The Muni Bond Spread: Credit, Liquidity, and Tax*

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Abstract

Municipal (muni) bonds are risky and trade in illiquid markets, and both effects serve to raise muni yields relative to Treasuries. On the other hand, the tax exemption of muni bonds tends to lower their yields. We decompose the muni yield spread into credit, liquidity, and tax components. Before 2008, muni yields are reliably lower than Treasuries. After the 2008 financial crisis, the muni-Treasury spread flips sign to, on average, 0.87%, comprising credit, liquidity, and tax components of 0.57%, 2.14%, and -1.84%, respectively. Muni credit and liquidity components exhibit strong covariation with credit and liquidity factors prevailing in other asset classes.

1 Introduction

With \$3.7 trillion issues outstanding at the end of 2013, and approximately \$370 billion in new issuance each year, the municipal (muni) bond market is large, essential for local and state governments to invest in public assets such as roads and schools, and an important savings vehicle for millions of Americans.[1] The size of the muni market is approximately one-third of the U.S. Treasury market, but it differs in important ways: muni bonds carry credit risk, they are far more illiquid, and munis are exempt from Federal income tax. Changing muni spreads (muni yields minus Treasury yields) over time must reflect variation in one, two, or all three of these components.

We decompose the muni spread into credit, liquidity, and tax components. We measure the credit risk component by using the discount rates of munis that are secured by Treasuries. These munis are called prerefunded (also known as advance refunded or defeased), and they are created by municipalities pre-committing to the early exercise of an existing bond and issuing a new bond. Proceeds from the new bond issue are placed into a trust containing risk-free Treasuries, which pays the remaining payments of the existing bond up until the original call date.[2] The U.S. Treasury issues special bonds, called State and Local Government Securities (SLGS or "slugs") especially for the purposes of advance refunding. We construct risk-free muni yield curves using prerefunded munis, adjusting them to have the same liquidity as regular munis, and compute the credit risk component by taking the difference between regular muni yields and yields computed using the risk-free muni discount rates.

Liquidity premiums arise when securities with identical credit and other risks but with different turnover, price impact, volume, or other liquidity characteristics trade at different prices. Since our risk-free muni discount rates remove the effect of credit risk, we can use them to compute the prices of munis on the same risk-free basis as Treasuries. When we adjust the Treasuries to have the same after-tax basis from the perspective as an individual, we can compare a muni with no credit risk and an after-tax Treasury. These securities trade at different

[1] Figures from the Financial Accounts of the United States and the Securities Industry and Financial Markets Association (SIFMA).

[2] The process of advance refunding is explained in Chalmers (1998) and Ang, Green, and Xing, (2014). Technically, we do not require that Treasuries or prerefunded munis are truly risk free–only that risk-free munis have the same credit risk as Treasuries. In reality, Treasuries have some a small risk of default (cf. Ang and Longstaff, 2013, for example).

prices but have the same credit and tax treatment, and thus the difference in yields represents the contribution of liquidity risk.

The last component of the muni spread, taxation, is defined as the difference between nominal (or pre-tax) and after-tax Treasury yields. Because the only difference between the two involves income tax and they have identical underlying credit and liquidity characteristics, we isolate the effect of tax treatment. Whereas default risk and liquidity risk, by themselves, increase muni yields, on average, the tax advantage of munis tends to shrink the muni spread.

We find that the muni yield spread exhibits a regime change before and after the 2008 financial crisis. From 1996 to 2007, the difference between muni and Treasury yields is -0.87%, on average, and this jumps to 0.87% from 2008 to 2013. While the global financial crisis roiled many security markets, it appears that its effects in muni markets have been much more long lasting. Pre- and post-2008, the credit component does not change very much from 0.40% to 0.57%, nor does the tax component which moves from -2.09% to -1.84%. In contrast, we find that most of the changing level of the muni yield spread before and after the financial crisis comes from a shifting liquidity premium: the liquidity component changes from 0.82% before 2008 and more than doubles to 2.14% after 2008.

We decompose the variance of the yield spread into credit, liquidity, and tax components, and estimate that over 90% of the variation in muni spreads is attributable to time-varying liquidity components. In contrast, the credit component accounts for only 4% of the variation of the muni yield spread after 2008 and the attribution of the variance of the muni spread to the tax component is even lower, at 2%. Muni credit and liquidity components exhibit strong covariation with credit and liquidity factors in other asset classes. In particular, innovations in muni credit components are significantly related to contemporaneous changes in credit spreads in corporate bond markets, and the muni liquidity component increases when price impact and bid-ask spreads increase in stock markets.

Our study follows a number of papers that examine the role of credit risk, illiquidity effects, and taxation issues in municipal bonds, but most investigate only one of these components. The literature comes to different conclusions regarding the importance of credit risk in explaining muni bond prices. Certainly in the first half of the 20th century, Hempel (1971) shows there was considerable default risk with many municipalities, and one state (Arkansas) went bankrupt during the 1930s. In the post-World War II period, credit risk seems to play a minor role. Moody's reports that between 1970 to 2009, there were only four defaults on debt issued by towns, cities, or counties, and only 54 defaults of municipal entities over this period. The average five-year historical cumulative default rate was 0.03% compared to approximately 1% for investment-grade corporate issuers. Recovery rates on defaulted munis are also higher than recovery rates on defaulted corporate issues. Even though the number of defaults are very low, credit risk may account for a significant fraction of muni spreads if agents are very sensitive to default risk. Stock (1994) and Liu, Wang, and Wu (2003) find this is the case, but Skelton (1983), Chalmers (1998), and others demonstrate that default risk cannot account for the much steeper slope of the muni yield curve relative to Treasury yields. We find that although the credit risk component is elevated after 2008, it explains only a minor part of the large increase in the muni yield spread.

Several studies investigate the poor price transparency, illiquidity, and large differential information between dealers and customers (see Ang and Green, 2013, for a summary). In our model, the liquidity term captures all of these effects. Hong and Warga (2004), Harris and Pirowar (2006), Green, Hollifield, and Schürhoff (2007a), and others, show that the costs of trading munis are large—even for institutions. Typical spreads on retail-sized trades are approximately 2%, and often upwards of 5%, and represent half to one full year of interest. (The median muni bond coupon rate in our sample is 5%.) There is also pronounced dispersion in trading costs, which decline with trade size. According to Green, Hollifield, and Schürhoff (2007b) and Green, Li, and Schürhoff (2010), opacity and monopoly power of broker-dealers play major roles in explaining these facts.[3] Since we measure the muni spread relative to Treasuries, the magnitude of the liquidity component can be interpreted as the reduction in yields that muni issuers would experience if market reforms could be taken to engender the same deep, low trading cost, and information-rich conditions as Treasury markets. We find that liquidity components account for most of the level, and almost all the variation, of the muni spread. The large increase in the muni spread after 2008 is due mostly to an increase in the

[3] Interestingly, Schultz (2012) shows that since muni yields have been reported in real time since January 31, 2005, there has been no change in the markups from the reoffering price. (The reoffering price is the price which bonds are supposed to be "reoffered" to the public by the underwriter.) Schultz finds that markups have increased, at least for large trades. Consequently, the lack of transparency cannot be the only cause of pricing inefficiency and illiquidity.

liquidity component.

Green (1993), Ang, Bhansali, and Xing (2010), and Longstaff (2011) are among the papers examining tax effects in munis. Green (1993) shows how to construct a portfolio of risk-free, taxable Treasuries so that income is transformed and treated as capital gains. In this way, he reconciles the relative shape and level of the muni and Treasury yield curves. Ang, Bhansali, and Xing (2010) and Longstaff (2011) estimate tax rates implied by muni bond prices. They find that implied tax rates can be very high; Longstaff interestingly finds that marginal tax rates are lower under the risk-neutral measure and that marginal tax rates are pro-cyclical, so there is a negative tax risk premium. The tax component, as defined by the reduction in muni yields relative to the case if there were no tax advantage for munis, decreases after the financial crisis, but has been fairly stable.

