The Term Structure of Liquidity Premia in the U.S. Treasury Market

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Abstract

Bond yield spreads are affected by several factors like credit risk, liquidity risk, and taxes. Usually, these spread components are difficult to disentangle empirically. In the U.S. Government bond market, however, the regular issuing policy of the U.S. Treasury allows us to isolate a term structure of liquidity premia by exactly matching the observed yields of Treasury STRIPS and the theoretical yields obtained via bootstrapping Treasury notes. Studying the yield differences between coupon STRIPS and Treasury notes, we detect a surprisingly stable sign change between short and long maturities. We control for on-the-run effects and show that a differential taxation cannot explain the observed differences. Our approach also provides an explanation for the empirical puzzle that different STRIPS with exactly the same cash flows trade at different yields. Moreover, we show that the obtained liquidity premia significantly increase during the recent financial crisis and we trace them back to a flight-to-liquidity behavior.

JEL classification: E43, G01, G12

Keywords: Bond Liquidity, U.S. Treasury STRIPS, Coupon Stripping, Financial Crisis

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I Introduction

Bonds are ideal financial assets to study the impact of changing liquidity on prices or yields as liquidity differences cancel out at the maturity date. The natural hypothesis that more liquid bonds trade at lower yields than their less liquid, but otherwise identical counterparts, however, is difficult to test. The obvious reason is that bonds differ in various dimensions and, therefore, their yield differences cannot be traced back to liquidity effects unambiguously. Other effects are related to credit risk, specialness, tax treatment, option features, maturity and the coupon rate. Even if one restricts the analysis to a Government bond market to exclude most of the spread determinants, differences in the bonds' cash flow dates almost always remain. As a consequence, interpolation techniques are applied to control for coupon and maturity effects in liquidity studies. However, since empirically obtained yield differences are rather small, it is unclear whether these differences are caused by interpolation errors or whether they can be traced back to liquidity effects.

The purpose of this study is to carefully isolate liquidity premia within the U.S. Treasury market. The issuing policy of the U.S. Treasury provides us with a clinical environment to test for liquidity effects between the Treasury notes and the Treasury STRIPS market since 2002 for two reasons. First, the coupon dates of regularly issued Treasury notes coincide and at least one Treasury note matures at every coupon date. This ideal ladder-type structure in the maturities of traded Treasury notes allows us to perfectly obtain theoretical yields via bootstrapping.[1] These yields reflect the *liquidity of the Treasury notes* used in the bootstrapping procedure. Second, and equally important, the theoretical yields can directly be compared to the observed STRIPS yields as their maturities exactly match the coupon and maturity dates of Treasury notes. The observed yields contain a *STRIPS-specific liquidity component* which depends on calender time, time to maturity, and whether the STRIPS corresponds to a coupon or principal payment.

It is well known that Treasury notes, bonds and STRIPS are direct obligations of the U.S. government and, thus, are exposed to identical credit risk. They also are both exempt from state and local taxes and do not have special contractual provisions. Therefore, the

[1]Throughout this paper, we use the term *theoretical yield* for the yield-to-maturities of theoretical zero bonds obtained via bootstrapping coupon Treasury securities. This yield is also called the *spot rate*.

markets for Treasury notes, bonds, and STRIPS are as homogenous as possible with three exceptions: *specialness, federal taxes, and liquidity.* On-the-run Treasury notes or bonds typically are special in the sense that they experience a relative excess demand, e.g. as collateral in the repo market. As a consequence, they trade at relatively lower yields.[2] The specialness of on-the-run bonds represents a specific heterogeneity in the Treasury market and it is relatively easy to control for this effect empirically. On the contrary, it is much more difficult to model and measure the impact of taxes on bond prices. In this paper, we show that neither tax clientele nor tax timing effects have an impact on the observed yield differences. Therefore, any remaining yield difference can be attributed to a different liquidity.

U.S. Treasury STRIPS are obtained by stripping a Treasury note or bond into the coupon and the principal payments. Coupon STRIPS from different notes and bonds are assigned the same CUSIP number if they have the same maturity date. Therefore, they are not distinguishable. On the contrary, principal STRIPS of each note and bond are unique and not interchangeable with other principal or coupon STRIPS. Hence, there is a specific heterogeneity in the STRIPS market caused by the different treatment of coupon and principal STRIPS. We analyze the consequences of this difference in our empirical study.

Our clinical sample allows us to determine *three term structures of interest rates* with exactly matched maturities. The first is obtained by bootstrapping Treasury notes, the second from coupon STRIPS, and the third from principal STRIPS. Analyzing these term structures of interest rates allows us to gain insight into maturity dependent liquidity premia between the different markets.

Our study is related to three important strands of literature. The first one identifies liquidity premia in Treasury bills, notes and bonds. Amihud and Mendelson (1991) and Kamara (1994) study yield differences between Treasury bills and Treasury notes with maturities below six months. They find significant liquidity premia in the yields of notes compared to bills. A couple of studies analyze the on-the-run phenomenon, e.g., Warga (1992), Krishnamurthy (2002), Goldreich et al. (2005), and Pasquariello and Vega (2009).

[2]See, e.g., Duffie (1996), pp. 494-496.

These studies find that most recently issued government bonds have lower holding-period returns or trade at lower yields than previously issued bonds maturing on similar dates. They attribute this effect to a higher liquidity of the recently issued bonds. Elton and Green (1998) compare portfolios of Treasury securities with approximately the same cash flows but different liquidity (as proxied by trading volume) and find that a higher liquidity leads to lower yields. Longstaff (2004) investigates price differences between Treasury STRIPS and stripped Refcorp bonds and relates them to flight-to-liquidity proxies. All these studies, however, suffer to some extend from interpolation errors related to not perfectly matched cash flows or they econometrically control for differences in the coupons or maturities. As the yield differences are typically small, e.g. only up to 1.5 bp on average in the study by Goldreich et al. (2005), it cannot be excluded that a larger part of these differences are introduced by matching methods. This critique does not apply to the studies by Fleming (2002) and Strebulaev (2002). In contrast to our study, however, these studies have to restrict their sample to bills and notes with less than six months prior to maturity to obtain exactly matched cash flows. Recently, Goyenko et al. (2010) study bond market liquidity by analyzing time-series of quoted bid-ask spreads for different maturities over an extended period of time. While this study analyzes three broad maturity classes, we provide a in-depth analysis with 20 maturity classes.

The second strand of literature deals with the impact of taxation on bond prices. One of the major problems is the existence of tax clienteles which was first studied by Schaefer (1982) and Litzenberger and Rolfo (1984b). Using the typical approach for estimating implied tax rates of the marginal investor, Green and Ødegaard (1997), Elton and Green (1998), and Liu et al. (2007) find support for the absence of tax clientele effects in the U.S. Treasury market for periods after the Tax Reform Act of 1986. Based on buy-and-hold strategies, our results support the findings of these authors that the marginal investor is tax-exempt and taxes do not substantially impact government bond prices. A second problem is the existence of tax timing options. Constantinides and Ingersoll (1984) theoretically derive the value of these options. Empirically, Litzenberger and Rolfo (1984a), Jordan and Jordan (1991), and Elton and Green (1998) determine their value by using bond "triplets" and find evidence for their existence. Regarding the yield differences between Treasury STRIPS and Treasury notes, however, we deduce that tax timing effects do not impact our results.

The third strand of literature specifically deals with Treasury STRIPS and consists of two groups. The first one primarily focusses on arbitrage opportunities between coupon bonds and the replicating portfolio consisting of STRIPS. Most studies, e.g. Lim and Livingston (1995), Grinblatt and Longstaff (2000), Jordan et al. (2000), and Sack (2000), find that arbitrage opportunities are rare and cannot be exploited successfully if transaction costs are considered. Grinblatt and Longstaff (2000) show that observed price differences between the portfolios can partially be explained by liquidity-related factors. Contrary to our study, these studies analyze price differences only on a portfolio basis and, therefore, do not allow to isolate liquidity effects in the term structure of interest rates. The second group of studies investigates observed price and yield differences between matched-maturity coupon and principal STRIPS.[3] Daves and Ehrhardt (1993) find that principal STRIPS typically trade at a lower yield than otherwise identical coupon STRIPS. They attribute the difference to a reconstitution option embedded in principal STRIPS and to liquidity differences. Jordan et al. (2000) obtain a similar result. They observe, however, that principal STRIPS sometimes trade at lower yields and attribute these yield differences to the richness of the underlying note or bond. We contribute to this strand of literature by showing that these differences can be ascribed to the theoretically obtained liquidity differences between coupon STRIPS and Treasury notes.

The main results of our study are the following. First, we find that coupon STRIPS yields significantly differ from theoretical yields obtained via bootstrapping Treasury notes. We provide evidence that these differences cannot be explained by tax clientele or tax timing effects. Thus, we empirically isolate an average liquidity premium of up to 13.7 bp during normal market conditions and up to 28.6 bp during the recent financial crisis. More importantly, the term structure of liquidity premia between coupon STRIPS and Treasury notes has a different sign for short and for long maturities. This effect is surprisingly stable over time and can be attributed to the higher liquidity of coupon

[3]Other studies of U.S. Treasury STRIPS examine motives for stripping and rebundling (Grinblatt and Longstaff (2000)), term structure estimation (Sack (2000)), and cointegration (Kung and Carverhill (2005)).

STRIPS for short maturities. The well-known on-the-run effect is of minor importance. For principal STRIPS, on the contrary, we find that their yields basically coincide with the theoretical yields. This result can be reasoned by the principal STRIPS' unique reconstitution feature and no distinct liquidity premium can be isolated.

Second, we analyze the maturity structure of yield differences between different coupon and principal STRIPS maturing on the same day. For short maturities (below two years), we find higher yields for coupon STRIPS than for principal STRIPS. For long maturities (7-10 years) we find lower yields. This result extends the finding of Daves and Ehrhardt (1993) and Jordan et al. (2000) that, on average over all maturities, principal STRIPS trade at lower yields than otherwise identical coupon STRIPS. Since matched-maturity STRIPS are taxed synchronously, taxation obviously cannot explain these differences. In this paper, we show that the empirically observed yield differences between coupon and principal STRIPS can be traced back to theoretically obtained liquidity premia between coupon STRIPS and Treasury notes. Extending this approach, we show that yield differences between different principal STRIPS maturing on the same day can be ascribed to the fact that they differ with respect to their underlying instrument, either a Treasury note or a Treasury bond. Hence, the liquidity differences between Treasury notes and bonds transmit to the STRIPS market and any direct liquidity effect between the STRIPS is of minor importance.

Finally, our analysis shows that liquidity premia between coupon STRIPS and Treasury notes significantly increased during the recent financial crisis. Using a model similar to Longstaff (2004) we relate the observed yield differences to flight-to-liquidity premium explanatory variables. The results suggest that short-term coupon STRIPS and long-term notes can be regarded as a “safe haven” with regard to liquidity risk in times of higher uncertainty.

The remainder of this paper is structured as follows. In Section II, we carefully describe the institutional details of the STRIPS program and discuss potential effects on the yield differences. Further, the empirical design is presented. In Section III, we provide and discuss the empirical results. Section IV concludes.

II Design of the Study

Subsequently, we recall some well-known institutional features of the U.S. Treasury STRIPS program as far as they are relevant for our study.[4] We further render the calculation of observed and theoretical yields more precisely. Moreover, we discuss the potential impact of taxation, liquidity, and the unique reconstitution feature on our results. Finally, we present the empirical design of our study.

