expected. Opposingly however, the T-bill supply remains significant in all regressions. It loses some significance when controlling for the rate, but still maintains high significance throughout. Ultimately, we can thus conclude that T-bill supply and the federal funds rate both seem to have explanatory value for the liquidity premium between short maturity liquid assets. Thus, it is not only the opportunity cost of capital that is controlling this spread.

Table IV
Liquidity Premia and The Opportunity Cost of Money: Including Near-Money Asset Supply

	(1)	(2)	(3)	(4)	(5)	(6)
			1976-2023			
Panel A: Two-year T-note on-the-run/nearest off-the-run						
Fed funds rate	0.27 **		0.32 **		0.28 **	0.33 **
	(0.09)		(0.10)		(0.10)	(0.10)
VIX	0.03	0.02	0.03	0.03	0.03	0.04
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)
log(Debt/GDP)		-1.46 .	0.80			1.26
		(0.82)	(0.60)			(0.90)
log(T-bill/GDP)				-1.74 *	0.22	-0.83
				(0.78)	(0.61)	(0.88)
Intercept	-0.06	0.29	0.27	-3.00	0.45	-1.49
	(0.75)	(0.93)	(0.78)	(1.93)	(1.43)	(1.72)
Adj. R^2 (%)	7.24	1.76	7.41	1.12	7.10	7.38
#Obs.	576	576	576	576	576	576
Panel B: One-year T-bill on-the-run/nearest off-the-run						
Fed funds rate	0.17 *		0.01		0.13	0.01
	(0.09)		(0.11)		(0.09)	(0.11)
VIX	0.01	0.00	0.01	0.02	0.02	-0.00
	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)
log(Debt/GDP)		-2.60 **	-2.52 *			-3.09 *
		(0.92)	(1.19)			(1.31)
log(T-bill/GDP)				-2.43 .	-1.55	1.02
				(1.26)	(1.43)	(1.30)
Intercept	-1.20	-2.24 *	-2.24 *	-6.41 *	-4.85	-0.08
	(0.87)	(1.00)	(0.99)	(3.18)	(3.47)	(3.09)
Adj. R^2 (%)	3.02	6.58	6.42	2.56	3.77	6.47
#Obs.	576	576	576	576	576	576

*p<0.05, ** p<0.01, *** p<0.001

Notes: The dependent variable in Panel A is the spread, in basis points, of daily effective annual yields between two-year on-the-run T-notes and their nearest off-the-run counterpart. In Panel B the dependent variable is the spread in basis points between one-year on-the-run T-bills and their nearest off-the-run counterpart. VIX refers to the CBOE S&P500 implied volatility index. From January 1990 onward, the data are the monthly average of the daily VIX index. Prior to 1990, the VIX variable refers to the linear projection of the monthly average VIX index on the monthly average of daily squared returns on the S&P500. The other explanatory variables are the federal funds rate expressed in percent. The log government debt/GDP ratio, and the log of outstanding amounts of Treasury bills to GDP. Newey-West standard errors (12 lags) are shown in parentheses.

In panel B, the spread between 6-month maturities displays a pronounced difference compared to 3-month maturities, as the fed funds rate has no significance, regardless of if a supply variable is employed or not. However, there is a highly significant negative correlation with the supply of T-bills illustrated consistently in the regressions. Thus, for medium term liquid securities we can conclude that the

Table V

Liquidity Premia and The Opportunity Cost of Money: Including Near-Money Asset Supply