The paper closest to ours is Wang, Wu, and Zhang (2008), which is one of the few papers simultaneously estimating credit, liquidity, and tax effects. Our identification strategies, however, are different. We measure each of the three components by altering only one variable, say credit risk, and hold fixed other effects, say liquidity and tax treatment. An important result by Duffie and Singleton (1999) is that we can compute yields with present value models that treat the cash flows as risk-free and use a series of zero-coupon rates which appropriately incorporate (the lack of) time-varying default and liquidity risk, holding everything else equal. We use this result to estimate the credit, liquidity, and tax components by turning off only one of these risks: for example, the credit component is estimated by comparing the yields of munis with and without credit risk, but holding fixed liquidity characteristics and tax treatment. We allow the discount rates which incorporate these different effects to vary over time. In contrast, Wang, Wu, and Zhang make somewhat arbitrary assumptions on recovery rates and assume that default rates are constant. They estimate liquidity risk with a regression with bond returns and signed trading volume following Pástor and Stambaugh (2003). This presumes that munis regularly trade—but the typical muni bond trades only twice per year. Our decomposition is also done at the individual bond level.

2 Data

We obtain transaction data for municipal bonds from the Municipal Securities Rule Making Board (MSRB). This database includes every trade made through registered broker-dealers, and identifies each trade as a purchase from a customer, a sale to a customer, or an interdealer trade. Over our sample period from January 1995 to December 2013, there are 138,571,970 individual transactions involving 3,071,610 unique municipal securities which are identified through a CUSIP number. The MSRB database contains only the coupon, dated date of issue, and maturity date of each security.

We obtain other issue characteristics for all the municipal bonds traded in the sample from Bloomberg: the bond type (callable, putable, sinkable, etc.); the coupon type (floating, fixed, or original issue discount [OID]); the issue price and yield; the tax status (federal and/or state tax-exempt, or subject to the Alternative Minimum Tax [AMT]); the issue size; the S&P rating;[4] whether the bond is insured; and information related to advanced refunded municipal bonds, which is whether the bond is prerefunded, the prerefunded date, the prerefunded price, and the escrow security type.

We take only straight bonds and use the same data filters as Ang, Bhansali, and Xing (2010). In particular, we take only interdealer trades, use only bonds exempt from federal taxes and not subject to the AMT, and require that the bond's maturity at the time of the transaction is less than 10 years. We impose the latter requirement because there are relatively few prerefunded bonds (only 3.5% of prerefunded bond transactions) with maturities greater than 10 years. By taking bond transactions where the transaction price is greater than the bond's revised price, which is defined as the present value of the remaining cashflows of the bond discounted at the bond's original issue yield, we exclude all muni bonds with market discount (see Ang, Bhansali, and Xing, 2010, for further details). After imposing these and other filters, our universe of regular, straight muni bonds has 12,986,506 trades of 440,484 bonds with unique CUSIPs.

Prerefunded bonds can be collateralized with non-U.S. Treasury securities, including U.S. agency securities and Aaa/AAA-rated guaranteed investment contracts (GICs). We exclude

[4] The ratings are taken at February 2014, and do not reflect historical credit rating changes. Ratings in municipal bond markets change infrequently, and updates, when they occur, usually happen only when a municipality is issuing a new bond series.

these types of prerefunded bonds and take only those bonds backed by U.S. Treasuries. We impose similar data filters on the prerefunded bond transactions as our muni bond universe. In addition, we take prerefunded bonds where we can identify the prerefunding date, the call date, call price, and time when the bonds are advance refunded. Our final sample of prerefunded bonds contains 234,714 bonds which represents 64.8% of the CUSIPs and 58.49% of total aggregate par amount of the full set of prerefunded bonds that traded during the sample period. There are a total of 4,392,943 prerefunded bond transactions.

Table 1 reports summary statistics of the regular muni and prerefunded bond samples in Panels A and B, respectively. Regular and prerefunded muni transactions have roughly the same breakdown in terms of issuing states: bonds with issuers in California and New York have the most transactions, followed by Florida and Texas. Approximately half of munis are rated AAA by S&P. (While some prerefunded issues carry credit ratings, they are largely irrelevant as our prerefunded bonds are backed by U.S. Treasuries.) There are some subtle differences between the prerefunded and regular muni samples in Table 1. For example, regular munis tend to have slightly higher coupon rates and longer maturities. This is because much advance refunding activity occurs after interest rates have declined relative to the original bond issue (see Ang, Green, and Xing, 2014) so the coupon rates on prerefunded bonds are lower. Second, when an advance refunding occurs, the refunded bond's maturity is usually the first call date of the original bond.

The most important differences between regular and prerefunded munis involve liquidity characteristics. The median par amount traded is $50,000 for regular munis compared to $40,000 for prerefunded munis. Regular munis also trade more frequently than prerefunded bonds with an average number of trades of 7.6 times for straight bonds and 4.8 times for prerefunded munis. The median number of trades are 2.4 and 1.7 for regular and prerefunded bonds, respectively. While the very low number of transactions is a defining characteristic of muni bond markets (see, among others, Harris and Piwowar, 2006; Ang and Green, 2013), there are fewer transactions for prerefunded munis. Even for regular munis, the infrequent trading makes computing liquidity premiums with transaction data problematic, such as the Pástor and Stambaugh (2003) signed volume regressions employed in equity markets. Even with portfolios of munis, there are large problems with non-synchronous trading. We adjust for the lower liquidity of prerefunded bonds relative to regular munis in computing risk-free muni discount rates, as we detail below.

3 Identifying Credit, Liquidity, and Tax Components

We denote the yield on a muni bond of maturity N as Y_N^m, which we observe at the transaction level. Using the standard definition, the price of the muni, P_N^m, is given by

$$P_N^m = \sum_{n=1}^{N} \frac{C/2}{(1+r_n^m/2)^n} + \frac{100}{(1+r_N^m/2)^N}, \tag{1}$$

where C is the semi-annual coupon with N remaining coupon payments, we assume the bond's face value is 100, and $\{r_n^m\}$ is the term structure of muni zero-coupon rates at each half-year maturity n. In the exposition below, we work with maturities defined as the number of remaining coupon payments in half years so that the corresponding bond prices are "clean."[5] The discount rates reflect the intrinsic risk characteristics of munis, including systematic default risk and liquidity risk. The prices of munis also reflect the tax benefits of holding them, and the value of the tax benefit also fluctuates over time (cf. Feenberg and Poterba, 1991; Sialm, 2009; Longstaff, 2011). We denote the yield of the muni corresponding to price P_N^m in equation (1) as Y_N^m.

In our empirical work, we take transaction prices as given on the left-hand side of equation (1) to estimate the term structure of zero-coupon rates using the method of Nelson and Siegel (1987), where the zero-coupon yield for maturity of n half-years, r_n, is given by

$$r_n = \beta_0 + (\beta_1 + \beta_2) \times \frac{1 - \exp(-n/\tau)}{n/\tau} - \beta_2 \exp(-n/\tau). \tag{2}$$

[5] In our empirical work, we also adjust for accrued interest and face values for non-par issues. The accrued interest adjustment is as follows. For a discount rate curve $\{r_n\}$, we use the price

$$P = \sum_{n=1}^{N} \frac{C/2}{(1+r_n/2)^{n-1+w}} + \frac{100}{(1+r_N/2)^{N-1+w}} - \frac{A}{360} \times C,$$

where A is the number of accrued days from the beginning of the interest payment period to the settlement date. The fraction w is defined as

$$w = \frac{180 - A}{180}.$$

We follow the 30/360 convention in the municipal bond market to compute A, so we count 30 days for each complete month which yields 180 days in each interest rate period and 360 days in one calendar year.