II.1 Institutional Details on Stripping and Reconstitution

The Separate Trading of Registered Interest and Principal Securities (STRIPS) programm was set up by the U.S. Treasury in 1985. Since October 1997 almost all newly issued notes and bonds have been eligible for stripping. STRIPS are direct obligations of the U.S. government and are obtained by delivering a Treasury note or bond to the Federal Reserve in exchange of a bundle of zero bonds corresponding to the coupon and principal payments. As notes and bonds are held in book-entry form the transaction can be executed at little cost.[5]

STRIPS are identified by whether they are created from a coupon or a principal payment. Coupon STRIPS that are due on the same day are assigned the same CUSIP number, even if they originally come from a different note or bond. Contrarily, the principal STRIPS of each note and bond are assigned a unique CUSIP number and they are not interchangeable with other principal or coupon STRIPS. To reconstitute a previously stripped note or bond, the appropriate proportions of the component STRIPS must be delivered to the Federal Reserve. For the principal payment, the principal STRIPS must have been derived from the note or bond being reconstituted. For the coupon payments, however, matched-maturity coupon STRIPS from arbitrary notes or bonds can be used.

For tax purposes, STRIPS are treated as originally issued discount (OID) instruments and taxed according to the constant yield method. Therefore, the annually

[4]A detailed description of the Treasury STRIPS program can be found, e.g., in Grinblatt and Longstaff (2000) and Jordan et al. (2000).

[5]Further details are given in Sack (2000).

accrued interest on STRIPS is taxed even though no interest is payed, leading to negative cash flows for taxable entities prior to maturity.

II.2 Determination of Observed and Theoretical Yields

For our analysis, we first determine the observed and theoretical yields on a pre-tax basis. According to market convention, we compute the annualized yield of a STRIPS at time t with price $P_t^{STRIPS}(T)$ and maturity T $(t < T)$ as follows:

$$y_t^{STRIPS}(T) \quad = \quad 2 \cdot \left\{ \left(\frac{100}{P_t^{STRIPS}(T)} \right)^{\frac{1}{T-t}} - 1 \right\}. \tag{1}$$

These yields are determined from directly observed prices and, therefore, denoted as observed yields in contrast to theoretical yields obtained via bootstrapping Treasury notes and bonds. The difference $T - t$ is measured in units of coupon periods of Treasury notes and bonds (semiannual coupon payments) using the actual/actual day count convention. More precisely, we calculate the remaining fraction of the current coupon period $f = \frac{\text{number of days from settlement until the next coupon payment}}{\text{number of days in the coupon period}}$ and the difference $T-t$ as f + number of remaining coupon periods. Moreover, we adjust the difference if the maturity date T falls on a weekend or a public holiday to consider the cash flows exactly. The annual (or bond-equivalent) yield is obtained by simply doubling the yield per coupon period, i.e. by neglecting compounding effects. We denote the annualized yield of a coupon STRIPS by $y_t^C(T)$ and the annualized yield of a principal STRIPS by $y_t^P(T)$.

For extracting theoretical yields we use the standard bootstrapping procedure. In this procedure, the observed dirty price $P_t^{CB}(T)$ of a coupon bond with coupon C and maturity T is defined as the sum of discounted future cash flows. The discount factors or, equivalently, the theoretical yields $r_t(t + f + i), i = 0, \ldots, T - t - f$ are unknown:

$$P_t^{CB}(T) \quad = \quad \frac{C}{\left(1 + \frac{r_t(t+f)}{2}\right)^f} + \frac{C}{\left(1 + \frac{r_t(t+f+1)}{2}\right)^{1+f}} + \cdots + \frac{100 + C}{\left(1 + \frac{r_t(T)}{2}\right)^{T-t}}, \tag{2}$$

The remaining fraction of the current coupon period f is defined as above and we pay regard to using the same day count conventions and adjustments as for STRIPS.[6]

Given observed prices of coupon bonds with identical coupon dates and given that at every coupon date up to some date $\bar{T}$ exactly one bond matures we can recursively obtain the theoretical yields from t until $T = t + f, t + f + 1, t + f + 2, \ldots, \bar{T}$ as follows:

$$r_t(T) \;=\; 2 \cdot \left\{ \left(\frac{100 + C}{P_t^{CB}(T) - C \cdot \sum_{i=0}^{\lfloor T-t \rfloor - 1} \left(1 + \frac{r_t(t+f+i)}{2}\right)^{-(f+i)}} \right)^{\frac{1}{T-t}} - 1 \right\}, \qquad (3)$$

where $\lfloor T - t \rfloor$ is the largest integer that is smaller than $T - t$. $r_t(T)$ denotes the *final theoretical yield* of a coupon bond with maturity T at time t. If there is more than one note or bond maturing on the same coupon date, their final theoretical yields should be the same. However, small yield differences are typically observed.[7] We discuss the potential bias when presenting our data.

Considering the current U.S. tax law we are also able to calculate the theoretical after-tax yields for Treasury notes. We assume that the investors' tax rates do not change over time and that they choose the optimal amortization rule, i.e. deferring market discount amortization to maturity and amortizing market premium by the constant yield method.[8] Then, the theoretical after-tax yields can be calculated by using the bootstrapping procedure with after-tax cash flows.[9] When computing the after-tax yields for Treasury STRIPS we apply the constant yield method. It is important to note that the after-tax yield y_t^τ, with maturity T and tax rate τ cannot simply be calculated from its pre-tax yield y_t as $y_t^\tau(T) = y_t(T) \cdot (1 - \tau)$. This approach disregards the obligatory intermediate tax payments during the maturity of the STRIPS. Instead, a bootstrapping-type procedure is applied to the after-tax cash-flows.[10]

[6] As common in the secondary market, we apply the "street" convention, i.e. we compound interest until the next coupon date.

[7] See, e.g., Warga (1992), Duffie (1996), and Krishnamurthy (2002).

[8] We abstract from the case that the amortization of a market discount may be optimal if the investor expects an increasing tax rate.

[9] For a theoretical derivation confer, e.g., to the appendix of Green and Ødegaard (1997).

[10] The difference between these after-tax yield calculations is discussed in Daves and Ehrhardt (2008).

II.3 Potential Effects on Observed and Theoretical Yields

(1) Taxation

The differential federal taxation between coupon Treasury securities and Treasury STRIPS may affect the observed and theoretical yields calculated as in Section II.2. Therefore, we analyze potential tax clientele and tax timing effects. First, we empirically investigate whether different tax clienteles may have an impact on the yield differences between these markets. Second, we derive that tax timing effects do not influence our results.

Considering buy-and-hold investors, a clear-cut tax advantage or disadvantage of one of these markets does not exist. In particular, the feedback effect between the prices of notes or STRIPS and their taxation leads to non-linear tax effects with respect to various factors. The direction of the tax effect in a buy-and-hold setting depends on the maturity time, the shape of the term structure of interest rates, and whether a note trades below or above par.[11] For obtaining the direction of a potential tax effect we now assume that investors value Treasury notes and STRIPS using identical after-tax yields. If taxes play a role in the Treasury market, prices (and therefore pre-tax yields) have to adjust to meet this requirement. In the following, we discuss the potential effects for any marginal tax rate greater than zero.

Discount notes obtain a tax advantage relative to STRIPS that is increasing in its market discount. In contrast to the discount of STRIPS, the market discount of a coupon bond trading below par does not have to be amortized until maturity. This leads to a tax deferral compared to STRIPS and this advantage will appear in a lower final pre-tax yield required for discount bonds compared to STRIPS. Thus, we expect the theoretical final pre-tax yield of the note to be lower the higher its discount, leading to a higher pre-tax yield difference between Treasury STRIPS and notes.

For premium notes the result is ambiguous and the direction of the tax effect may slightly depend, among others, on the shape of the term structure.[12] The premium of coupon bonds, however, can be amortized by applying the constant yield method. Since STRIPS are also taxed by the constant yield method, there is virtually no difference in

[11]Gregory and Livingston (1989) analyze tax differences between a note and a pre-tax cash-flow matching portfolio of STRIPS for different tax scenarios in detail.

[12]Precisely, the effect depends on the pre-tax and after-tax yields for all payment dates $t < T$.

the after-tax yields. Therefore, we cannot establish a general relationship, as for the case of notes trading at a discount.

These effects are in line with the analysis of Gregory and Livingston (1989) for the current U.S. tax law. In contrast to the findings of Kamara (1994), our setting differs in two respects: First, Kamara (1994) analyzes maturities of less then six month such that the taxation is identical regardless buying a note, a bill or STRIPS. Second, we do not consider the sellers' point of view as their tax strategy highly depends on the time of the purchase and whether the note was bought at a premium or at a discount.

In contrast to this potential tax clientele effect, we do not expect tax timing options to have an impact on the yield differences. Obviously, one could argue that a STRIPS portfolio has more tax timing options than the corresponding Treasury note, leading ceteris paribus to a higher value of the STRIPS portfolio. However, as tax timing opportunities arise, the note can immediately be stripped and some STRIPS can separately be sold in the market, possibly leading to advantageous capital gains or losses.[13] Hence, the tax timing options in the coupon Treasury market should not differ from the tax timing options in the STRIPS market. This result is in line with Grinblatt and Longstaff (2000) who discuss the effect of tax timing on the relative pricing of Treasury notes and STRIPS.

Fortunately, for an important part of our study potential tax differences do not matter. The yields of matched-maturity coupon and principal STRIPS are affected identically by taxation.[14] Hence, the yield differences between these STRIPS can exclusively be traced back to liquidity differences and specific reconstitution features. The size of these differences also allows us to control for tax effects in the differences between observed STRIPS yields and theoretical yields obtained from Treasury notes and bonds by the bootstrapping procedure.

[13]Section 1286 of the Internal Revenue Code states that the basis of the stripped Treasury note or bond shall be allocated with respect to the fair market values to the corresponding STRIPS.

[14]Daves and Ehrhardt (1993), p. 317, note that until the tax reform of 1989 there have been tax advantages for Japanese investors buying principal STRIPS instead of coupon STRIPS. This benefit was supposed by Stigum (1990), p. 695, to explain yield differences between coupon and principal STRIPS. Nowadays, however, coupon and principal STRIPS are treated equally in terms of taxation issues.

(2) Liquidity

Typical proxies for the liquidity of a fixed income security are trading activity, the outstanding amount, the bid-ask spread, and the age.[15] Only the first two proxies need a clarification for the STRIPS market and are defined in the following.

Trading activity is typically measured by the number of trades, the trading volume, the time period between trades, or by the full order book. As none of these variables are available for STRIPS we use the stripping activity as best available proxy. We define the stripping activity $SA^P(T)$ of a principal STRIPS with maturity T by the face value of the underlying note or bond being stripped within a given time interval (one month). For coupon STRIPS with a certain maturity T we define the monthly stripping activity $SA^C(T)$ by the sum of matched-maturity coupon STRIPS being obtained via stripping notes or bonds with equal or longer maturities within a given time interval, i.e.

$$SA^C(T) \quad = \quad \sum_{s \geq T} \frac{C_s}{100} \cdot SA^P(s), \tag{4}$$

where C_s is the corresponding semiannual coupon payable at T. This definition reflects the fact that matched-maturity coupon STRIPS are interchangeable (are assigned the same CUSIP number). As a consequence, the stripping activity of coupon STRIPS increases if the remaining time to maturity decreases. Stripping activity is positively related to trading volume as the incentive to strip typically comes from retail. This fact was already pointed out by Stigum (1990), p. 696, and reconfirmed by recent conversations with traders. The STRIPS trader initiates the stripping procedure with the Federal Reserve and sells coupon or principal STRIPS to the customers.[16]

The outstanding amount of a security provides information about the absolute supply of this security. The actually outstanding amount of a specific note or bond at a given point in time is the total outstanding volume minus the amount held in stripped form. Analogously, the outstanding amount $OA^P(T)$ of a specific principal STRIPS with maturity T equals the total outstanding volume of the underlying note or bond held in

[15] See, e.g., Fleming (2003).