	(1)	(2)	(3)	(4)	(5)	(6)
			1976-2023			
Panel A: Two-year T-note/Three-month T-bill						
Fed funds rate	1.13 ***		0.78 *		0.75 **	0.86 **
	(0.25)		(0.33)		(0.25)	(0.31)
VIX	0.47 ***	0.41 **	0.45 **	0.52 ***	0.52 ***	0.54 ***
	(0.14)	(0.16)	(0.14)	(0.14)	(0.13)	(0.14)
log(Debt/GDP)		-10.80 ***	-5.34			2.92
		(2.58)	(3.66)			(4.10)
log(T-bill/GDP)				-17.50 ***	-12.24 **	-14.66 **
				(4.17)	(4.32)	(5.19)
Intercept	-7.18 **	-9.36 **	-9.39 **	-45.36 ***	-36.08 **	-40.59 **
	(2.69)	(3.26)	(3.18)	(10.93)	(11.16)	(12.85)
Adj. R^2 (%)	16.64	14.89	17.81	17.38	21.22	21.29
#Obs.	576	576	576	576	576	576
Panel B: Two-year T-note/Six-month T-bill						
Fed funds rate	-0.22		-0.34		-0.52	-0.26
	(0.39)		(0.51)		(0.40)	(0.50)
VIX	0.31 *	0.32 *	0.30 *	0.35 **	0.35 **	0.40 **
	(0.13)	(0.12)	(0.14)	(0.12)	(0.13)	(0.12)
log(Debt/GDP)		0.53	-1.86			6.57 .
		(2.68)	(3.12)			(3.64)
log(T-bill/GDP)				-5.89 .	-9.52 **	-14.97 ***
				(3.28)	(2.90)	(3.97)
Intercept	-1.90	-2.68	-2.67	-17.96 *	-24.39 **	-34.53 ***
	(2.74)	(2.75)	(2.78)	(8.68)	(7.48)	(9.33)
Adj. R^2 (%)	6.15	5.32	6.29	7.99	11.53	13.46
#Obs.	576	576	576	576	576	576
Panel C: Two-year T-note/One-year T-bill						
Fed funds rate	-0.63		-0.68		-0.84 .	-0.61
	(0.46)		(0.52)		(0.47)	(0.51)
VIX	0.26 *	0.29 **	0.25 *	0.29 **	0.29 *	0.33 **
	(0.12)	(0.10)	(0.12)	(0.10)	(0.11)	(0.10)
log(Debt/GDP)		3.95	-0.77			5.98 .
		(3.61)	(2.60)			(3.47)
log(T-bill/GDP)				-1.10	-7.04 .	-12.00 *
				(4.68)	(3.59)	(5.04)
Intercept	2.94	2.59	2.62	-3.19	-13.68	-22.91 *
	(2.52)	(2.53)	(2.59)	(11.08)	(8.63)	(10.84)
Adj. R^2 (%)	9.60	5.76	9.49	3.61	12.09	13.45
#Obs.	576	576	576	576	576	576

*p<0.05, ** p<0.01, *** p<0.001

Notes: The dependent variable in Panel A is the spread, in basis points, of daily effective annual yields between three-month T-bills, and a two-year T-notes with an equal maturity. In Panel B the dependent variable is the same spread for six-month T-bills and a two-year T-notes with an equal maturity. In Panel C, the spread in basis points between one-year T-bills, and a two-year T-notes with an equal maturity. VIX refers to the CBOE S&P500 implied volatility index. From January 1990 onward, the data are the monthly average of the daily VIX index. Prior to 1990, the VIX variable refers to the linear projection of the monthly average VIX index on the monthly average of daily squared returns on the S&P500. The other explanatory variables are the federal funds rate expressed in percent. The log government debt/GDP ratio, and the log of outstanding amounts of Treasury bills to GDP. Newey-West standard errors (12 lags) are shown in parentheses.

liquidity supply is a determining factor, whereas the opportunity cost of money cannot be determined to have a similar significant effect. In panel C we see that no variable on its own holds significant explanatory power for the liquidity premia between longer maturity liquid assets. When we control for all variables at the same time, we ultimately see that T-bill supply holds explanatory value, similar to the medium-term liquidity premia. However, the weak explanatory effects of all variables makes it hard to determine that there is a substantial relation between the supply of liquid assets and the premia for longer term liquid assets. These weak relations do indicate that another variable with more explanatory value for longer maturity T-bills is excluded from our framework.

Overall, our results do indicate a discrepancy between different maturities of Treasury securities. The opportunity cost of capital holds explanatory value over time for short term maturities, but fail to do the same for longer maturities. Similarly, the supply of liquidity does explain the liquidity premia between medium term securities but cannot be found to have the same effect for long term liquid securities. Ultimately, this indicates that there are other factors excluded from the model that have significant explanatory value for our observed liquidity premia in recent time.