We estimate the parameters $\theta = \{\beta_0, \beta_1, \beta_2, \tau\}$ at the daily frequency by fitting the Nelson-Siegel curve to all trades within the day.[6]

3.1 Components of the Muni Yield Spread

We compare munis to U.S. Treasuries—a market where default risk is negligible and liquidity is plentiful. Treasury coupons are, however, taxable, unlike munis. The yield spread of munis in excess of Treasuries, $Y_N^m - Y_N^T$, or the muni spread, thus reflects credit, liquidity, and tax effects. To identify these components, we compute a theoretical value of the muni using discount rates that turn off one, or more, of these features. We compute prices of securities which, although not observed in data, would result if we were able to change the discount rates to remove certain types of risk. This is the key to our identification strategy to separate default, liquidity, and tax components, and it follows Duffie and Huang (1996) and Duffie and Singleton (1997, 1999) who show that in present value models, we can treat the cash flows of securities as default-free but use different discount rates to reflect various sources of systematic risk.

Suppose there exists a U.S. Treasury with the same maturity, N, and cash flow, C, as a given muni. Then, its price would be given by

$$P_N^T = \sum_{n=1}^{N} \frac{C/2}{(1 + r_n^T/2)^n} + \frac{100}{(1 + r_N^T/2)^N}, \tag{3}$$

where $\{r_n^T\}$ is the set of Treasury spot rates. In computing this theoretical price, we have treated the cash flows of the muni bond as risk-free and used discount rates with zero credit and lower liquidity risk. We denote the yield implied by the price P_N^T as the "Treasury yield," Y_N^T. In our empirical work, we use an updated sample of the Treasury zeros estimated by Gürkaynak, Sack, and Wright (2007) for $\{r_n^T\}$.

We define the muni yield spread as the difference between the muni yield and the Treasury yield, $Y_N^m - Y_N^T$, and decompose it into credit, liquidity, and tax components:

$$Y_N^m - Y_N^T = \underbrace{\left(Y_N^m - Y_N^{m,rf}\right)}_{\text{Credit}} + \underbrace{\left(Y_N^{m,rf} - Y_N^{T,\text{after-tax}}\right)}_{\text{Liquidity}} + \underbrace{\left(Y_N^{T,\text{after-tax}} - Y_N^T\right)}_{\text{Tax}}, \tag{4}$$

[6] Since the muni yield curve has always been upward sloping, there is little additional benefit to using an extended Nelson-Siegel (1988) model.

where we define $Y_N^{m,rf}$ as the risk-free muni yield and $Y_N^{T,\text{after-tax}}$ as the after-tax Treasury yield. Both these yields, like the Treasury yield, are computed with discount rates that remove default risk. We also assume the risk-free muni and after-tax Treasury yields have the same same tax treatment and liquidity characteristics as regular munis. In the after-tax Treasury yield, we also assume that the cash flows are received on an after-tax basis by an individual investor.

The first term in our decomposition (4), $Y_N^m - Y_N^{m,rf}$, represents the effect of credit risk as it compares defaultable and risk-free muni yields, everything else held equal. Risk-free muni yields, $Y_N^{m,rf}$, are constructed using prerefunded munis, which are risk-free, and we adjust them to have the same liquidity properties as regular munis. The second term, $Y_N^{m,rf} - Y_N^{T,\text{after-tax}}$, captures liquidity effects as both the risk-free muni yield, $Y_N^{m,rf}$, and the after-tax Treasury yield, $Y_N^{T,\text{after-tax}}$ have zero credit risk and the same tax treatment (from the viewpoint of an individual investor). Thus, variation in this term represents liquidity risk. The final component is the difference between after-tax and pre-tax Treasury yields and represents tax effects.

3.2 Risk-Free Munis

Because prerefunded munis are backed by Treasuries, they have zero credit risk. We cannot, however, directly use prerefunded munis to construct a spot rate curve of risk-free munis because prerefunded munis are, in general, less liquid than their defaultable muni counterparts. In our muni yield spread decomposition (equation (4)), we require a series of risk-free muni discount rates that turn off default risk but have the same liquidity characteristics, on average, as other munis. Prerefunded yields are "too high" because they are less liquid than regular munis, and this necessitates adjusting the prerefunded muni bond prices for liquidity effects.

We illustrate the greater illiquidity of prerefunded munis in Table 2. Panel A reports price impact and turnover measures on all transactions of regular and prerefunded munis. Following Amihud (2002), the price impact is defined as the absolute percentage price change between the last and current transaction divided by the par amount traded. In the table, we scale the measure by a factor of one million. The turnover statistic is defined as the average par value traded each month expressed as a fraction of total outstanding par value. It is reported as a percentage. Panel A shows that prerefunded munis are significantly less liquid than regular munis. In a given transaction, bond prices move more for prerefunded munis: the average price impact measure for prerefunded bonds is 0.687, which is significantly higher than the price impact measure of 0.368 for regular munis. Turnover is also lower for prerefunded munis. Conditional on there being a transaction, the par amount traded in a given month is 15.5% of the issue size for prerefunded munis versus 47.9% for regular munis.

Lower liquidity increases yields, and we need to estimate the impact of the increase in yields induced by the greater illiquidity. We do this by first examining the differences between the full muni sample and a subset of regular munis with the same liquidity characteristics (lower liquidity) of prerefunded bonds. For a given transaction of a prerefunded muni, we construct a sample of regular muni bond transactions on that trading day with similar maturities (± 1 year) and coupons ($\pm 0.5\%$). From this restricted subsample, we select the regular muni with the closest liquidity to the prerefunded muni by minimizing the mean squared error of standardized turnover and price impact.[7] Stated simply, each prerefunded muni transaction is matched to a regular muni transaction with a similar liquidity profile. Panel B of Table 2 shows the results of this procedure and reports the difference in price impact and turnover between the liquidity-matched regular muni sample and the prerefunded bonds. The liquidity differences are now very small and statistically insignificant for price impact. The t-statistic for the differences in turnover is borderline significant at 1.96, but it should be noted that there are a very large number of transactions (8,476,183) in our sample.[8] Thus, this procedure creates a subsample of regular munis with the same liquidity characteristics as prerefunded munis. We refer to this subsample as the "liquidity-matched muni" sample.

For each trading day, we estimate three sets of zero-coupon rates on:

1. Regular munis
2. Liquidity-adjusted (regular) munis
3. Prerefunded munis

Yields on the liquidity-adjusted sample are higher than on the full set of regular munis because

[7] Similar results are obtained by selecting the regular muni minimizing the mean squared error (MSE) over only one liquidity measure, or also including the maturity and coupon characteristic in the MSE matching procedure.

[8] We acknowledge that this procedure may not perfectly adjust for liquidity effects. That is, some of the credit term could count a component that would be more strictly classified as liquidity risk. The credit component is small, and is the smallest of the three components, and thus represents a conservative upper bound. The corresponding illiquidity component can also be viewed as a lower bound.

they are as illiquid as prerefunded munis. The difference in yields between the liquidity-matched sample and the full set of munis, $(2) - (1)$, represents the liquidity premium accruing to the lower liquidity of prerefunded bonds. We use this difference $(2) - (1)$ as a "liquidity adjustment," and emphasize it is computed from the regular muni universe. We adjust down the prerefunded muni curve, which is more illiquid than the universe of regular munis, by the amount of the liquidity adjustment. We refer to the prerefunded zero curve minus the liquidity adjustment as the "risk-free muni" curve. Thus, the risk-free munis adjust for the greater illiquidity of prerefunded munis. All of these adjustments are done at the zero-curve level.

We illustrate this procedure in Figure 1. For illustration, we average the zero curves over September 2008, one of the most turbulent months of the financial crisis. In Panel A, we plot spot rates for regular munis and the sample of liquidity-matched munis. The difference between the two is the liquidity adjustment. In Panel B, we adjust downwards the prerefunded muni zeros downwards by the liquidity adjustment to form the risk-free muni zero curve.

Figure 2 graphs the average zero curves of Treasuries, prerefunded munis, the risk-free munis, and regular munis. Prior to the financial crisis up to 2007 in Panel A, muni yields (dashed-dot green line) lie below Treasuries (solid blue line). During and after the financial crisis in Panel B, the traditional relation between munis and Treasuries flips, so that muni yields lie above Treasuries. We examine below which of the credit, illiquidity, and tax components (equation (4)) is responsible for this regime shift. Figure 2 also shows the effect of the liquidity adjustment. In the pre-financial crisis sample in Panel A, the liquidity adjustment takes down the raw 10-year prerefunded discount rate from 4.96% to the risk-free muni rate of 4.44%. There is, however, only a small adjustment at the short-end of the yield curve from 2.73% to 2.59% at the one-year maturity. A similar pattern occurs in the second subsample in Panel B, where the difference between the raw prerefunded spot rate and the risk-free muni rate is 0.50% for a maturity of 10 years.