[16] Reconstitution activity could also be used as a proxy for trading activity. As it is highly positively correlated to stripping activity we do not consider it.

stripped form. For coupon STRIPS with a specific maturity date T, the outstanding amount $OA^C(T)$ equals the total coupon volume of all notes and bonds that mature at or after this specific maturity date and are held in stripped form, i.e.

$$OA^C(T) \quad = \quad \sum_{s \geq T} \frac{C_s}{100} \cdot OA^P(s). \tag{5}$$

Treasury notes and bonds clearly differ from Treasury STRIPS with respect to their outstanding amount. Shortly after an issuance of a note or bond, typically hardly any STRIPS related to this issue exist. As pointed out above, the outstanding amount of coupon STRIPS maturing on the same day but coming originally from different issues add up due to the fungibility. Therefore, $OA^C(T)$ increases with decreasing time to maturity and it is possible that this amount exceeds the outstanding amount of the note or bond.[17] A similar relationship holds between the outstanding amounts of coupon and principal STRIPS.[18]

Besides these liquidity proxies we also consider the well-known on-the-run effect. Ample empirical studies have found that most recently issued notes trade at lower yields and more liquid than older ones.[19] We control for this specific effect by including a dummy variable with value one if the note trades on-the-run, and zero otherwise.

(3) Reconstitution

An important effect that may lead to yield differences between coupon and principal STRIPS is that matched-maturity coupon and principal STRIPS are not perfect substitutes. When reconstituting a note or bond, one has to deliver exactly those principal STRIPS originally derived from the note or bond that is being reconstituted. Therefore, an "option to reconstitute" is implicitly embedded in principal STRIPS and can be assumed to have a positive value.[20] On the one hand, considering the reconstitution effect only, principal STRIPS should have a lower yield as matched-maturity coupon STRIPS.

[17]In December 2004, e.g., the outstanding amount of the 12% Treasury Bond maturing on 15 May 2005 was USD 1,957 million whereas the outstanding amount of corresponding coupon STRIPS was USD 3,684 million.

[18]Daves and Ehrhardt (1993), p. 319, provide an example of this effect.

[19]See, e.g., Krishnamurthy (2002), Goldreich et al. (2005), and Pasquariello and Vega (2009).

[20]See, e.g., Daves and Ehrhardt (1993), p. 325.

On the other hand, due to their fungibility, coupon STRIPS may have a larger outstanding amount, especially for short maturities. Assuming that a larger outstanding amount is related to a better liquidity and lower yields, two opposite effects on the difference between coupon and principal STRIPS exist. It is not obvious which effect dominates. In Section III.3 we empirically investigate this problem.

Another interesting question refers to the yield differences between matched-maturity principal STRIPS derived from Treasury notes and Treasury bonds, respectively. Our sample allows to measure the relative richness of the two coupon Treasury securities in a clean way.[21] It is sufficient to compare the final theoretical yields of the respective Treasury note or bond. The Treasury note, e.g., is rich compared to the Treasury bond if and only if its final theoretical yield is lower than that of the Treasury bond. Using this measure we are able to study the effect of relative richness of Treasury securities on yields in the STRIPS market. Section III.4 is devoted to this question.

II.4 Empirical Design

Our sample period covers the time span from February 2002 until November 2008 on a daily basis. This period is determined by the ability to compute theoretical yields via bootstrapping. We divide our sample into two sub-samples. The first sample period covers the time span previous to the financial crisis and ranges from 15 February 2002 until 29 June 2007. The second sample period starts in July 2007. We consider this month as the first month of the financial crisis as two hedge funds managed by Bear Stearns almost collapsed in the end of June 2007. Comparing these two periods gives us insights whether the financial crisis has an impact on liquidity premia within the Treasury market.

For our analysis, we need prices of coupon bonds with identical coupon dates and, ideally, with exactly one coupon bond maturing at every coupon date. U.S. Treasury notes and bonds are usually auctioned quarterly with semi-annual coupon payments in February/August and May/November. The coupons and the redemptions are always payed on the 15th of a corresponding month.[22] Being issued on a regular basis, these

[21] Contrary to the richness and cheapness as defined by Jordan et al. (2000), our measure does not depend on a spline-based estimation procedure.

[22] If this day coincides with a weekend or public holiday, the payment is made on the next trading day.

series are adequate to perform our study. Moreover, these series are representative for the whole treasury market as they capture approximately 60% of the issues and 59% of the total outstanding volume of all marketable Treasury notes and bonds.[23]

Our observation period starts in February 2002. Prior to this month, the exact bootstrapping methodology is not applicable because no Treasury note or bond with maturity on 15 February 2002 exists. Hence, it is the natural starting date for the February/August series. Similarly, we start on 15 May 2003 with the May/November series. We consider all Treasury notes and bonds from the two series for which we are able to compute the final theoretical yields during or observation period. This restricts our sample to notes and bonds with maturities until August 2018. The maximum maturity up to which we are able to exactly determine the theoretical yields for the different series is depicted in Figure 1. From 17 February 2004 on, we are able to determine theoretical yields up to ten years for the February/August series. For the May/November series, however, due to a missing maturity of a note or bond on 15 May 2011 we are able to compute the theoretical yields for up to six years only.

After these refinements our total sample consists of 48 Treasury notes and 6 Treasury bonds of the February/August series and 32 Treasury notes and 2 Treasury bonds of the May/November series. These notes and bonds have fixed coupons and do not have any embedded option. For each Treasury note and bond we consider the corresponding principal STRIPS. We further consider all 48 coupon STRIPS maturing at a coupon date of a note or bond in our sample. From these data we determine three discrete term structures of interest rates for theoretical yields, coupon STRIPS and principal STRIPS on a daily basis. In the first part of the empirical study we further reduce our sample by considering Treasury notes only. They typically differ from Treasury bonds by their outstanding amount, their age and potentially by an on-the-run feature. Later, we also include Treasury bonds to measure effects of yield differences between matched-maturity Treasury notes and bonds on their corresponding matched-maturity principal STRIPS.

Frequently, two or three Treasury notes mature on the same date. Thus, the bootstrapping procedure may lead to two or three final theoretical yields for a given

[23]This ratio is as of December 2007 and calculated using data from the *Monthly Statement of the Public Debt of the United States*.

maturity. We treat these yields as separate observations. However, we have to decide about the appropriate yield for discounting the coupons of notes with longer maturities. Since the differences between the final theoretical yields of those notes are very small in our data set, we simply take the arithmetic mean when proceeding with the bootstrapping. As alternative we have used the smallest and largest final theoretical yield. This robustness check shows that the potential absolute error being introduced is 0.02 bp on average with a maximum of 0.26 bp. Therefore, averaging does not significantly affect our results.

We obtain daily price data for Treasury notes and bonds and coupon STRIPS via Bloomberg over the whole observation period. For the corresponding principal STRIPS, daily price data are available since 27 November 2006.[24] The so-called Bloomberg Generic Prices used in this study are consensus prices calculated from the information delivered by a variety of bond dealers and financial institutions.[25] Bloomberg ensures the data quality by marking a security "not priced" if there are not at least three prices being contributed to their system. To further verify the reliability, we checked a number of prices with data from different sources and did not find significant differences.[26]

We clean our data set in the following: we delete the observations on dates where prices are missing for several notes such that the exact bootstrapping is not applicable. Moreover, we eliminate the observations with zero returns for almost all securities.[27] Consistent with Amihud and Mendelson (1991) we exclude all securities with less than 15 days to maturity. The trading close to maturity is particularly thin and small pricing errors will convert to extreme annualized yield errors. After this data preparation, we remain with more than 63,000 theoretical yields, about 44,000 yields of principal STRIPS, and about 53,000 yields of coupon STRIPS. Summary information of the data set is presented in Table 1.

Consistent with Bloomberg, we follow the Treasury security market convention of next-day settlement and calculate accrued interest on an actual/actual basis. We are

[24]Therefore, we further reduce our sample by excluding the Treasury bonds maturing prior to this date.

[25]Although the prices are recorded at the same time, actual transaction times may slightly differ or the quotes may just reflect the dealers' price evaluation. This may introduce measurement errors, but should not asynchronously effect the yields and, thus, not bias the results systematically.

[26]Moreover, other data providers such as GovPX, Markit, Thomson Datastream, and Xtracter deliver indicative end-of-day STRIPS quotes only.

[27]Mostly, these dates correspond to public holidays and the quotes just seem to be carried forward.

aware of the market convention that price information for STRIPS are usually quoted as (three-digit) yields. Since Bloomberg's methodology, however, is based on consensus prices we believe in being more accurate by taking the given prices and calculating the corresponding yields. Moreover, by using price data we are consistent with our methodology for calculating the theoretical yields. The absolute differences to the yields delivered by Bloomberg are below 0.2 bp and are due to rounding differences.

We use end-of-day mid prices for calculating the theoretical yields from Treasury notes as well as the yields of coupon and principal STRIPS. Thereby, we do not take transaction costs into account. Nevertheless, when interpreting the results we analyze whether the yield differences exceed the typical bid-ask spreads. We calculate the bid and ask yields for STRIPS using bid and ask prices delivered by Bloomberg. For assessing theoretical bid and ask yields we simply add or subtract half of the typical bid-ask yield spread from or to theoretical yields.[28]

To study liquidity effects we further collect monthly observations on the total outstanding volume, the amount held in stripped form, and the stripping and reconstitution activity of Treasury notes and bonds. This data covers our 82-month sample period from February 2002 to November 2008 and is obtained from the *Monthly Statement of the Public Debt of the United States* issued by the U.S. Treasury. Furthermore, for analyzing the flight-to-liquidity premium, we obtain monthly observations of the Chicago Board Options Exchange Volatility Index (VIX) and the OECD US Leading Indicators Business Climate Indicator. This data covers our sample period from February 2002 to November 2008 and is obtained via the Bloomberg system.

[28]The Bloomberg methodology usually assumes a representative bid-ask spread of 1/16 in terms of prices for notes and bonds (1/32 for maturities up to 1 year and on-the-run issues). For STRIPS they assume a representative bid-ask spread of 0.02% or 2 bp in terms of annual yields. These values are in line with evidence by Elton and Green (1998), Jordan et al. (2000), and Longstaff (2004).

III Empirical Results

III.1 Coupon STRIPS Yields vs. Theoretical Yields

We first investigate the differences between the yields of coupon STRIPS and the theoretical yields, $y^C - r$. We classify them with regard to their remaining time to maturity in half-year maturity bins. Bin T ($T = 0.5, 1.0, \dots$) consists of all yield differences for maturities in the interval $[T - 0.25; T + 0.25)$. The yield differences for a given maturity bin are averaged across notes and the descriptive statistics calculated across time.[29]

Table 2 displays the results for these differences. Almost all mean and median differences between y^C and r are significantly different from zero. Moreover, the differences tend to increase with time to maturity. For short maturities up to five years, coupon STRIPS yields are on average significantly smaller than theoretical yields. This relationship reverses for maturities above five years and the differences are the largest for the maturity bin of ten years.