3.4. Summary & Interpretation

The framework we utilize for exploring the difference in liquidity premia provides insights into the magnitudes of different liquidity premia inherent in the U.S. Treasury securities market. We find that most previously identified liquidity premia are existent in line with their previous findings, and that they are persistent overtime. However, our analysis also indicates certain shifts in liquidity premia for T-bills with longer maturities, especially in recent time. We also conclude that the spread between on-the-run T-bills and off-the-run T-bills, that is commonly found to be less persistent than that between on-the-run/off-the-run T-notes, has displayed an opposite relation in recent time. The on-the-run/off-the-run T-bills have instead seen the off-the-run bills trade at a premium to their on-the-run counterpart. These two findings are interesting, as they display an effect where the premia differ depending on the maturity of the assets. The negative spread for on-the-run/off-the-run T-bills also has an indication that off-the-run bills are preferred to their on-the-run counterparts. This distortion could be a consequence of that GMMFs maturity requirements limit their potential to hold the longer maturity on-the-run bills, and thus they prefer off-the-run bills that have been available longer to the market.

Consequently, the regression frameworks also provides insightful observations where we can conclude that while Nagel's (2016) findings that the liquidity premia between deposits and T-bills hold in the long-run, there is a slight different effect in the shorter term. Here, supply variables gain more explanatory power, contradicting Nagel's (2016) theory that the opportunity cost of money is the main driver of the liquidity premia. Concurrently, regressions on different maturities of T-bills display a similar effect where the supply of liquid assets better explain the premia for longer term maturities. This further indicates that the premia is driven by different factors depending on the maturity of the underlying assets compared. Thus, reasonably other factors left out of our model such as mutual fund maturity mandates could explain this discrepancy further.

We acknowledge various limitations with this approach. First, the model utilized focuses on supply of liquid assets and the opportunity cost of capital. However, it excludes any variable that could ultimately confirm and substantiate the effects of mutual fund mandates on the liquidity premia. Given this limitation, future research should consider incorporating other variables that would substantiate the effects of the discussed mutual fund mandates on the liquidity premia such as specific mutual fund characteristics and their changes, or analysis of different markets where one could be used as a control group not affected by the mandates. We also recognize the possibility that our filling of the missing one-year bills rates might to some degree distort the conclusions drawn.

4. Conclusion

The liquidity premia in the U.S. Treasury market are complex. The evidence indicates that for the premia between T-bills and less liquid deposits the findings of Nagel (2016) still holds over a long time period. The opportunity cost of money drives this liquidity premia in the long run, but contrary to this the supply of Treasuries has gained a significant impact when looking at a more recent shorter time period indicating a shift in the driver of this premia. When changing scope towards the liquidity premia between US Treasuries of different maturities, the opportunity cost of money has no significant impact for Treasuries of longer maturities, but for three-month maturity securities it still has. Reasonably, on could claim that this effect is due to the stricter maturity constraints that GMMFs are subject to following the Global Financial Crisis, leading to the increased explanatory value of T-bill supply in more recent time, and for longer maturity assets. This leaves room for further research on the reasons behind these distinct differences of the drivers behind the liquidity premium between Treasuries of different maturity, and the changed demand dynamics for T-bills following the implementations of regulatory constraints. Going into the less explored area of the on-the-run/off-the-run phenomena between T-bills, it appears as expected to be non-existent for these highly liquid assets in the long run, justifying it being neglected by the researchers at the forefront of the on-the-run and off-the-run field. Interestingly, we also observe a premium for the off-the-run one-year T-bills in recent time as opposed to what would be expected in theory. The preference for the off-the-run bills confirms a distorting effect from omitted variables in our framework. This effect might very well arise from strict maturity mandates imposed on GMMFs.

References

Literature:

Amihud, Yakov and Mendelson, Haim. Liquidity, Maturity, and the Yields on US Treasury Securities. *Journal of Finance*, 46 (1991) 1411-1425.

Bohn, Henning. The Sustainability of Fiscal Policy in the United States. *Sustainability of Public Debt*, R. Neck and J. Sturm, eds., pp. 15–49, 2008).

Buffa, Andrea M. and Hodor, Idan. Institutional investors, heterogeneous benchmarks and the comovement of asset prices. *Journal of Financial Economics*. 147 (2023), 352-381.

Chaudhary, Manav and Fu, Zhiyu and Li, Jian. Corporate Bond Multipliers: Substitutes Matter (December 2, 2022). Available at SSRN: https://ssrn.com/abstract=4292266 or http://dx.doi.org/10.2139/ssrn.4292266

D'Avernas, Adrien and Vandeweyer, Quentin. Treasury Bill Shortages and the Pricing of Short-Term Assets. (March 15, 2023) Journal of Finance (Forthcoming). Available at https://adriendavernas.com/papers/tbillshortages.pdf

Glasgo, Philip W and Landes, William J and Thompson A. Frank. Bank Discount, Coupon Equivalent, and Compound Yields. *Financial Management*, 11, (1982).