In Figure 3, we plot Treasury, regular muni, and risk-free zero-coupon yields for the five-year maturity over our sample. While it is clear there is a large common component between all yields (the "level factor," see Litterman and Scheinkman, 1991), Figure 3 shows that the relative positions of the three series changes pre- and post-2008, consistent with the pronounced shift in the average yield curves shown in Figure 2. Figure 3 shows that until the financial crisis, Treasuries were generally higher than munis, which were higher than risk-free munis. During the financial crisis, there was a "flight to quality" to liquid Treasuries, causing their yields to decrease below regular and risk-free munis. We further examine this shifting pattern below.

3.3 Credit Component

Using the estimated risk-free muni discount rates, we compute the risk-free muni bond price, $P_N^{m,rf}$, using the following present value formula:

$$P_N^{m,rf} = \sum_{n=1}^{N} \frac{C/2}{(1 + r_n^{m,rf}/2)^n} + \frac{100}{(1 + r_N^{m,rf}/2)^N}, \tag{5}$$

where $\{r_n^{m,rf}\}$ are the risk-free muni zero-coupon yields of maturity n. The risk-free muni yield, $Y_N^{m,rf}$, is the yield implied by the price $P_N^{m,rf}$. The risk-free muni spot rates used in equation (5) set credit risk to zero but preserve the same liquidity characteristics as regular munis, at least as far as our liquidity adjustment allows. We can then take the difference $Y_N^m - Y_N^{m,rf}$ to represent the credit risk component in munis as it holds constant liquidity risk but turns off credit risk:

$$\text{Credit} = Y_N^m - Y_N^{m,rf}.$$

3.4 Liquidity Component

The liquidity component of munis,

$$\text{Liquidity} = Y_N^{m,rf} - Y_N^{T,\text{after-tax}},$$

requires computing the after-tax Treasury yield, $Y_N^{T,\text{after-tax}}$, which we do by making two adjustments to the standard bond valuation formula. First, since Treasuries are taxable, we assume the muni's cash flow is received on an after-tax basis. Second, we remove credit and liquidity risk by using discounting with the Treasury spot curve:

$$P_N^{T,\text{after-tax}} = \sum_{n=1}^{N} \frac{C/2 \times (1-\tau)}{(1 + r_n^T/2)^n} + \frac{100}{(1 + r_N^T/2)^N}, \tag{6}$$

where τ is the highest marginal federal income tax rate. The yield corresponding to the price $P_N^{T,\text{after-tax}}$ is the risk-free muni yield, $Y_N^{m,rf}$. It is obvious that there is no credit risk in equation (6) as we use Treasury spot rates, $\{r_n^T\}$. We need to adjust for tax because Treasuries are taxable, and we place the cash flows on an after-tax basis as received by an individual investor. Thus the difference, $Y_N^{m,rf} - Y_N^{T,\text{after-tax}}$ represents the effect of liquidity because the credit risk and tax treatment of the two yields are identical.

Equation (6) assumes the bond is held to maturity. This is consistent with the definition of the yield, and also consistent with our intention to decompose the muni yield spread.[9] The tax rate, τ, has changed across our sample. The rate is 39.6% in 1995, decreases to 39.1% in 2001, then to 38.6% in 2002, in 2003 to 35%, and then in the final year of our sample, 2013, increases to 39.6%. We use the prevailing tax rate at the time of the transaction and hold this fixed for future dates. For example, when a municipal bond is traded in 2001, investors assume the highest marginal tax rate remains at 39.1% for all future cash flows. We use statutory tax rates. Longstaff (2011) estimates average tax rates close to statutory tax rates, but marginal estimates can be volatile and often exceed the highest marginal tax rates. Ang, Bhansali, and Xing's (2010) estimates of implied tax rates from market discount muni bonds (which we exclude in our analysis), are also extremely high. Finally, we assume there is no tax paid on capital gains with the final cashflow of the bond. This is because at issue, there is a trade-off between a muni's tax-exempt yield and OID (or original issue premium). We only consider the effect of income tax rates in equation (6), rather than capital gains rates because our data screens remove any market discount muni bonds subject to income tax or capital gains tax at maturity or the subsequent sale of the bond.[10]

3.5 Taxation Component

The last component in our decomposition in equation (4) captures the effect of taxes:

$$\text{Tax} = Y_N^{T,\text{after-tax}} - Y_N^T.$$

[9] Equation (6) assumes that an individual holds a bond to maturity and excludes the tax benefits of intermediate trading (see Constantinides and Ingersoll, 1984). As Chalmers (2000) points out, these effects are small in the muni bond market because bond premiums cannot be deducted, and it is difficult to short municipal bonds.

[10] For further details on market discount taxation, with a de minimis exception which is subject to capital gains taxes, see Ang, Bhansali, and Xing (2010).

Both the after-tax Treasury yield, $Y_N^{T,\text{after-tax}}$, and the regular Treasury yield, Y_N^T have the same liquidity and credit risk. The former is after-tax while the latter is pre-tax, and thus the difference arises purely from the effect of taxes. While the additional credit and illiquidity risk both raise muni yields relative to Treasuries (at least prior to the financial crisis), the tax component is negative. The after-tax Treasury yield must be lower than the regular Treasury yield because the bond coupons are reduced on an after-tax basis.

4 Empirical Results

For each straight municipal bond transaction in our sample period, we compute the three components: credit, illiquidity, and tax given in equation (4). We average each component over all transactions on each trading day. To obtain a monthly time series, we take averages of the components within each month. In Section 4.1, we characterize the average magnitudes of the components. Sections 4.2 to 4.4 separately investigate the credit, illiquidity, and tax components.

4.1 Credit, Liquidity, and Tax Components

Table 3 reports summary statistics of the muni yield spread, and the credit, liquidity, and tax components over the full sample (Panel A), the subsample before the financial crisis (Panel B), and the subsample from 2008 (Panel C).

We begin by discussing the numbers over the full sample. If we start with the Treasury yield curve, increasing the credit risk to the level priced in the muni market raises yields by 0.45%. If Treasuries were as illiquid as munis, their yields would increase by 1.26%. Everything else held equal, Treasury yields would decline by 2.0% if they were tax-exempt instead of taxable. On average, the muni yield spread is -0.29%. Thus, the main component of the negative yield spread reflects the tax advantage of muni bonds. All three of these components vary over time, with the credit component having the lowest standard deviation of 0.15% and the liquidity component the highest of 0.72%. The components are all very persistent; all of them have autocorrelation coefficients greater than 0.9.

The unconditional averages hide a regime shift in 2008. Panels B and C show that the muni spread moves from -0.87% before the financial crisis to 0.87% after the financial crisis. By far the component most responsible for this large change is an increase in the muni liquidity premium. In the 1996-2007 sample, the liquidity component is 0.82%. This more than doubles to 2.14% in the 2008-2013 period. There is a relatively small increase in the credit risk premium, from 0.40% to 0.57% from the pre- to post-2008 periods. The tax benefit also shrinks pre- and post-2008 from -2.09% to -1.84%, but, overall a sharp increase in the liquidity component is responsible for the large increase in muni yields relative to Treasuries after 2008.