For interpreting the economic significance we also take transaction costs into account. Therefore, we compare the corresponding bid and ask yields. For maturities up to 1.5 years the mean difference of $y^C_{bid} - r_{ask}$ is significantly smaller than zero. For maturities larger than seven years we observe that y^C_{ask} is on average significantly greater than r_{bid}. These differences could theoretically be exploited by buying (selling) the theoretical zero bond and selling (buying) the coupon STRIPS. However, we do not claim that a violation can immediately be exploited as an arbitrage opportunity since the theoretical zero bond cannot be traded directly. Nevertheless, these differences cannot be explained by a typical variation within the bid-ask spread. For maturities between two and seven years, however, the coupon STRIPS can, on average, be considered as being priced in line with the theoretical yields when taking transaction costs into account.

Up to this point, we only have shown the existence of significant differences between observed coupon STRIPS yields and theoretical yields. Subsequently, we relate these differences to liquidity proxies. These proxies are the stripping activity of a coupon

[29] We also calculated the results by only using the exact times to maturity of 0.5, 1.0, 1.5, etc. years. The results are qualitatively in line with the results presented here. This restriction, however, would reduce our data set by more than 90%.

STRIPS SA^C and the outstanding amount of a coupon STRIPS OA^C. As argued in Section II.3 both variables are positively related with coupon STRIPS liquidity and we expect that the yield differences decrease with each of these proxies. The third variable we consider is the age of a note, i.e. the time since the note was issued. This variable reflects the fact that notes have a tendency to become less liquid when they age whereas this relation is ambiguous for coupon STRIPS as they come from a variety of underlying notes and bonds.[30] Hence, we expect the yield differences to be decreasing with the age of a note.

Stripping information is available on a monthly basis only and, therefore, we use end-of-month observations of the yield differences in our regression analysis. The augmented Dickey-Fuller tests shows that the null of non-stationary monthly yield differences can be rejected on a 1% significance level. Panel A of Table 3 shows four regression results which differ by the inclusion of the age variable and the lagged yield differences. The results show a significant and negative relation between the yield differences and the liquidity proxies. A higher stripping activity is related to a lower yield difference reflecting the increasing mean yield difference for a larger time to maturity as reported in Table 2. The relation between the yield differences and the outstanding amount of coupon STRIPS is also significantly negative. As expected, the effect of the age of a note is always significantly negative. The results are robust to the inclusion of the lagged yield difference. The lagged yield difference is significantly positive for all regressions reflecting the fact that there is a high degree of persistence in the yield differences.

So far, we did not consider any effects due to a asynchronous taxation of Treasury notes and STRIPS. As derived in Section II.3, the yield difference $Y^C - r$ should increase with the market discount of a note if taxes play a role. Therefore, we include the market discount in our analysis. It is measured as the amount of discount for each note assuming a face value of USD 100, $100 - P^{Note}$, and zero otherwise. First, we test whether the discount may fully explain the observed yield differences. Next, we insert the discount as a variable into the liquidity regression above to control for potential tax effects. Panel B of Table 3 shows that the market discount has a significant positive effect when being considered as

[30]This argument is also supported by the fact that Bloomberg's indicative bid-ask spread for notes relative to STRIPS is increasing when they age.

single explanatory variable. The adjusted R^2, however, shows that this variable hardly explains any variation of the yield differences. Including the lagged variable, the parameter of the market discount is no longer significant. These findings suggest that taxation does not have any impact on the observed yield differences. Next, we include the market discount as a control variable into the liquidity regression. Compared to regression (2) and (4) of Panel A we observe that the results do not substantially change. Hence, the liquidity effect remains stable even though controlling for potential tax effects.

To further validate this conclusion, we also have analyzed the impact of various variables related to the taxation of a Treasury note or STRIPS (not reported here). The inclusion of a simple dummy variable for market discounts neither has the expected sign nor does it improve the regression results. A correction of the market discount for the time to maturity, i.e. $\frac{DISCOUNT}{T-t}$, leads to a significant negative parameter that is not in line with our theoretical effect. Including time to maturity, however, may distort the accuracy of the econometric analysis since it is negatively correlated with the liquidity proxies and the age. The inclusion of similar variables for Treasury notes above par does not significantly improve results either. Therefore, we conclude that tax effects do not have an influence on the yield differences between coupon STRIPS and Treasury notes.

To further verify our results, we additionally control for the well-known on-the-run effect by including a dummy variable. As expected, Panel C of Table 3 shows that the yield differences are significantly larger if the corresponding Treasury note is trading on-the-run. Compared to the regressions in Panel A, however, the results for the liquidity proxies do not change substantially and the adjusted R^2 hardly improves. Therefore, the on-the-run effect seems to be of minor importance. The differences in the liquidity proxies can, however, to a substantial extend explain the term structure of the yield differences between coupon STRIPS and Treasury notes.

III.2 Principal STRIPS Yields vs. Theoretical Yields

In this section, we investigate the differences between the yields of principal STRIPS and the theoretical yields, $y^P - r$. The results are computed and illustrated in the same manner as the results in the previous section and displayed in Table 4. Comparing this table with Table 2, it is striking that the yield differences $y^P - r$ do not show any clear maturity dependence. Except for the longest maturity, the principal STRIPS yield is slightly lower than the theoretical yield whenever the difference is significant. With two exceptions the absolute difference is below 2 bp and not significant when transaction costs are considered. Hence, taking transaction costs into account, principal STRIPS can be regarded as being priced in line with Treasury notes.

At first glance, the high yield premium for principal STRIPS with a time to maturity of about ten years seems to be an outlier compared to the results for other maturity bins. An in-depth analysis of our data reveals the following explanation. For the ten year maturity bin we only have two principal STRIPS in our data set. These are the principal STRIPS of the ten-year notes with maturities in August 2016 and February 2017, respectively. In the first three month after issuance of the notes only 0.007% of the former was held in stripped form and the latter has even never been stripped. Hence, hardly any trade has been executed and the yield quotes seem to reflect a high liquidity premium. This premium is significantly higher regarding the latter principal STRIPS. This security, however, was definitely illiquid because it did not (yet) "exist".

As in Section III.1, we formally test the relationship between the obtained yield differences and liquidity proxies. Accordingly, we use the stripping activity of a principal STRIPS SA^P, its outstanding amount OA^P, and the age as explanatory variables. Table 5 shows that, in contrast to the results for coupon STRIPS, we find no significant relationship between the yield differences and the liquidity proxies. Only the lagged yield difference is significantly positive for all regressions. The coefficient, however, is relatively small and reflects a low degree of persistence in the yield differences. Moreover, the adjusted R^2 is relatively small for all regressions.

We further include the market discount in our analysis to control for potential tax effects. In an univariate regression the discount variable has a significantly negative impact at the 10% level. The adjusted R^2, however, is negligible. Including the lagged variable, the impact of the discount becomes insignificant. By regressing the yield differences on both the taxation and liquidity variables, we test the possibility that both effect cancel out each other. The results clearly neglect this conjecture as all parameters are statistically insignificant. Our findings do not considerably change when controlling for the on-the-run effect. Panel C, however, shows that the theoretical yield is significantly lower than the principal STRIPS yield if the note is trading on-the-run. As the most recently issued notes mainly have a time to maturity of about ten years, this result is in line with the high yield premium for maturity bin 10.0. In summary, the regression results support the findings presented in Table 4, and we conclude that, aside from the longest maturity bin, principal STRIPS are on average priced in line with the theoretical yields.

This result is surprising and it allows for three preliminary conclusions. First, differences in the taxation of Treasury notes and principal STRIPS do not result in systematic yield differences. Second, there are no systematic differences in the liquidity premia between the principal STRIPS and the coupon Treasury market. Third, principal STRIPS are priced in line with Treasury notes, suggesting that the unique reconstitution feature drives the relationship. These conclusions will be tested in the next section. There, we explicitly control for tax effects by comparing the yields of coupon and principal STRIPS.

Our analysis, however, cannot explain that, except for maturity bin 10.0, the mean yield differences are slightly negative whenever significant. An important difference is that principal STRIPS can be traded directly whereas a theoretical zero bond obtained via bootstrapping notes cannot. To receive such cash flows with notes one has to shorten the corresponding notes with lower maturities, leading to additional shorting costs. The slightly lower yield for principal STRIPS may reflect these cost.

III.3 Coupon STRIPS vs. Principal STRIPS

Matched-maturity coupon and principal STRIPS provide exactly the same cash flows at maturity. Tax differences between these two types of STRIPS do not exist and, therefore, should have no impact on yields. Due to a different liquidity, however, they may actually trade at different prices. Moreover, principal STRIPS are unique in terms of their reconstitution feature. If this feature would be the only determinant for yield differences, the coupon STRIPS should show larger yields than principal STRIPS. If liquidity effects are the only reason for yield differences, we expect larger yields of coupon STRIPS for long maturities and vice versa for short maturities.

Table 6 displays the results of the differences between the observed yields of coupon STRIPS, y^C, and of principal STRIPS, y^P. In contrast to the finding of Daves and Ehrhardt (1993) that, in general, coupon STRIPS trade at a yield premium relative to principal STRIPS, we find that principal STRIPS trade at a significantly higher yield for maturities up to three years.[31] This table is directly comparable with Table 2 and shows striking similarities: First, the means and medians are, with one exception, significant different from zero. Second, they tend do increase with time to maturity and change their sign between the maturity bins of 5 and 5.5 years. Third, including transaction costs, for maturities larger than seven years we observe that y^C_{ask} is on average significantly greater than y^P_{bid}. Since we have found previously that principal STRIPS are usually priced according to the theoretical yields, the liquidity premia between coupon STRIPS and Treasury notes seem to just pass through.

Similar to the previous sections, we formally test the relationship between the observed yield differences and liquidity proxies. Since the endogenous variable is the difference between coupon and principal STRIPS yields, we now use the difference of the stripping activities, $SA^C - SA^P$, and the difference of the outstanding amounts, $OA^C - OA^P$, as explanatory variables. Furthermore, we include the age of the principal STRIPS which coincides with the age of the underlying note. Panel A of Table 7 presents the four regression results which differ by the inclusion of the age variable and of the lagged yield differences. As expected, a significantly negative relation between the yield differences and the difference in the stripping activity exists. The coefficient of the difference in the outstanding amount is not significant in regression (4) when considering all explanatory variables. Hence, the positive effect in regressions (1)-(3) seem to be driven by the other factors. The age has a significantly negative impact. This effect can be reasoned by the fact that principal STRIPS tend to vanish in the investors' portfolios similar to their underlying notes whereas there are always active short-maturity coupon STRIPS in the market. The lagged yield difference is significantly positive for all regressions reflecting the fact that there is a high degree of persistence in the yield

[31] Carverhill (1995) also found a negative price premium of principal STRIPS over coupon STRIPS at short term to maturity.

differences.

In addition to these variables, we also include the theoretical yield difference $y^C - r$ as a measure for liquidity differences between the coupon STRIPS and the coupon Treasury market. Thereby, we test the conjecture that, due to the unique reconstitution feature, the liquidity differences transmit to the STRIPS market. Panel B of Table 7 shows the significantly positive impact of the liquidity difference $y^C - r$ on the observed yield differences between coupon and principal STRIPS. Comparing the adjusted R^2 from regressions (3) and (4) to regressions (5) and (6) it is striking that the liquidity difference $y^C - r$ explains even more of the variation compared to the lagged yield difference. This result is in line with the findings of Jordan et al. (2000) that yield differences between matched-maturity coupon and principal STRIPS can be explained by the richness or cheapness of the note or bond that is underlying the principal STRIPS.