Goldreich, David and Hanke, Bernd and Nath, Purnendu. The Price of Future Liquidity: Time-Varying Liquidity in the U.S. Treasury Market. *Review of Finance*, 9 (2005), 1-32.

Greenwood, Robin and Hanson, Samuel G and Stein, Jeremy C. A Comparative-Advantage Approach to Government Debt Maturity. *Journal of Finance*, 70 (2015), 1683-1722.

He, Zhiguo and Nagel, Stefan and Song, Zhaogang. Treasury Inconvenience Yields during the COVID-19 Crisis. *Journal of Financial Economics,* 143 (2022), 57-79.

He, Zhiguo and Song, Zhaogang, Agency MBS as Safe Assets (November 7, 2022). Available at SSRN: https://ssrn.com/abstract=4173140 or http://dx.doi.org/10.2139/ssrn.4173140

Kamara, Avraham. Liquidity, Taxes, and Short-Term Treasury Yields. *Journal of Financial and Quantitative Analysis,* 29 (1994), 403-417.

Koijen, Ralph S.J and Yogo, Motohiro. A Demand System Approach to Asset Pricing. *Journal of Political Economy*. 127 (2019), 1475-1515.

Krishnamurthy, Arvind and Li, Wenhao. The Demand for Money, Near-Money, and Treasury Bonds. *The Review of Financial Studies*, 36 (2023), 2091–2130.

Krishnamurthy, Arvind and Vissing-Jorgensen, Annette. The Aggregate Demand for Treasury Debt, *Journal of Political Economy*, 120 (2012), 233-267.

Li, Wenhao and Ma, Yiming and Zhao, Yang, The Passthrough of Treasury Supply to Bank Deposit Funding. Columbia Business School Research Paper, USC Marshall School of Business Research Paper, (2023).

Longstaff, Francis A. The Flight-to-Liquidity Premium in US Treasury Bond Prices. *Journal of Business,* 77 (2004), 511-526.

Moore, Mark E and Winters, Drew B. When Is a Treasury Security On-the-Run? *The Financial Review*, 49 (2014), 77-88.

Musto, David K. and Nini, Gregory and Schwarz, Krista. Notes on Bonds: Liquidity at all Costs in the Great Recession. Jacobs Levy Equity Management Center for Quantitative Financial Research Paper, (2015).

Nagel, Stefan. The liquidity premium of near-money assets. *Quarterly Journal of Economics*, 131 (2016), 1927-1971.

Pasquariello, Paolo and Vega, Clara. The on-the-run liquidity phenomenon. *Journal of Financial Economics*. 92 (2009), 1-24.

Warga, Arthur. Bond Returns, Liquidity, and Missing Data. *Journal of Financial and Quantitative Analysis*, 27 (1992), 605-617.

Electronic:
Electronic Code of Federal Regulations. (2024, May 9). 17 CFR§ 270.2a-7 – Money market funds. Retrived from https://www.ecfr.gov/current/title-17/chapter-II/part-270/section-270.2a-7

Appendix

This thesis incorporates the use of external digital tools to aid in the preparation of the paper. Specifically, ChatGPT is utilized, an AI language model developed by OpenAI, for grammar checking, spelling corrections, and assistance with the structuring of content.

Appendix 1 – Missing values in the one-year T-bill on-the-run and nearest-off-the-run spread