4.1.1 Credit, Liquidity, and Tax Components Over Time

In Figure 4, we plot the muni bond spread, along with its credit, liquidity, and tax components, over time. The minimum value of the muni spread is -1.68%, which occurs in July 1996. The muni bond increases to a local maximum of -0.43% in October 1998 in the aftermath of the Russian default and when Long Term Capital Management, a large hedge fund, failed. We clearly see the large jump in the muni spread post-2008, which turns positive and remains so until the end of the sample. Its highest level of 2.21% occurs in December 2008. There are two pronounced spikes in the muni spread after January 2008: the earlier one corresponding to the failure of Lehman Brothers in September 2008 where Treasury yields jumped but muni yields barely moved, and the second one in early 2009 when Treasury yields fell due to large liquidity injections by the Federal Reserve. During the latter period, muni yields increase as the after-effects of the financial crisis on muni issuers become apparent as the slowing economy decreases tax revenue.[11]

Figure 4 shows that the credit component of the muni spread is relatively stable, especially prior to 2008. It reaches a peak of 0.91% in Feb 2009. At the end of December 2013, its value is 0.44%. The liquidity component is the largest component of the muni spread and largely mimics the overall variation in the total muni spread. The liquidity component shoots up to 3.3% in December 2008 during the financial crisis. The tax component is shown in the bottom dotted line and is always negative. It increases in 2000 due to the Bush tax cuts. In 2001, the Economic Growth and Tax Relief Reconciliation Act reduces the highest bracket of personal

[11] There are earlier market disclocations in muni markets before this time, like the failure of auction market securities, which makes headlines in February 2008, but these do not seem to affect straight muni yields. See McConnell and Sarretto (2010).

income tax rate from 39.6% to 39.1%. The highest personal tax rate further decreases to 38.6% in 2002 and 35% in 2003. Our tax component is the difference between the after-tax Treasury yield and the before-tax Treasury yield so the higher the tax rate, the larger the magnitude of the tax component, all else equal. This partly accounts for the decreasing tax component from 2000 to 2004. Changing tax rates, however, cannot account for the falling tax component from 2010 to 2012 when the tax component falls from -1.72% in January 2010 to -1.99% at December 2012. In fact, tax rates increase from 35% to 39.6% in 2013 and the tax component increases during this time. We further characterize the tax component in Section 4.4.

The large difference in the mean of the muni spread and the liquidity component pre- and post-2008 in Figure 4 explains their much larger standard deviation over the whole sample compared to smaller standard deviations in the 1996-2007 and 2008-2013 subsamples. For example, Table 3 reports that the full-sample standard deviation of the muni spread is 0.93% compared to 0.47% over 1996-2007 and 0.38% over 2008-2013. The changing mean over each period accounts for these statistics. The full-sample standard deviation includes fluctuations relative to the unconditional mean of -0.29%. These deviations are smaller when we consider a mean of -0.87% over the first subsample and 0.87% over the second, which is what the subsample-specific standard deviations pick up.

4.1.2 Variation of Credit, Liquidity, and Tax Components

The difference in the behavior of the muni spread pre- and post-financial crisis also affects the correlation estimates of the three components. As Table 4 reports in both the pre- and post-crisis subsamples, the credit risk premium is negatively correlated with the liquidity premium (correlations of -0.31 and -0.22 in the pre- and post-2008 subsample, respectively). But, since both the credit and illiquidity components increase during 2008, we observe a positive correlation between credit and illiquidity component over the full sample. In contrast, the behavior of the tax component with credit and liquidity are markedly different in the two subsamples. Credit and tax components are negatively correlated, at -0.60, before the financial crisis, but positively correlated, at 0.28, afterwards. The correlations of tax and liquidity components also change sign, from 0.58 to -0.83, in the two subsamples. These changing correlations should be carefully interpreted because the overall variation in the tax component is itself very small, as we now show.

In Table 5, we attribute the variance of the muni spread into its components. We use a Cholesky decomposition with the ordering: credit, liquidity, and tax. Variance decompositions can be sensitive to the ordering, and given the large correlations in Table 4, this is true for our decomposition of the muni spread. Unambiguously, the largest component is liquidity, as clearly shown in Figure 4. Placing credit first works against finding liquidity important. We choose to order tax last because it is computed using only Treasury discount rates while the credit and liquidity components require discount rates estimated in the muni market. Thus, in our ordering we are assigning more weight to effects identified specifically from the muni market. As shown in Figure 4, the tax component also does not change much over time.

Table 5 reports that the variance decomposition of the muni spread is largely stable, even though the level of the muni spread has fluctuated dramatically. The main result is that liquidity accounts for at least three quarters of the variance of the muni bond spread. The variance attributions to liquidity after the financial crisis are even higher. Since 2008, over 90% of variation in muni spreads is attributable to liquidity or liquidity risk. On a percentage basis, credit risk is less important after 2008 than before. With a variance decomposition of 2%, variation in tax components also explains very little of muni spreads after the financial crisis. In summary, liquidity is the main driver of muni yield spreads.

4.1.3 Term Structure of Muni Spread Components

Figure 5 plots the average credit, liquidity, and tax components across three different maturity buckets: less than two years, between two and five years, and between five and 10 years. The left-hand and right-hand columns show the breakdown from 1996-2007 and from 2008-2013, respectively. The figure shows that the changing muni spread across the pre- and post-financial crisis samples also coincides with significant changes in the term structures of the credit, liquidity, and tax decompositions.

Panel A shows that in the subsample up to December 2007, the term structure of the credit component is downward sloping with a value of 0.64% for less than two years and 1.13% for the bucket between five and 10 years. Downward-sloping term structures are observed in credit spreads for low-quality corporate issuers (see, among others, Lando and Mortensen, 2005). Economically, risky entities with asset values close to default boundaries face a relatively high probability of default in the short run, but if no default occurs, credit quality improves. The decreasing default probabilities conditional on survival induce a downward-sloping term structure of credit (see Johnson, 1967; Longstaff and Schwarz, 1995; Collin-Dufresne and Goldstein, 2001). After 2008, the term structure becomes upward-sloping, with values of 0.33% and 0.43% for maturities less than two years and between five and 10 years, respectively. Given the relatively low credit risk present in the muni market—at least compared to the corporate bond market—the upward-sloping term structure post-2008 is more consistent with a comparison with high-quality corporate issuers, which generally have upward-sloping term structures of credit risk.

In Panel B, the term structure of liquidity is monotonically upward sloping in both subsamples. However, it becomes relatively more concave after the financial crisis. The difference in the liquidity component between the bucket of five and 10 year maturities and the bucket with maturities less than two years is 0.363% before 2008 and 0.416% afterwards. This effect, however, is secondary to the large increase of approximately 1% in the overall level of the liquidity component.

The tax components in Panel C also change their slopes before and after 2008, like the credit component in Panel A. The tax term structure increases from -2.21% for less than two years to -1.20% between five and 10 years from 1996-2007. The decreasing tax components prior to 2008 are consistent with the more steeply sloped muni curve relative to Treasuries (see Green, 1993). The slope becomes much more negative after 2008, with corresponding tax component values of -1.09% and -1.54% for maturities less than two years and between five and 10 years, respectively. This is also a period where munis trade, on average, higher than Treasuries.

4.2 Credit

In this section, we investigate how the credit component is related to other credit proxies. In Figure 6, we plot the muni credit component and the credit spread, which is the BAA corporate bond yield minus the AAA yield. The correlation between the two series is 0.46. There is a notable increase for both series in 2008 during the financial crisis. Interestingly, during the early 2000s when the economy slows, the muni credit risk spread does not increase whereas corporate bond yield spreads do.

In Table 6, we consider other credit proxies as well as the credit spread: the swap spread (10-year swap rate minus 10-year Treasury rate), high yield spread (Barclay high yield CAA redemption yield minus the 10-year Treasury yield), and the credit/liquidity spread estimated by Longstaff (2011). The latter is a combined credit and liquidity risk premium estimated from muni swaps. We run univariate and multivariate regressions using changes in all variables with the change in the muni credit component as the dependent variable. Given the large persistence in the credit component and spreads (see Table 3), changes in the variables can be considered to be, to a first approximation, innovations (or shocks).

Table 6 shows that changes in muni credit spreads are contemporaneously related to changes in corporate bond spreads. The coefficient on the credit spread is 0.06 with a t-statistic of 3.07, and this remains positive and statistically significant in the multivariate regression. Changes in swap spreads and the high yield spread are insignificant. This is perhaps not unexpected, given that swap spreads reflect credit risk mostly of large banks and high yield corporate bond issuers have much higher credit risk than municipal issuers.