In summary, these results show that the observed yield differences between coupon and principal STRIPS can be explained, at least partially, by the theoretically obtained liquidity premia between coupon STRIPS and Treasury notes. Due to the unique reconstitution feature of principal STRIPS, the liquidity premia just pass through and affect the yield differences between coupon and principal STRIPS. Direct liquidity differences between coupon and principal STRIPS are of minor importance.

III.4 Notes vs. Bonds

So far we have analyzed yield differences using only Treasury notes and their corresponding STRIPS. Jordan et al. (2000) have shown that matched-maturity principal STRIPS coming from different underlying notes and bonds may trade at different prices even if they provide exactly the same cash flows at maturity. We now investigate these yield differences and relate them to differences in the final theoretical yields of the corresponding Treasury notes and bonds. The latter differences are due to characteristics like a different outstanding amount or the on-the-run feature and should, due to the unique reconstitution feature, translate into yield differences of the corresponding principal STRIPS.

For lack of traded short-maturity Treasury bonds, we are not able to apply the exact bootstrapping procedure with Treasury bonds only. Therefore, we compute their final theoretical yields by discounting their coupon payments using the theoretical yields obtained by bootstrapping Treasury notes. The payments, however, occur at exactly the same dates so that we do not have any time distortion. Using this procedure, we are able to measure the relative richness or cheapness of a Treasury bond compared to Treasury notes accurately.

The notes examined in this section have an initial time to maturity of ten years and the bonds have an initial time to maturity of 30 years.[32] Our data allows us to analyze four matched-maturity notes and bonds and their corresponding principal STRIPS on a daily basis starting on 27 November 2006. Panel A of Table 8 shows that theoretical yields of bonds are significantly larger than theoretical yields of notes. In fact, the difference is positive for almost all observations. Surprisingly, the same finding can be observed when comparing the corresponding principal STRIPS. Furthermore, the average difference is similar for matched-maturity theoretical yields and for principal STRIPS yields and amounts to about 10 bp for maturities in 2015 and 2016 and to more than 20 bp for the maturity in 2017.

For the theoretical yields we observe the typical on-the-run phenomenon. The positive yield differences can be reasoned by the fact that notes are traded more actively than clearly off-the-run bonds which already exist for approximately 20 years. Therefore, these differences reflect a liquidity yield premium for the aged bonds. Regarding the different magnitude of the yield differences one should consider that the notes maturing in 2015 and 2016 are not most recently issued during our observation period whereas the note maturing in 2017 is trading on-the-run for a sizable fraction of our observation period. Thus, the different magnitude can be explained by a liquidity yield discount for recently issued notes.

Next, we focus on explaining the yield differences between the matched-maturity principal STRIPS corresponding to notes and bonds, respectively. There are two effects that should affect the yield differences in opposite directions. First, the principal STRIPS have a different liquidity in terms of stripping activity and outstanding amount. There is a huge amount of bonds held in stripped form and the notes are rarely stripped since they

[32]See Panel B of Table 1 for details on the bonds considered.

are recently issued.[33] Moreover, there is reasonable stripping activity for the bonds and only sparse stripping activity for the notes. This observation suggests a higher trading activity for the principal STRIPS of bonds compared to notes. Therefore, the liquidity effect should lead to a negative yield difference between principal STRIPS of bonds and principal STRIPS of notes.

Second, having the required amount of coupon STRIPS, the principal STRIPS of notes and bonds allow the owner to reconstitute a note or a bond, respectively. Hence, a specific principal STRIPS is unambiguously connected to the underlying note or bond. If the underlying bond is trading at a premium compared to a note, the principal STRIPS of a bond should also trade at a premium compared to a principal STRIPS of a note. Thus, the reconstitution effect should result in the concordance of the yield differences between the principal STRIPS and the yield differences between the underlying notes and bonds.

Our results in Panel A of Table 8 clearly indicate that the second effect is prevalent. We formally test this result by regressing the yield differences between the principal STRIPS on the yield differences between the theoretical yields. The regression results are shown in Panel B of Table 8. As already suggested by interpreting the summary statistics of the yield differences, we find a positive and highly significant relation between the observed yield differences $y^{P,bond} - y^{P,note}$ and the theoretical yield differences $r^{bond} - r^{note}$ for all pairs of notes and bonds. The estimated slope coefficient is between 0.74 and 0.89 and the adjusted R^2 is above 82%. This finding suggests that the empirically observed yield differences between matched-maturity principal STRIPS can, to a large extend, be explained by the differences of the corresponding theoretical yields. Any direct liquidity effect between the different principal STRIPS is of minor importance.

III.5 Financial Crisis and Flight-to-Liquidity

Finally, we analyze the yield differences during the period of the financial crisis. This time period is apparently related with a change in the bond market liquidity, whereas the institutional features of the stripping program as well as the taxation remains unchanged.

[33] The percentage held in stripped form of the four bonds is on average 16% and the maximum is at 36%.

Also, U.S. Treasury securities still do not contain significant default risk. Any observed difference to the previous sections should therefore be related with a different liquidity premium.

Table 9 presents the summary statistics of the yield differences for the time period after July 2007. The results do not change qualitatively compared to the pre-crisis period. Comparing Panel A to Table 2, we can still observe that y^C is significantly smaller than r for shorter maturities and vice versa for longer maturities. Considering transaction costs we find that the coupon STRIPS ask yield y^C_{ask} is significantly greater than the theoretical bid yield r_{bid} for maturities larger than three years already. Moreover, the yield differences $y^C - r$ for maturities larger than two years significantly increase compared to the pre-crisis period. This finding provides an indication that medium- and long-term coupon STRIPS are traded with a significant liquidity premium compared to notes in times of the financial crisis.[34] The two sub-samples also differ with respect to the observed volatility. As expected, for each maturity bin the standard deviation of the yield differences during the financial crisis is considerably greater than during normal market conditions. This finding suggests that a greater uncertainty in times of financial turbulence can also be seen in a higher variation of the liquidity premium.

Comparing Panel B of Table 9 with Table 4 shows that, in contrast to the results for coupon STRIPS, the absolute size of the differences between principal STRIPS and Treasury notes approximately stays the same during the financial crisis. For shorter maturities the sign changes. Again, considering transaction costs, the differences are with two exceptions not significant. For maturities larger than nine years the principal STRIPS trade at a yield discount compared to the theoretical yields, even though considering transaction costs. In the pre-crisis period, Table 4, this can also be seen for maturity bin 9.0. Practitioners usually attribute this effect to an excess demand for long-maturity principal STRIPS by retail investors.

For the observed yield difference between coupon STRIPS and principal STRIPS in Panel C, we again find the striking similarity to the differences between y^C and the theoretical yield r in Panel A. The differences are essentially the same, also during the

[34]These results are even more pronounced when investigating the subsample for the period after the beginning of 2008.

financial crisis.

When analyzing the liquidity differences between coupon STRIPS yield and theoretical yields we have already seen that they differ with regard to the chosen time period. In the pre-crisis period, yield differences are less pronounced and during the financial crisis, they are higher in absolute terms and fluctuate stronger. In such periods, flights-to-quality and flights-to-liquidity are widely observed, i.e. investors prefer to have less exposure to credit risk and to hold more liquid securities.[35] Since the U.S. Treasury market can be regarded as default-free and is one of the most liquid markets in the world, we expect a relative higher demand for Treasury securities during those periods. As liquidity differences also exist within the Treasury market, the same behavior may hold for the most liquid segments therein.

We already have argued that short-maturity coupon STRIPS can be regarded as more liquid than notes. For long maturities, notes can be considered to be more liquid than coupon STRIPS. Therefore, if a flight-to-liquidity effect exists during the financial crisis within the Treasury market, the yield differences $y^C - r$ should decrease for short maturities and increase for long maturities. To test for this effect, one ideally relates the yield differences to fund flows into the respective segments. Due to lacking data, we alternatively follow Longstaff (2004) and relate the yield differences to different market-wide variables that measure the investors' sentiment. The first of these variables is the change in the Chicago Board Options Exchange Volatility Index ΔVIX. VIX is often interpreted as "investor fear gauge."[36] Ben-Rephael et al. (2009) and Ederington and Golubeva (2009) recently find empirical evidence that flows from equity to bond funds are positively related to changes in VIX. Hence, an increase in the index may signal that investors prefer to hold less risky assets and, thus, mitigate to the most liquid Treasury securities. Therefore, the yield differences $y^C - r$ should decrease for short maturities and increase for long maturities when VIX increases. The second variable is the change of the OECD U.S. Leading Indicators Business Climate Indicator ΔBCI. A decline in the index may signal that investors are more cautious in holding risky assets. We expect that the yield differences $y^C - r$ decrease for short maturities and increase for long maturities

[35] See, e.g., Beber et al. (2009).

[36] See, e.g., Whaley (2009).

if the indicator moves downward.

Table 10 presents some summary statistics of these two explanatory variables and the results of regressing the yield differences on the first differences of VIX and BCI. As BCI is available on a monthly basis only, we use end-of-month yield differences. We consider short- and long-term maturities separately and control for potential autocorrelation of the monthly yield differences by including the lagged yield differences. Panel B of Table 10 shows the coefficient estimates. For short maturities, we find a significant negative relation between ΔVIX and $y^C - r$ and a significant positive relation between ΔBCI and $y^C - r$. For long maturities the results are vice versa. These results are consistent with the hypothesis that a movement to the more liquid segments occurs when uncertainty increases or business climate drops. The results are robust to the inclusion of the lagged yield difference. In summary, the analysis provides support for the existence of a maturity-dependent flight-to-liquidity premium between the market for coupon STRIPS and the market for Treasury notes.

IV Summary and Conclusion

In this paper we investigate matched-maturity yield differences in the U.S. Treasury market. We find significant differences by comparing the yields of coupon STRIPS with theoretical yields obtained from Treasury notes via bootstrapping. For longer maturities, coupon STRIPS trade at higher yields and for short maturities, Treasury notes trade at a premium. These differences cannot be explained by a differential taxation. We rationalize that the observed yield differences can be attributed to a different liquidity that is changing with respect to time to maturity due to the fungibility of coupon STRIPS. Moreover, the liquidity premium is increasing during the financial turmoil of 2007/2008. This premium can be related to flight-to-liquidity explanatory variables.

The results show that the fungibility of coupon STRIPS was successful to create a rather liquid market for Treasury zero bonds, primarily for maturities up to three years. In particular, this finding has been proven during the recent financial crisis. Therefore, we can conclude that short-term coupon STRIPS can be regarded as a "safe haven" with regard to credit and liquidity risk.

Even though principal STRIPS and Treasury notes clearly differ with respect to their liquidity, we cannot isolate a distinct liquidity premium between these markets. Our findings rather suggest that the uniqueness of principal STRIPS with regard to reconstitution leads the investors to price principal STRIPS in line with their corresponding Treasury notes.

We gain new insights in explaining the empirically observed yield differences between coupon and principal STRIPS as well as between principal STRIPS having the same maturity. In contrast to previous studies, our findings have made discernible that the yield differences between matched-maturity coupon and principal STRIPS can be traced back to the theoretical liquidity differences between coupon STRIPS and Treasury notes. Comparing matched-maturity principal STRIPS, the yield differences can be ascribed to the theoretical differences of the corresponding notes and bonds. Hence, the liquidity differences within the STRIPS market are of minor importance and, due to the unique reconstitution feature, any yield difference between matched-maturity STRIPS is directly affected by the corresponding theoretical yield difference.