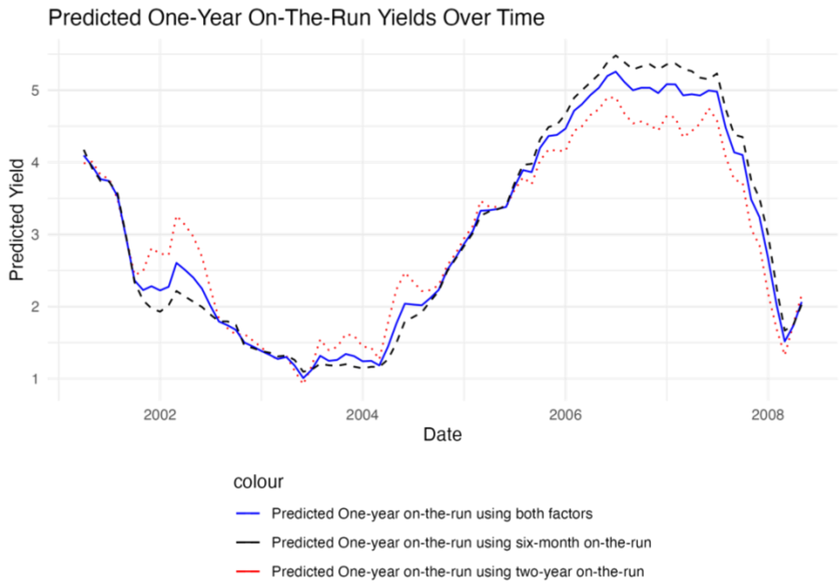
We choose not to include the six-month on-the-run and nearest off-the-run bills in our analysis to be conservative with our findings. The authors Gurkaynak, Sack, and Wright (2006) who created the yield curve we use disclaim that it might not accurately reflect shorter maturities. Thus, the adjustments might not be entirely accurate, mostly when concerned with how big a potential liquidity premium between these bills might be. Hence, we leave the spread out of the analysis. However, the time variation for these bills still holds explanatory power for the variation in the on-the-run and adjusted off-the-run yield for one-year bills, especially since they also reflect a bill/bill spread, as opposed to the off-the-run and on-the-run two-year notes. We will now further exemplify this conclusion and motivate our linear regression estimation for the missing values between 2001 and 2008.

To fill the missing values using a similar method to Nagel (2016), there are two options. We can either train a regression on the spread directly, or on the yields for the on-the-run one-year bills and the adjusted off-the-run one-year bills separately. To be able to accurately predict a spread it has to be trained on a variable which carries similar characteristics to the variable that we want to predict. For the first option we can either train it directly on the spread between two-year on-the-run and nearest off-the-run notes, or the spread between six-month on-the-run and nearest off-the-run bills. Or we could use both. However, when training directly on the spread the model gains little explanatory value. To be specific, the model trained on just the two-year note spread gains an adjusted R^2 of 7.45, and similarly the model trained on both spreads an adjusted R^2 of 24.27. We can thus quickly determine that this approach does not provide sufficient explanatory value for our purpose.

We also want to refrain from training our model on any independent variables in our regression framework to avoid biases. That leaves us only with the option to train two separate yields and take the spreads between these. This could arguably be done in many ways, but ultimately the end results are always similar in the time-variation, and very close in the spread. To visualize this, figure 1.1 panel A plots three different estimation methods for the yields of the on-the-run one-year bill, and Panel B plots the same estimation methods for the off-the-run one-year bill yield. To further solidify the estimations of our regression models, we also construct the synthetic yield of an off-the-run one-year bill using the same method as explained in our model. This is arguably the most accurate representation that is obtainable for a one-year bill during the period, and as we can see, the model that we ultimately utilize to predict the off-the-run one-year bill yield moves very close to the synthetic off-the-run one-year-bill constructed with the off-the-run yield curve, further explaining the appropriateness of our prediction model.

Finally, we want to disclose that no matter which one of these prediction methods we use, ultimately the end results in this thesis are similar and the same conclusions can be drawn.