Despite the statistically strong relation with the credit spread, the fact that the multivariate regression R^2 is only 1% indicates that most of the variation in muni credit spread changes is unrelated to credit risk changes in other fixed income markets. This echoes Collin-Dufresne, Goldstein, and Martin's (2001) finding that most of the variation in corporate bond spreads is unrelated to fundamental credit risk proxies. The sign of the coefficient on Longstaff's (2011) credit and liquidity spread is negative, but insignificant. This is perhaps surprising, but Longstaff does not separate credit and liquidity in this premium. Given our small credit component compared to liquidity, and the fact that credit and liquidity are negatively correlated (see Table 4), it is likely that the liquidity component dominates giving rise to the negative coefficient.

4.3 Liquidity

A key finding is that after 2008, liquidity spreads in muni markets increase markedly and are mostly responsible for driving the muni spread to turn negative. Does the increase in the muni liquidity component reflect underlying increasing illiquidity in the muni market? In Figure 7, we plot muni price impact and turnover in Panels A and B, respectively. We draw a vertical dashed line to mark January 1, 2008 and then plot the average liquidity measures before and after this date in horizonal lines. In Panel A, the average price impact is higher in the pre-2008 sample, or, put another way, the muni market is more illiquid in the pre-financial crisis period. This difference is statistically significant, with a test for the difference in the two means having a t-statistic of 5.11. The average pre- and post-2008 price impact measures, however, hide a pronounced decreasing trend in price impact prior to 2008. Price impact shoots up in the early 2008 sample and remains elevated until 2012. Most recently, muni market price impact increases in the last year of our sample, 2013. Viewing the sudden increase in price impact from its low values in 2007, the muni market is more illiquid in terms of price impact during the financial crisis.

Panel B of Figure 7 shows that turnover in muni markets has been lower after 2008. The average turnover is 0.51% up to 2007, falling to 0.43% after 2008. This difference is highly statistically significant with a test for the difference having a t-statistic of 12.4. As the financial crisis unfolds in 2008, both price impact and turnover are adversely affected. (The correlations between the two series pre- and post-2008 are 0.37 and -0.27, respectively.) There are sharp decreases in muni turnover prior to 2008, in particular in early 2000 which coincides with the falling prices of stocks, especially in the technology sector, at this time.

In Table 7, we examine if muni liquidity is related to liquidity risk components in other asset markets. We regress changes in the muni liquidity component onto changes in liquidity spreads or liquidity factors (returns) reflecting time-varying liquidity risk in other bond markets and stock markets. The on-the-run/off-the-run spread reflects liquidity premiums in Treasury bond markets (see Amihud and Mendelson, 1991; Krishnamurthy, 2002): it is the difference between more liquid ("off-the-run") and more liquid ("on-the-run") 10-year Treasury yields. We use several measures of liquidity risk premiums in equity markets: the Amihud (2002) measure, the average bid-ask spread over all common stocks listed on NYSE, AMEX, and NASDAQ, and the percentage of zero returns over a month computed by Lesmond, Ogden, and Trzcinka (1999). We also include the Pástor-Stambaugh (2003) liquidity factor. Sadka's (2006) two measures decompose equity price impact into transitory-fixed and permanent-variable components. The Longstaff (2011) spread includes credit and liquidity effects estimated from muni swaps, and

Bao, Pan, and Jiang (2010) is a price impact measure of corporate bonds. All these variables are expressed as first differences, except the Pástor-Stambaugh factor which is already a return.

In the univariate regressions in Table 7, the variable with the highest level of statistical significance is corporate bond liquidity: the coefficient on the Bao, Jiang, and Pan (2010) measure is 0.50 with a t-statistic of 8.48. Liquidity in Treasury bond markets also matters; the positive coefficient of 1.74 (t-statistic of 3.61) on the on-the-run/off-the-run bond spread implies that when liquidity conditions in U.S. Treasuries become stressed, muni market liquidity also deteriorates. There are also statistically significant positive relations with stock market liquidity. Higher price impact and bid-ask spreads in the stock market contemporaneously occur with deteriorations of liquidity in the muni market. There are, however, unexpectedly negative coefficients with the percentage of zero returns and the Sadka (2006) transitory component of price impact. The sample for the latter, however, ends in December 2008, and so misses most of the post-crisis experience.

In the multivariate regressions performed over the full sample, the significant comovements with the on-the-run/off-the-run spread and the stock bid-ask spread remain robust while the coefficient on the percentage of zero returns becomes insignificant. Overall, a fairly large 27% of variation in changes in the liquidity component is related to movements in other liquidity measures.

4.4 Tax

The tax component of muni yield spreads is around -2.0% and is relatively stable across the pre- and post-2008 subsamples. By definition of the after-tax Treasury yield (see equation (6)), the tax component is affected by the shape of the risk-free Treasury curve, the drivers of duration (maturity and coupons) of the muni bonds, and tax rates. The higher the tax rate, the more negative the tax component. Since 1996, the highest marginal income tax rate changes, with a low of 35% between 2003 and 2012 and a high of 39.6% in 1996 and also in 2013. There is a correlation of -85% between the historical highest marginal tax rate and the tax component. As noted previously and observed in Figure 4, one important exception to the general negative relation between the tax component and statutory tax rates is in 2013, when tax rates increase and there is an increase in the muni tax spread.

Figure 9 compares our tax component with Longstaff (2011), who estimates marginal tax rates with a term structure model applied to muni swaps. There appears to be little relation. A regression of changes of the muni tax component onto changes in Longstaff's (2011) marginal tax rate estimates confirms this fact: running this regression produces a coefficient of -0.021 with an insignificant t-statistic of -1.18. There are several reasons behind the insignificant comovement. First, the muni swaps used by Longstaff probably reflect taxes other than Federal income tax (state, and possibly county, city, and other local income taxes) and ours is computed only with Federal income tax effects. Second, our tax component is estimated purely under the physical measure, whereas Longstaff's tax rates implied form muni swaps are risk-neutral estimates. Third, the clienteles in muni swaps are mostly institutional whereas muni bonds are predominantly held by individuals. Capital market conditions like funding liquidity, capital requirements, and the general health of financial institutions affect the pricing of options (Gârleanu and Pedersen, 2011) and swaps (Krishnamurthy, 2010), and this could be true for muni derivatives. The large drawdown after 2008 in Longstaff's (2011) series is consistent with such a story and such effects would play a smaller role in our more stable tax component.

5 Conclusion

Compared to U.S. Treasuries, muni bonds are risky, they are much less liquid, and they are exempt from tax. We decompose the muni spread, or the yields of muni bonds relative to Treasuries, into default risk, liquidity, and taxation components. We find that liquidity is by far the most important component in driving muni bond spreads.

We find that before 2008, the muni spread averaged -0.87% and there was a pronounced shift in the behavior of the spread after the financial crisis. After 2008, the muni spread flips sign to 0.87%. The liquidity component is mostly responsible for the change in the level of the muni spread: from 1996 to 2007, the average muni liquidity component is 0.82% compared to 2.14% after 2008. The credit component does not change very much, moving from 0.40% to 0.57% in the pre- and post-2008 samples. The tax component is also relatively stable at -2.09% before 2008 and -1.84% afterwards. We find that muni credit and liquidity components are strongly related to credit and liquidity factors in stock and other fixed income markets.

Our estimates of the decomposition of the muni spread have some implications for public policy. Using the decomposition after 2008, the large liquidity component of 2.14% can be interpreted as the compensation required by investors to bear the large illiquidity in muni bond markets, all else equal. If muni bonds had the same liquidity as Treasuries, then muni issuers would see their funding costs drop by 2.14% per year. Similarly, the absolute value of the tax component (-1.84%) can be interpreted as the amount that muni rates would rise if Congress were to remove muni issuers' tax exemption.