These results are important for academics and market practitioners when considering STRIPS instead of coupon bonds in empirical studies. Sack (2000) and Steeley (2008), for example, advise to use STRIPS data for estimating zero-coupon yield curves. However, one has to decide whether to use coupon or principal STRIPS for such empirical studies. Our findings directly imply that, due to their unique link via reconstitution, principal STRIPS are the superior choice when measuring effects compared to other coupon bonds. Due to their fungibility, coupon STRIPS do not contain idiosyncratic effects of coupon bonds and are the appropriate choice for comparison with other zero bonds. Certainly, in any empirical study with STRIPS one should always consider possible distortions due to the liquidity effects shown in this paper.

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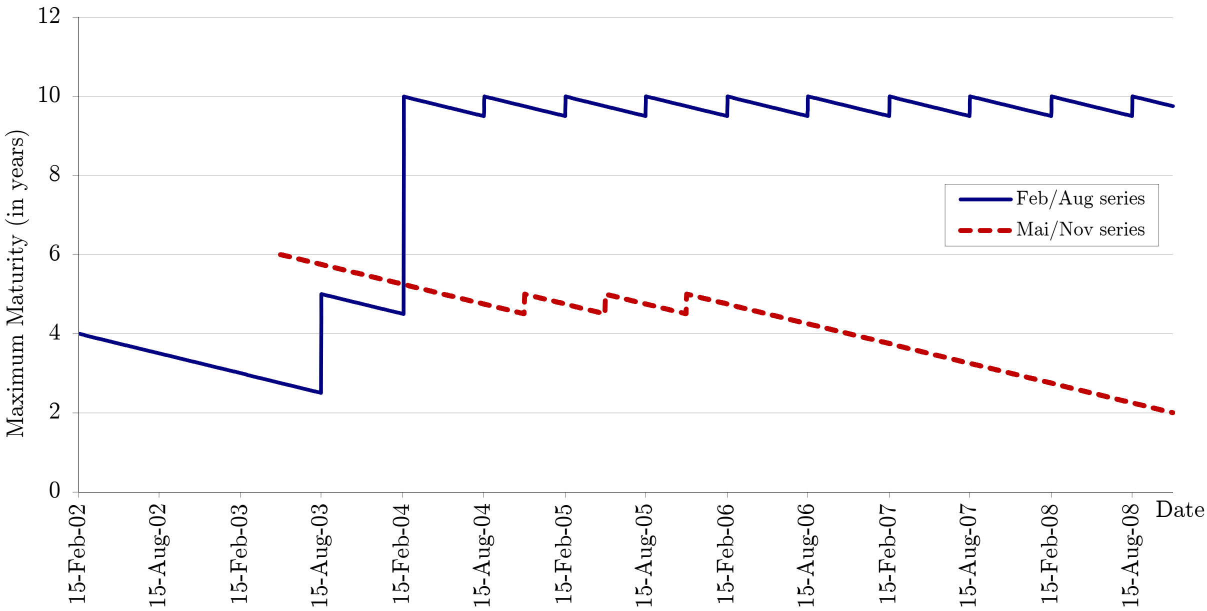

Figure 1: Maximum Maturity for Theoretical Yields obtained via Bootstrapping U.S. Treasury Notes.

Table 1: Summary Information for U.S. Treasury Notes and Bonds and U.S. Treasury STRIPS

This table shows summary information for the U.S. Treasury securities considered in our study. The total outstanding volume, the amount held in stripped form, and the stripping activity are monthly averages given in USD million. For notes and coupon STRIPS the data is averaged across the different issues. The number of daily observations is the number of observed or theoretical yields of all issues during the whole sample period from February 2002 to November 2008. The overall statistics are based on equal weights of all observations.

Notes and Principal STRIPS of Notes

Series	# Issues	Coupon	Total Outstanding	Amount Stripped	Monthly Stripping Activity	# Daily Observations Notes	# Daily Observations PSTRIPS
FebAug 3 years	8	3.625	23,507.86	270.53	30.75	5,445	2,803
FebAug 5 years	10	3.963	20,248.52	374.87	30.58	8,922	3,978
FebAug 10 years	30	5.246	22,174.71	683.35	55.09	24,604	23,074
MayNov 3 years	8	3.734	24,778.92	362.02	25.72	5,248	2,164
MayNov 5 years	15	4.342	25,759.00	647.53	60.12	11,896	5,641
MayNov 10 years	9	6.319	18,654.85	832.64	53.39	7,513	6,641
Overall	80	4.723	22,451.48	596.94	48.43	63,628	44,301

Bonds and Principal STRIPS of Bonds

Series and Coupon	Issue Date	Maturity Date	Total Outstanding	Amount Stripped	Monthly Stripping Activity	# Daily Observations Bond	# Daily Observations PSTRIPS
FebAug 11.25 %	02/15/1985	02/15/2015	10,526.79	1,792.91	392.83	1,068	1,448
FebAug 10.625 %	08/15/1985	08/15/2015	4,023.92	666.12	182.16	943	1,448
FebAug 9.25 %	02/18/1986	02/15/2016	5,433.48	293.12	157.32	813	1,448
FebAug 8.875 %	08/15/1987	08/15/2017	10,974.28	2,804.04	651.68	441	1,448
Overall			7,739.62	1,389.05	346.00	3,265	5,792

Coupon STRIPS

Series	# Issues	First Maturity	Last Maturity	Amount Stripped	Monthly Stripping Activity	# Daily Observations
FebAug	33	08/15/2002	08/15/2018	2,501.06	599.96	13,805
MayNov	15	11/15/2003	11/15/2010	3,351.41	471.28	39,281
Overall	48			2,710.32	568.29	53,205

Table 2: Coupon STRIPS Yields - Theoretical Yields ($y^C - r$)

This table shows the summary statistics for the differences between coupon STRIPS yields and theoretical yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields are tested using one-sided t-tests with Newey-West HAC standard errors. N Obs is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from February 2002 to June 2007.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N Obs	% > 0	$y^C_{bid} - r_{ask}$	$y^C_{ask} - r_{bid}$
0.5	-9.7***	10.6	-62.9	-9.0***	23.8	2,401	19.2%	-7.7***	-11.7
1.0	-7.8***	7.1	-37.5	-7.9***	20.8	2,408	12.2%	-5.8***	-9.8
1.5	-3.6***	4.2	-23.5	-3.4***	9.2	2,409	17.6%	-1.6***	-5.6
2.0	-1.9***	2.7	-13.8	-2.0***	8.6	2,409	21.5%	0.1	-3.9
2.5	-0.3*	3.3	-15.0	-0.3***	14.3	2,409	44.7%	1.7	-2.3
3.0	0.3	3.9	-14.6	0.3***	11.9	2,351	54.1%	2.3	-1.7
3.5	-0.5**	3.9	-9.8	-0.1***	10.5	2,222	49.1%	1.5	-2.5
4.0	-1.1***	4.4	-13.0	-1.6***	9.3	1,998	39.5%	0.9	-3.1
4.5	-2.2***	6.3	-18.8	-1.6***	10.2	1,811	41.2%	-0.2	-4.2
5.0	-1.5***	6.9	-20.0	-0.7***	16.5	1,445	42.1%	0.5	-3.5
5.5	1.1**	6.7	-18.5	-0.1***	21.2	1,045	48.5%	3.1	-0.9
6.0	1.6***	4.2	-6.3	0.6***	12.7	920	55.9%	3.6	-0.4
6.5	1.9***	4.1	-11.7	1.3***	12.9	852	62.7%	3.9	-0.1
7.0	3.8***	5.3	-6.6	4.9***	21.5	852	70.0%	5.8	1.8***
7.5	5.0***	3.6	-2.7	5.5***	15.4	852	89.4%	7.0	3.0***
8.0	6.6***	3.4	-1.2	6.8***	15.1	852	99.1%	8.6	4.6***
8.5	8.4***	3.9	0.5	8.3***	18.0	852	100.0%	10.4	6.4***
9.0	8.8***	3.6	2.0	8.7***	18.3	852	100.0%	10.8	6.8***
9.5	10.2***	3.7	3.6	9.6***	24.6	852	100.0%	12.2	8.2***
10.0	13.7***	4.1	5.9	13.6***	22.1	464	100.0%	15.7	11.7***
Overall	-0.7	7.9	-62.9	-0.5	56.2	31,236	46.1%	1.3	-2.7

Table 3: Regression Results of Explanatory Variables for Differences between Coupon STRIPS Yields and Theoretical Yields

This table reports the estimated coefficients and the t-statistics from the regression of the difference between coupon STRIPS yields and theoretical yields with the same time to maturity. The specific model is:

$$y_t^C(T) - r_t(T) = \beta_0 + \beta_1 \cdot SA_t^C(T) + \beta_2 \cdot OA_t^C(T) + \beta_3 \cdot AGE + \beta_4 \cdot DISCOUNT + \beta_5 \cdot OTR + \rho \cdot (y_{t-1}^C(T) - r_{t-1}(T)) + \varepsilon_t$$

The yield differences are calculated in basis points and the stripping activity SA^C as well as the outstanding amount OA^C are denoted in billion USD. AGE is given in years, $DISCOUNT$ in USD. OTR equals one if the note is on-the-run, and zero otherwise. The t-statistic is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N Obs is the number of monthly observations. The sample consists of monthly observations from February 2002 to June 2007.

PANEL A: Liquidity

Reg.	β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	β_5	t-stat	ρ	t-stat	N Obs	Adj. R^2
(1)	21.78	13.9***	-5.49	-10.5***	-6.82	-13.9***	–		–		–		–		2,376	0.144
(2)	22.22	14.4***	-5.72	-11.1***	-6.20	-12.9***	-0.53	-7.4***	–		–		–		2,376	0.182
(3)	4.50	3.9***	-1.34	-4.3***	-1.46	-4.0***	–		–		–		0.76	24.8***	2,310	0.582
(4)	4.87	4.1***	-1.46	-4.5***	-1.41	-3.9***	-0.11	-2.6**	–		–		0.74	23.9***	2,310	0.584

PANEL B: Taxation and Liquidity

Reg.	β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	β_5	t-stat	ρ	t-stat	N Obs	Adj. R^2
(5)	-2.00	-7.9***	–		–		–		0.27	2.2**	–		–		2,376	0.002
(6)	-0.58	-4.8**	–		–		–		0.00	0.0	–		0.79	30.0***	2,310	0.576
(7)	22.57	14.3***	-5.58	-10.4***	-6.25	-12.9***	-0.56	-7.3***	-0.17	-1.4	–		–		2,376	0.183
(8)	5.05	4.2***	-1.39	-4.2***	-1.44	-4.0***	-0.13	-2.7***	-0.08	-1.4	–		0.74	23.9***	2,310	0.584

PANEL C: On-the-run Effect and Liquidity

Reg.	β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	β_5	t-stat	ρ	t-stat	N Obs	Adj. R^2
(9)	21.16	13.8***	-5.42	-10.4***	-6.68	-13.8***	–		–		4.78	5.5***	–		2,376	0.156
(10)	21.81	14.2***	-5.66	-11.0***	-6.16	-12.9***	-0.49	-6.6***	–		2.87	3.2***	–		2,376	0.186
(11)	4.46	3.9***	-1.35	-4.3***	-1.45	-4.0***	–		–		1.57	4.1***	0.75	24.4***	2,310	0.583
(12)	4.81	4.0***	-1.46	-4.5***	-1.41	-3.9***	-0.10	-2.3**	–		1.22	3.1***	0.74	23.7***	2,310	0.584

Table 4: Principal STRIPS Yields - Theoretical Yields (y^P - r)