Panel A



Panel B

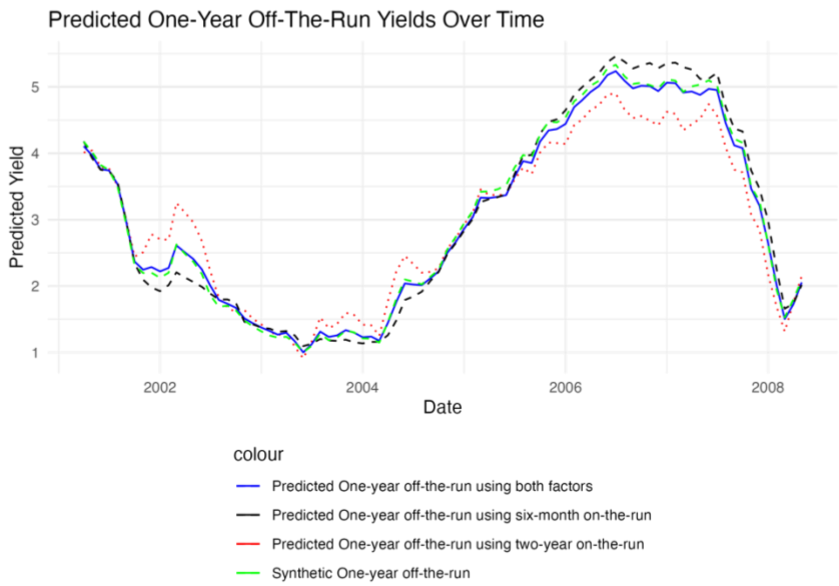


Figure 1.1 – Yield Estimation Results for On-The-Run and Adjusted Off-The-Run One-Year T-bills. The figures present the estimation results from three different trained linear models predicting the annual effective yield for missing one-year Treasury bills. Panel A presents the estimated on-the-run yield, and Panel B the estimated adjusted off-the-run yield. The coefficient used for training is referred to in the legend. The model trained using both factors incorporate the six-month T-bill and two-year T-note yields in training. Panel B also displays a synthetic off-the-run one year T-bill constructed using the off-the-run yield curve.

Appendix 2 - Missing values in the interpolate one-year T-bill yield

The method for filling the missing values using the linear method has already been argued for in appendix 1. Thus, here we mostly explain the choice of the variables used for estimating the interpolated one-year T-bill yield. Given that we do have the two-year T-note with a maturity closest to 365-days, implementing the trained coefficient become easier as we have a reference variable. Training the interpolated one-year T-bill yield also provides us with a trained variable that is equal in terms of maturity to the two-year T-note. Thus, the two-year T-note with a maturity closest to 365-days becomes an essential variable to include in the regression. Given that, we add some controls to our estimate of the time variation between the interpolated one-year T-bill yield and the two-year note yield with 365-days left to maturity. Adding these controls are simply an attempt to gain the most accuracy possible. However, as can be seen in in Figure 2.1, they make virtually no difference on the end estimation. In figure 2.1 we plot our prediction results using all the defined control variables, then we also plot one estimate utilizing only the two-year note yield with 365-days left to maturity, and the interpolated yield of three-month T-bills and six-month T-bills. Finally, we plot an estimate using no controls at all. As seen, the controls make virtually no difference, and the result becomes very similar either way.

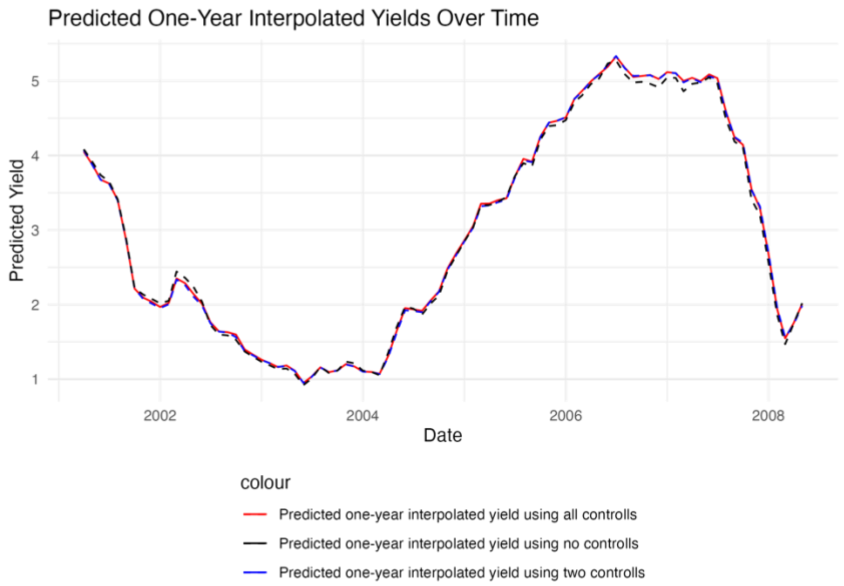


Figure 2.1 – Yield Estimation Results for Linearly Interpolated one-year T-bills. The figures present the resulting estimations from three different trained linear models predicting the interpolated effective annual yield for missing one-year Treasury bills. The coefficient used in training referrers to the yield of a T-note with a maturity closest to 365-days. The two controls refer to the linearly interpolated yields of T-bills with three- and six-months left to maturity respectively. The subsequent controls refer to two-year T-notes with maturities closest to the three- and six-month T-bills

Appendix 3 – Spread between six month on-the-run and nearest of the run T-bills

For those who might be interested, Tables 3.1 and 3.2 also display the six-month on-the-run/off-the-run summary statistics and regressions respectively. Figure 3.1 also plots the time difference in this liquidity premium to the federal funds rate.