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Table 1: Characteristics of Muni Transactions

Panel A: Straight Bonds

States of Issues with Most Transactions	CA 14.91%	NY 11.95%	FL 5.77%	TX 6.64%	NJ 4.65%	MI 3.54%	OH 3.28%	PA 3.22%
Type of Bond	General Obligation 47.11%		Revenue 47.42%		Other 5.46%			
S&P Credit Rating	AAA 48.13%		AA+, AA, AA- 36.21%		A+,A,A- 15.65%			
Coupon Rate	5% 3.625%	25% 4.50%	50% 5.00%	75% 5.25%	95% 6.00%			
Maturity at Trade	1-2 Years 11.02%	2-5 Years 44.08%	5-10 Years 44.90%					
Par Amount Traded	5% \$15,000	25% \$25,000	50% \$50,000	75% \$150,000	95% \$1,000,000			
Number of Trades per Year	Mean 7.61	Median 2.42						

Panel B: Prerefunded Bonds

States of Issues with Most Transactions	CA 12.63%	NY 11.81%	FL 5.34%	TX 6.95%	NJ 7.30%	MI 4.34%	OH 3.04%	PA 5.64%
Coupon Rate	5% 4.70%	25% 5.00%	50% 5.25%	75% 5.75%	95% 6.75%			
Maturity at Trade	1-2 Years 18.86%	2-5 Years 54.58%	5-10 Years 26.56%					
Par Amount Traded	5% \$10,000	25% \$20,000	50% \$40,000	75% \$100,000	95% \$725,000			
Number of Trades per Year	Mean 4.84	Median 1.66						

Note to Table 1

Panel A lists summary statistics of straight municipal bond transactions in our sample from the MSRB database where we take only inter-dealer straight bonds with maturities less than ten years at the time of transaction; bonds with an S&P rating of A- or higher; federal and state-exempt bonds not subject to the AMT; bonds issued in one of the 50 states; bonds trading at least 30 days after original issuance; transactions with par value greater than $10,000; and transactions with prices above revised prices. There are a total of 12,986,506 transactions involving of 440,484 bonds with unique CUSIPs. The table reports proportions of these transactions falling into various categories. Panel B lists summary statistics of prerefunded municipal bond transactions using the same filters as Panel A. The prerefunded munis must have an escrow comprising U.S. Treasuries or SLGS. After data filters, there are 4,392,943 prerefunded bond transactions involving 234,714 bonds with unique CUSIPs. For the coupon rate and par amount traded, we report the coupon rates and traded par amounts at various percentiles of the distribution.

Table 2: Liquidity Comparison Between Regular and Prerefunded Munis

	Price Impact	Turnover
Panel A: Before Liquidity Adjustment		
Regular Munis	0.368	0.479
Prerefunded Munis	0.687	0.155
Difference	-0.319	0.324
	[32.3]	[47.6]
Panel B: After Liquidity Adjustment		
Difference	0.004	0.004
	[0.64]	[1.96]

We compare liquidity measures between regular and prerefunded munis. Price impact is defined as the absolute percentage price change between the last and current transaction divided by the par amount traded. In the table, we scale the measure by a factor of one million. The turnover statistic is defined as the average par value traded each month expressed as a percentage of total outstanding par value. It is reported as a percentage. In Panel A, we report the liquidity characteristics for regular munis and prerefunded munis. In Panel B, we take a selected sample of regular munis matched to have similar liquidity characteristics as the prerefunded munis. For each prerefunded transaction, we construct a sample of regular muni bond transactions with similar maturities (± 1 year) and coupons ($\pm 0.5\%$) during each trading day. From this restricted subsample, we select the regular muni with the closest liquidity to the prerefunded muni by minimizing the mean squared error of standardized turnover and price impact. Panel B reports the difference in liquidity measures between the liquidity-matched regular muni and the prerefunded muni samples. We report t-statistics in square brackets.

Table 3: Decomposing Muni Spreads

	Mean	Stdev	Skew	Kurt	Auto
Panel A: Full Sample 1996-2013					
Muni Yield Spread	-0.290	0.934	0.393	1.929	0.982
Credit	0.454	0.146	1.131	4.077	0.939
Liquidity	1.264	0.725	0.722	2.413	0.968
Tax	-2.007	0.251	-0.610	1.956	0.987
Panel B: Subsample 1996-2007					
Muni Yield Spread	-0.870	0.473	0.182	2.146	0.954
Credit	0.396	0.102	1.408	6.653	0.869
Liquidity	0.825	0.316	0.326	2.836	0.897
Tax	-2.090	0.262	-0.080	1.488	0.986
Panel C: Subsample 2008-2013					
Muni Yield Spread	0.871	0.384	0.228	3.964	0.813
Credit	0.569	0.153	0.567	2.649	0.946
Liquidity	2.144	0.461	-0.044	2.179	0.859
Tax	-1.843	0.101	-0.209	1.633	0.962

We report summary statistics of the muni yield spread using muni transactions of straight bonds with 10 years maturity or less over the full sample, 1996-2007 (Panel A), and two subsamples: 1996-2007 (Panel B) and 2008-2013 (Panel C). All numbers are in percentages. We report means, standard deviations (stdev), skewness (skew), kurtosis (kurt), and the first-order autocorrelation (auto) of the monthly-frequency time series. The decomposition is given in equation (4). The muni yield spread is the difference between yields on muni bonds and Treasuries, $Y_N^m - Y_N^T$. The credit component is the difference in yields between munis and risk-free muni yields, which are yields on hypothetical munis with the same cash flows discounted with spot rates that have no credit risk and the same liquidity as regular munis, $Y_N^m - Y_N^{m,rf}$. The liquidity component is the difference in risk-free muni and after-tax Treasury yields, $Y_N^{m,rf} - Y_N^{T,\text{after-tax}}$. The latter are computed with the after-tax cash flows of the original muni bond with Treasury spot rates. The tax component is the difference between after-tax Treasury yields and Treasury yields, $Y_N^{T,\text{after-tax}} - Y_N^T$.

Table 4: Correlations of Muni Spread Components

	Muni Spread Components		
	Credit	Liquidity	Tax
Panel A: Full Sample 1996-2013			
Credit	1	0.373	0.011
Liquidity	0.373	1	0.507
Tax	0.011	0.507	1
Panel B: Subsample 1996-2007			
Credit	1	-0.307	-0.595
Liquidity	-0.307	1	0.581
Tax	-0.595	0.581	1
Panel C: Subsample 2008-2013			
Credit	1	-0.217	0.281
Liquidity	-0.217	1	-0.828
Tax	0.281	-0.828	1

We report the correlation matrix for the components of the muni spread: credit, illiquidity, and tax components. The decomposition is given in equation (4). The credit component is the difference in yields between munis and risk-free muni yields, which are yields on hypothetical munis with the same cash flows discounted with spot rates that have no credit risk and the same liquidity as regular munis, $Y_N^m - Y_N^{m,rf}$. The liquidity component is the difference in risk-free muni and after-tax Treasury yields, $Y_N^{m,rf} - Y_N^{T,\text{after-tax}}$. The latter are computed with the after-tax cash flows of the original muni bond with Treasury spot rates. The tax component is the difference between after-tax Treasury yields and Treasury yields, $Y_N^{T,\text{after-tax}} - Y_N^T$.

Table 5: Variance Decomposition of the Muni Spread

	Full	1996-2007	2008-2013
Muni Spread Variance	0.873	0.224	0.147
Variance Decompositions (Pct)			
Credit	20.1	10.2	4.4
Liquidity	74.8	75.3	93.5
Tax	5.1	14.5	2.1
Total	100.0	100.0	100.0

We compute variance decompositions of the muni yield spread using a Cholesky decomposition in the order: credit, illiquidity, and tax. The decomposition is given in equation (4). The credit component is the difference in yields between munis and risk-free muni yields, which are yields on hypothetical munis with the same cash flows discounted with spot rates that have no credit risk and the same liquidity as regular munis, $Y_N^m - Y_N^{m,rf}$. The liquidity component is the difference in risk-free muni and after-tax Treasury yields, $Y_N^{m,rf} - Y_N^{T,\text{after-tax}}$. The latter are computed with the after-tax cash flows of the original muni bond with Treasury spot rates. The tax component is the difference between after-tax Treasury yields and Treasury yields, $Y_N^{T,\text{after-tax}} - Y_N^T$.