This table shows the summary statistics for the differences between principal STRIPS yields and theoretical yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields are tested using one-sided t-tests with Newey-West HAC standard errors. N Obs is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from February 2002 to June 2007.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N Obs	% > 0	$y^P_{bid} - r_{ask}$	$y^P_{ask} - r_{bid}$
0.5	-0.3	5.5	-41.5	-0.3***	27.0	1,892	47.1%	1.7	-2.3
1.0	-1.6***	6.6	-32.3	-0.5***	18.0	1,902	42.7%	0.4	-3.6
1.5	-1.2***	6.0	-32.1	0.0***	11.4	1,963	49.5%	0.8	-3.2
2.0	-0.5***	3.2	-35.5	-0.1***	6.6	2,004	47.3%	1.5	-2.5
2.5	0.1	2.1	-18.2	0.2***	14.2	2,042	54.9%	2.1	-1.9
3.0	0.1	2.2	-19.6	0.2***	16.7	1,965	56.2%	2.1	-1.9
3.5	-0.5***	2.4	-12.7	0.0***	8.5	1,894	48.6%	1.5	-2.5
4.0	0.0	2.3	-10.0	0.1	23.8	1,714	54.0%	2.0	-2.0
4.5	-0.1	3.7	-32.8	0.2***	25.9	1,493	56.4%	1.9	-2.1
5.0	-0.6***	3.4	-22.8	0.0**	19.9	1,275	50.7%	1.4	-2.6
5.5	-0.9***	3.0	-13.7	-0.1***	16.0	1,045	48.0%	1.1	-2.9
6.0	-1.9***	5.7	-34.6	0.1***	41.6	920	53.8%	0.1	-3.9
6.5	-1.2***	5.8	-26.2	-0.1***	41.3	852	48.8%	0.8	-3.2
7.0	-0.3	4.4	-10.4	-0.1***	41.5	852	47.4%	1.7	-2.3
7.5	-1.8***	7.5	-44.1	-0.3***	55.3	851	45.8%	0.2	-3.8
8.0	-1.6***	4.9	-26.6	-1.1***	40.2	845	36.4%	0.4	-3.6
8.5	-1.7***	5.5	-36.1	-1.7***	37.3	716	29.5%	0.3	-3.7
9.0	-5.4***	11.7	-66.7	-1.3***	14.3	533	30.6%	-3.4***	-7.4
9.5	-1.3	14.5	-50.4	4.3	14.0	268	59.7%	0.7	-3.3
10.0	10.0***	8.6	-2.7	9.2***	31.1	116	87.1%	12.0	8.0***
Overall	-0.6	5.4	-66.7	0.0	55.3	25,910	49.4	1.4	-2.6

Table 5: Regression Results of Explanatory Variables for Differences between Principal STRIPS Yields and Theoretical Yields

This table reports the estimated coefficients and the t-statistics from the regression of the difference between principal STRIPS yields and theoretical yields with the same time to maturity. The specific model is:

$$y_t^P(T) - r_t(T) = \beta_0 + \beta_1 \cdot SA_t^P(T) + \beta_2 \cdot OA_t^P(T) + \beta_3 \cdot AGE + \beta_4 \cdot DISCOUNT + \beta_5 \cdot OTR + \rho \cdot (y_{t-1}^P(T) - r_{t-1}(T)) + \varepsilon_t$$

The yield differences are calculated in basis points and the stripping activity SA^P as well as the outstanding amount OA^P are denoted in billion USD. AGE is given in years, $DISCOUNT$ in USD. OTR equals one if the note is on the run, and zero otherwise. The t-statistic is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N Obs is the number of monthly observations. The sample consists of monthly observations from February 2002 to June 2007.

PANEL A: Liquidity

Reg.	β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	β_5	t-stat	ρ	t-stat	N Obs	Adj. R^2
(1)	-0.52	-2.0**	1.88	0.9	0.25	1.0	–		–		–		–		1,399	0.004
(2)	-0.76	-1.9*	1.99	1.0	0.08	0.3	0.08	1.2	–		–		–		1,399	0.004
(3)	-0.31	-1.7*	1.92	0.9	0.11	0.5	–		–		–		0.42	6.4***	1,333	0.155
(4)	-0.49	-1.8*	2.01	0.9	-0.00	-0.0	0.05	1.2	–		–		0.42	6.5***	1,333	0.155

PANEL B: Taxation and Liquidity

Reg.	β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	β_5	t-stat	ρ	t-stat	N Obs	Adj. R^2
(5)	-0.07	-0.4	–		–		–		-0.14	-1.7*	–		–		1,399	0.001
(6)	-0.04	-0.3	–		–		–		-0.05	-0.8	–		0.42	6.4***	1,333	0.153
(7)	-0.65	-1.2	2.00	1.0	0.09	0.4	0.06	0.8	-0.06	-0.5	–		–		1,399	0.004
(8)	-0.51	-1.4	2.01	0.9	-0.00	-0.0	0.06	1.0	0.01	0.2	–		0.42	6.5***	1,333	0.155

PANEL C: On-the-run Effect and Liquidity

Reg.	β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	β_5	t-stat	ρ	t-stat	N Obs	Adj. R^2
(9)	-0.64	-2.5**	1.70	0.8	0.33	1.3	–		–		5.89	2.6**	–		1,399	0.019
(10)	-1.03	-2.6**	1.85	0.9	0.08	0.3	0.12	1.9*	–		6.27	2.7***	–		1,399	0.021
(11)	-0.34	-1.8*	1.88	0.8	0.13	0.5	–		–		2.34	2.3**	0.41	6.2***	1,333	0.156
(12)	-0.56	-2.0**	1.98	0.9	-0.00	-0.0	0.06	1.4	–		2.56	2.6**	0.41	6.2***	1,333	0.157

Table 6: Coupon STRIPS Yields - Principal STRIPS Yields ($y^C - y^P$)

This table shows the summary statistics for the yield differences between coupon and principal STRIPS in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields are tested using one-sided t-tests with Newey-West HAC standard errors. N Obs is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from February 2002 to June 2007.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N Obs	% > 0	$y^C_{bid} - y^P_{ask}$	$y^C_{ask} - y^P_{bid}$
0.5	-9.3***	10.2	-66.6	-9.8***	38.2	1,892	22.5%	-7.3***	-11.3
1.0	-6.5***	8.2	-31.9	-6.1***	21.5	1,901	18.9%	-4.5***	-8.5
1.5	-2.3***	6.3	-20.2	-2.2***	21.6	1,963	26.7%	-0.3	-4.3
2.0	-1.6***	3.8	-12.3	-1.6***	33.5	2,004	25.9%	0.4	-3.6
2.5	-1.0***	3.2	-15.5	-0.4***	15.3	2,042	37.4%	1.0	-3.0
3.0	-0.5**	4.1	-17.2	-0.2***	18.1	1,965	46.8%	1.5	-2.5
3.5	0.0	4.2	-10.3	0.5	9.8	1,952	55.5%	2.0	-2.0
4.0	-1.0***	4.9	-17.7	-1.5***	10.1	1,836	42.6%	1.0	-3.0
4.5	-2.6***	7.5	-21.7	-2.8***	42.6	1,615	33.4%	-0.6*	-4.6
5.0	-1.3***	7.2	-19.1	-0.7***	17.4	1,339	38.5%	0.7	-3.3
5.5	2.1***	7.4	-18.7	0.2***	28.8	1,104	51.3%	4.1	0.1
6.0	3.2***	7.4	-30.2	0.8***	40.1	1,104	54.3%	5.2	1.2**
6.5	3.3***	7.3	-35.5	1.5***	33.1	1,078	59.0%	5.3	1.3***
7.0	4.3***	6.9	-32.3	5.3***	27.8	1,087	65.8%	6.3	2.3***
7.5	7.3***	9.1	-49.7	7.2***	51.0	1,043	82.4%	9.3	5.3***
8.0	8.4***	6.7	-31.8	10.5***	33.4	1,068	92.7%	10.4	6.4***
8.5	11.1***	7.7	-24.3	11.2***	54.1	904	97.2%	13.1	9.1***
9.0	14.9***	12.8	-11.2	11.1***	82.8	716	98.2%	16.9	12.9***
9.5	13.6***	15.9	-9.6	11.0***	65.3	382	73.6%	15.6	11.6***
10.0	7.4***	14.7	-22.7	5.5***	44.0	173	69.9%	9.4	5.4**
Overall	0.1	9.1	-66.6	-0.3	82.8	27,940	46.4%	2.1	-1.9

Table 7: Regression Results of Explanatory Variables for Yield Differences between Coupon STRIPS and Principal STRIPS

This table reports the estimated coefficients and the t-statistics from the regression of the difference between coupon STRIPS and principal STRIPS yields with the same time to maturity. The specific model is:

$$y_t^C(T) - y_t^P(T) = \beta_0 + \beta_1 \cdot (SA_t^C(T) - SA_t^P(T)) + \beta_2 \cdot (OA_t^C(T) - OA_t^P(T)) + \beta_3 \cdot AGE + \beta_4 \cdot (y_t^C(T) - r_t(T)) + \rho \cdot (y_{t-1}^C(T) - y_{t-1}^P(T)) + \varepsilon_t$$

The yield differences are calculated in basis points and the stripping activity SA as well as the outstanding amount OA are denoted in billion USD. AGE is given in years. The t-statistic is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N Obs is the number of monthly observations. The sample consists of monthly observations from February 2002 to June 2007.

PANEL A: STRIPS Liquidity Variables

Reg.	β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	ρ	t-stat	N Obs	Adj. R^2
(1)	-5.09	-5.4***	-4.85	-6.8***	3.32	8.9***	–		–		–		1,497	0.142
(2)	1.14	0.8	-5.77	-7.6***	2.10	5.4***	-0.67	-6.0***	–		–		1,497	0.173
(3)	-0.71	-1.5	-1.29	-3.9***	0.48	2.6***	–		–		0.79	34.1***	1,428	0.659
(4)	0.55	0.8	-1.52	-4.2***	0.27	1.4	-0.14	-2.6***	–		0.79	33.1***	1,428	0.660

PANEL B: STRIPS Liquidity Variables and Theoretical Yield Differences

Reg.	β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	ρ	t-stat	N Obs	Adj. R^2
(5)	-0.56	-1.0	-1.32	-3.9***	0.64	2.9***	–		0.87	21.5***	–		1,399	0.685
(6)	1.19	1.5	-1.64	-4.3***	0.32	1.6	-0.19	-2.6***	0.87	21.3***	–		1,399	0.687
(7)	0.40	1.1	-0.56	-2.8***	-0.05	-0.4	–		0.53	10.2***	0.48	11.2***	1,343	0.811
(8)	1.03	2.1**	-0.68	-3.0***	-0.16	-1.2	-0.07	-1.6***	0.53	10.3***	0.48	11.3***	1,343	0.811

Table 8: Statistics and Results for Differences of Matched-Maturity Principal STRIPS

PANEL A: Yield Differences between Principal STRIPS and Yield Differences between Theoretical yields (Same Maturity)

This table shows the summary statistics for the differences between principal STRIPS yields from matched-maturity notes and bonds as well as the differences between the corresponding theoretical yields. The notes have an initial time to maturity of ten years whereas the bonds have an initial time to maturity of 30 years. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median is assessed by a non-parametric Wilcoxon signed-rank test. N Obs is the number of daily observations. The sample consists of daily observations from November 2006 to November 2008.