Table 3.1

Summary Statistics

	(1)
Period	**6m off/on run**
Mean and standard deviation of yield spreads (basis points)	
1976–2023	-1.00
(std. dev.)	(2.74)
1976–2011	-0.78
(std. dev.)	(3.02)
1976–1990	-0.73
(std. dev.)	(3.85)
1991–2011	-0.82
(std. dev.)	(2.25)
2012–2023	-1.78
(std. dev.)	(1.49)

Notes. Means for yield spreads between on-the-run and off-the-run six-month T-bills in basis points are created with monthly averages of daily effective annual rates. The spread is calculated by taking the yield of an on-the-run six-month T-bill and comparing it with the yield of the nearest off-the-run six-month T-bill issued one auction earlier.

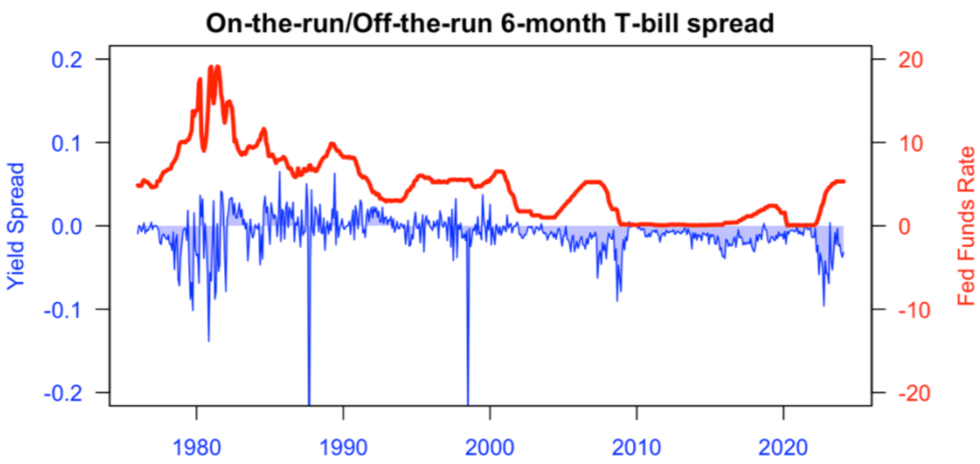


Figure 3.1 – Time Variation in Yield Spreads Between T-bills and T-notes of equal maturity, and the Level of Short-Term Interest Rates. The yield spreads in basis points is shown as the shaded areas with the corresponding axis to the left; the level of the federal funds rate, and the Federal Reserve Bank of New York discount rate prior to July 1954 is shown as the solid line with the corresponding axis to the right.

Table 3.2

Liquidity Premia and The Opportunity Cost of Money: Including Near-Money Asset Supply

6-month on-the-run & nearest off-the-run spread

	1976-2023					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Fed funds rate	-0.00		-0.05		0.01	-0.06
	(0.07)		(0.08)		(0.07)	(0.08)
VIX	-0.04 .	-0.04 .	-0.04 .	-0.04 .	-0.04 .	-0.06 *
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
log(Debt/GDP)		-0.41	-0.77			-1.90 *
		(0.57)	(0.67)			(0.77)
log(T-bill/GDP)				0.34	0.42	1.99 **
				(0.76)	(0.86)	(0.77)
Intercept	-0.21	-0.53	-0.53	0.65	0.79	3.71 *
	(0.50)	(0.56)	(0.56)	(1.91)	(2.06)	(1.69)
Adj. R^2 (%)	0.76	1.09	1.23	0.87	0.72	2.62
#Obs.	576	576	576	576	576	576

*p<0.05, ** p<0.01, *** p<0.001

Notes: The dependent variable is the spread, in basis points, between the six-month on-the-run T-bills and their nearest off-the-run counterpart. VIX refers to the CBOE S&P500 implied volatility index. From January 1990 onward, the data are monthly averages of the daily VIX index. Prior to 1990, the VIX variable refers to a linear projection of the monthly average VIX index on the monthly average of daily squared returns of the S&P500. The other explanatory variables are the federal funds rate and Federal Reserve Bank of New York's discount rate before 1953, expressed in percent. The log government debt/GDP ratio, and the log of outstanding amounts of Treasury bills to GDP from 1947. Newey-West standard errors (12 lags) are shown in parenthesis.