Yields Bonds - Yields Notes (in basis points) **Sample: 11/27/06 - 11/13/08**

Maturity		Mean	Std. Dev.	Min.	Median	Max.	N Obs	% > 0
02/15/2015	PSTRIPS	11.7***	13.5	-0.9	9.0***	88.9	483	97.1%
	theoretical	13.6***	14.9	0.1	10.8***	102.4	483	100.0%
08/15/2015	PSTRIPS	9.1***	9.9	-4.5	6.1***	69.5	476	98.9%
	theoretical	10.5***	11.6	-2.0	7.5***	78.3	476	97.1%
02/15/2016	PSTRIPS	9.0***	7.3	0.6	6.9***	66.7	480	100.0%
	theoretical	9.5***	8.8	0.6	7.4***	78.4	480	100.0%
08/15/2017	PSTRIPS	20.9***	10.2	2.4	20.4***	84.7	306	100.0%
	theoretical	23.7***	10.8	11.8	23.1***	86.0	306	100.0%

PANEL B: Regression Results for Differences between Principal STRIPS Yields on Differences between Theoretical Yields

This table reports the coefficient estimates and the t-statistics from the regression of the yield difference between matched-maturity principal STRIPS on the corresponding difference between theoretical yields. The specific model is:

$$y_t^{P,bond}(T) - y_t^{P,note}(T) = \beta_0 + \beta_1 \cdot (r_t^{bond}(T) - r_t^{note}(T)) + \varepsilon_t$$

The yield differences are calculated in basis points. The t-statistic is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N Obs is the number of daily observations. The sample consists of daily observations from November 2006 to November 2008.

Sample: 11/27/06 - 11/13/08

Maturity	β_0	t-stat	β_1	t-stat	N Obs	Adj. R^2
02/15/2015	-0.3723	-1.98**	0.8875	60.55***	483	0.958
08/15/2015	0.6007	3.60***	0.8048	41.25***	476	0.902
02/15/2016	1.9519	7.58***	0.7485	28.14***	480	0.823
08/15/2017	0.4024	0.62	0.8649	31.59***	306	0.833
Pooled	0.5605	3.52***	0.8438	66.07***	1,745	0.916

Table 9: Yield Differences during the Financial Crisis

This table shows the summary statistics for the yield differences $Y^C - r$ (Panel A), $Y^P - r$ (Panel B), and $Y^C - Y^P$ (Panel C) in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields are tested using one-sided t-tests with Newey-West HAC standard errors. N Obs is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from July 2007 to November 2008.

PANEL A: Coupon STRIPS Yields - Theoretical Yields ($Y^C - r$)

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N Obs	% > 0	$y^C_{bid} - r_{ask}$	$y^C_{ask} - r_{bid}$
0.5	-14.4***	22.9	-101.9	-15.6***	42.6	686	22.7%	-12.4***	-16.4
1.0	-12.0***	14.1	-46.4	-11.6***	30.5	686	19.1%	-10.0***	-14.0
1.5	-4.2***	7.3	-25.7	-3.3***	15.2	686	30.5%	-2.2***	-6.2
2.0	-2.6***	6.1	-14.0	-3.8***	19.7	686	24.3%	-0.6	-4.6
2.5	2.1**	9.0	-13.5	1.8***	37.4	625	59.7%	4.1	0.1
3.0	5.0***	9.3	-12.1	1.1***	42.1	500	55.0%	7.0	3.0***
3.5	5.6***	10.3	-9.0	5.2***	52.8	375	72.5%	7.6	3.6***
4.0	11.2***	13.6	-10.5	12.1***	62.5	343	77.8%	13.2	9.2***
4.5	5.8***	6.8	-3.9	5.3***	41.9	343	86.0%	7.8	3.8***
5.0	4.2***	4.3	-7.2	4.9***	12.3	343	82.2%	6.2	2.2***
5.5	5.8***	6.4	-6.2	4.7***	21.7	343	74.6%	7.8	3.8***
6.0	9.5***	8.3	-6.9	11.4***	31.2	343	75.2%	11.5	7.5***
6.5	15.8***	17.1	-0.4	11.8***	91.8	343	99.4%	17.8	13.8***
7.0	14.6***	12.9	-2.2	14.2***	74.8	343	95.9%	16.6	12.6***
7.5	13.6***	9.4	1.8	12.3***	70.5	343	100.0%	15.6	11.6***
8.0	12.8***	8.4	0.3	12.8***	56.4	343	100.0%	14.8	10.8***
8.5	14.0***	11.2	1.9	9.3***	63.8	343	100.0%	16.0	12.0***
9.0	16.5***	12.8	0.8	18.1***	72.4	343	100.0%	18.5	14.5***
9.5	20.7***	14.7	3.6	16.3***	86.8	343	100.0%	22.7	18.7***
10.0	28.6***	14.7	9.9	29.2***	76.6	207	100.0%	30.6	26.6***
Overall	4.5	16.4	-101.9	4.5	96.2	8,848	64.3%	6.5	2.5

Table 9 continued.

PANEL B: Principal STRIPS Yields - Theoretical Yields $(Y^P - r)$

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N Obs	% > 0	$y^P_{bid} - r_{ask}$	$y^P_{ask} - r_{bid}$
0.5	0.4	7.2	-81.7	0.8***	27.4	682	60.9%	2.4	-1.6
1.0	1.2***	3.0	-12.9	1.2***	16.5	685	67.3%	3.2	-0.8
1.5	0.8***	3.6	-29.6	0.9***	10.8	686	67.6%	2.8	-1.2
2.0	0.7***	2.6	-13.6	0.7***	13.1	686	64.0%	2.7	-1.3
2.5	0.6***	2.6	-9.8	0.6***	16.8	625	62.2%	2.6	-1.4
3.0	0.5***	2.4	-9.8	0.5***	13.7	500	59.4%	2.5	-1.5
3.5	0.4***	2.0	-7.0	0.5***	9.3	375	58.1%	2.4	-1.6
4.0	0.0	2.0	-7.0	0.1	6.5	343	52.5%	2.0	-2.0
4.5	-0.3**	2.3	-12.0	-0.1**	14.4	343	46.9%	1.7	-2.3
5.0	-0.3**	2.2	-13.0	-0.2**	11.5	343	44.6%	1.7	-2.3
5.5	-0.3*	1.9	-8.5	-0.1**	9.7	343	46.1%	1.7	-2.3
6.0	0.2	2.9	-9.0	0.1	16.4	343	53.4%	2.2	-1.8
6.5	0.4*	3.3	-15.1	0.3***	14.8	337	57.0%	2.4	-1.6
7.0	-0.1	3.1	-19.4	0.3*	14.0	335	57.6%	1.9	-2.1
7.5	-0.2	3.0	-19.4	0.2	8.6	333	54.7%	1.8	-2.2
8.0	-1.2***	2.7	-17.9	-1.0***	6.6	341	34.9%	0.8	-3.2
8.5	-2.0***	2.4	-14.7	-1.8***	6.5	343	17.8%	0.0	-4.0
9.0	-4.6***	7.4	-37.5	-3.1***	17.9	205	10.2%	-2.6***	-6.6
9.5	-2.3***	3.6	-20.4	-2.5***	16.1	258	17.4%	-0.3	-4.3
10.0	-4.0***	7.6	-43.5	-2.6***	18.1	200	14.5%	-2.0**	-6.0
Overall	0.1	4.7	-81.7	0.2	74.1	8,583	53.0%	2.1	-1.9

Table 9 continued.

PANEL C: Coupon STRIPS Yields - Principal STRIPS Yields $(Y^C - Y^P)$

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N Obs	% > 0	$y^C_{bid} - y^P_{ask}$	$y^C_{ask} - y^P_{bid}$
0.5	-14.7***	22.8	-104.4	-16.1***	40.1	682	21.7%	-12.7***	-16.7
1.0	-13.2***	14.2	-49.9	-11.7***	28.8	685	17.1%	-11.2***	-15.2
1.5	-5.0***	7.6	-38.1	-4.5***	24.6	686	25.1%	-3.0***	-7.0
2.0	-3.3***	6.4	-21.7	-4.7***	19.3	686	21.1%	-1.3***	-5.3
2.5	1.4*	9.0	-13.9	1.5***	44.9	625	57.9%	3.4	-0.6
3.0	4.5***	9.2	-12.7	0.7***	43.0	500	53.2%	6.5	2.5***
3.5	5.2***	10.7	-11.8	4.7***	55.0	375	69.3%	7.2	3.2***
4.0	11.2***	13.9	-13.8	12.6***	66.5	343	77.6%	13.2	9.2***
4.5	6.1***	7.2	-10.4	5.5***	42.9	343	83.4%	8.1	4.1***
5.0	4.5***	5.0	-8.6	5.2***	17.7	343	79.9%	6.5	2.5***
5.5	6.1***	7.0	-9.5	5.3***	25.7	343	73.5%	8.1	4.1***
6.0	9.3***	8.9	-7.2	11.4***	35.0	343	72.6%	11.3	7.3***
6.5	14.3***	16.3	-1.6	10.5***	92.2	337	97.0%	16.3	12.3***
7.0	13.7***	12.5	-3.5	13.1***	79.0	335	93.7%	15.7	11.7***
7.5	13.0***	9.4	-0.3	11.8***	76.6	333	99.4%	15.0	11.0***
8.0	14.0***	10.1	-1.0	13.7***	67.5	341	98.8%	16.0	12.0***
8.5	16.0***	12.9	1.2	11.1***	77.8	343	100.0%	18.0	14.0***
9.0	26.8***	13.0	3.2	25.6***	80.7	205	100.0%	28.8	24.8***
9.5	27.4***	15.9	2.8	27.8***	93.9	258	100.0%	29.4	25.4***
10.0	32.2***	18.6	9.7	31.9***	100.1	200	100.0%	34.2	30.2***
Overall	4.2	17.3	-104.4	3.6	100.1	8,583	61.0%	6.2	2.2

Table 10: Regression of Liquidity Premia on Flight-to-Liquidity Explanatory Variables

This table reports the summary statistics of the explanatory variables (Panel A) and the estimated coefficients for the regression (Panel B) of the yield difference between coupon STRIPS and theoretical yields against flight-to-liquidity proxies. The variable ΔVIX is the monthly change in the Chicago Board Options Exchange Volatility Index measured in basis points. The variable ΔBCI is the monthly change in the OECD US Leading Indicators Business Climate Indicator. The specific regression model is:

$$y_t^C - r_t = \beta_0 + \beta_1 \cdot \Delta VIX_t + \beta_2 \cdot \Delta BCI_t + \rho \cdot (y_{t-1}^C - r_{t-1}) + \varepsilon_t$$

The yield differences are calculated in basis points. The t-statistic is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N Obs is the number of monthly observations. The data is obtained via Bloomberg. The sample consists of monthly observations from February 2002 to November 2008.

PANEL A: Summary Statistics for Explanatory Variables

Variable	Mean	Std. Dev.	Minimum	Median	Maximum	ρ	N Obs
ΔVIX	0.48	4.36	-8.55	-0.26	20.50	0.09	80
ΔBCI	0.00	0.02	-0.06	0.00	0.04	0.08	80

PANEL B: Regression Results **Sample: 02/15/02 - 11/13/08**

Mat. Bins	β_0	t-stat	β_1	t-stat	β_2	t-stat	ρ	t-stat	N Obs	Adj. R^2
0.5-1.5	-7.5035	-13.03***	-0.4872	-2.59***	127.40	4.26***	–		435	0.113
0.5-1.5	-3.0543	-5.88***	-0.2712	-2.10**	81.53	3.26***	0.5951	11.95***	435	0.419
7.0-10.0	9.2761	18.83***	0.8678	4.53***	-100.86	-4.92***	–		372	0.267
7.0-10.0	-0.3625	-0.87	0.6232	5.75***	-41.57	-3.05***	1.0473	23.15***	356	0.780