Table 6: Muni Credit Risk

	Univariate Reg.		Multivariate Reg.	
	Coeff	T-Stat	Coeff	T-Stat
Swap Spread	-0.011	-0.19	0.004	0.10
Credit Spread	0.058	3.07	0.050	2.07
High Yield Spread	0.003	1.09	0.002	0.63
Longstaff Credit/Liquidity Spread	-2.209	-1.84		
			$R^2 = 0.9\%$	

The table reports univariate and multivariate regression estimates with the change in the credit component as the dependent variable. The right-hand side variables are changes in credit spreads which are defined as follows. The swap spread is the 10-year swap rate minus 10-year Treasury yield. The credit spread is the BAA corporate yield minus the AAA corporate yield, both investment grade yields. The high yield spread is the Barclays high yield CAA redemption yield minus the 10-year Treasury yield. The Longstaff credit/liquidity spread is from Longstaff (2011) and estimates combined credit and liquidity premiums from muni swaps. We obtain the 10-year swap rate from Bloomberg, the 10-year Treasury, BAA, and AAA yields from the Federal Reserve Bank at St. Louis, and the Barclay's high yield CAA redemption yield from Datastream. We average daily data observation series over a month to obtain the monthly-frequency series. The sample with the Longstaff (2011) series is from August 2001 to October 2009. Other regressions are run over our full sample from 1996 to 2013. We compute t-statistics with 12 Newey-West (1987) lags.

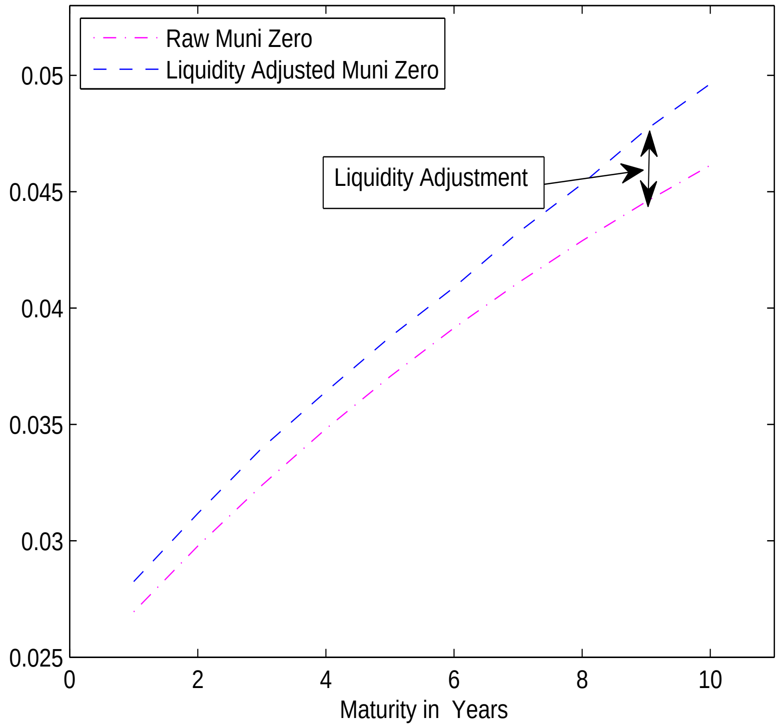
Table 7: Muni Liquidity Risk

	Univariate Reg.		Multivariate Reg.	
	Coeff	T-Stat	Coeff	T-Stat
On-the-Run/Off-the-Run Spread	1.744	3.61	1.059	3.21
Stock Amihud	17.50	3.84	1.112	0.25
Stock Bid-ask	41.77	4.49	31.49	4.13
Stock Turnover	0.262	2.64	0.085	0.70
Stock % Zero Ret	-5.921	-2.71	-3.346	-1.56
Pástor-Stambaugh Liquidity Factor	-1.154	-1.52	-0.754	-1.26
Longstaff Credit/Liquidity Spread	8.221	1.43		
Sadka Transitory-Fixed	-9.994	-2.23		
Sadka Permanent-Variable	1.893	0.82		
Bao, Jiang, & Pan Corp Bond Liquidity Spread	0.495	8.48		
			$R^2 = 27.3\%$	

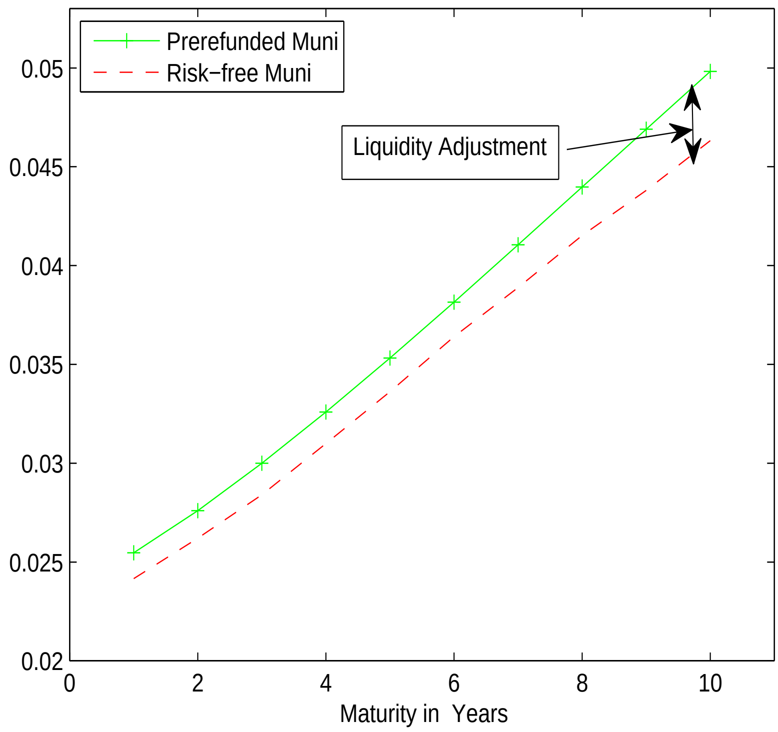
The table reports univariate and multivariate regression estimates with the change in the liquidity component as the dependent variable. The right-hand side variables are changes in liquidity measures spreads which are defined as follows. The on-the-run/off-the-run spread is the difference between off-the-run (less liquid) 10-year Treasury yields and on-the-run (more liquid) 10-year Treasury yields. The Stock Amihud (1999) is defined as the daily absolute percentage change in price divided by dollar volume scaled by a factor of 10,000. We compute the Stock Bid-ask spread as the difference between the bid and ask divided by the closing price. To obtain the monthly-frequency series, we first average the daily series of Amihud, bid-ask spread and turnover for each stock and then we average over all common stocks listed on NYSE, AMEX, and NASDAQ. The "Stock % Zero Ret" is the proportion of daily returns equal to zero over the month, and is constructed by Lesmond, Ogden, and Trzcinka (1999). The Pástor-Stambaugh (2003) Liquidity Factor is a return series, and so is not first-differenced. The Longstaff (2011) credit/liquidity spread estimates combined credit and liquidity premiums from muni swaps. Sadka (2006) decomposes price impact into fixed and variable component and constructs Transitory-Fixed and Permanent-Variable factors on stock price data. Bao, Pan, and Jiang (2010) construct a price impact liquidity measure with corporate bond transactions. The sample with the Longstaff (2011) series is from August 2001 to October 2009, the regressions with the Sadka (2006) variables are run from 1996-2008, and the Bao, Jiang, and Pan (2010) sample is from May 2003 to June 2009. Other regressions are run over our full sample from 1996 to 2013. We compute t-statistics with 12 Newey-West (1987) lags.

Figure 1: Liquidity Adjustment

Panel A: Regular Muni and Liquidity-Adjusted Muni Zeros



Panel B: Prerefunded and Risk-Free Muni Zeros

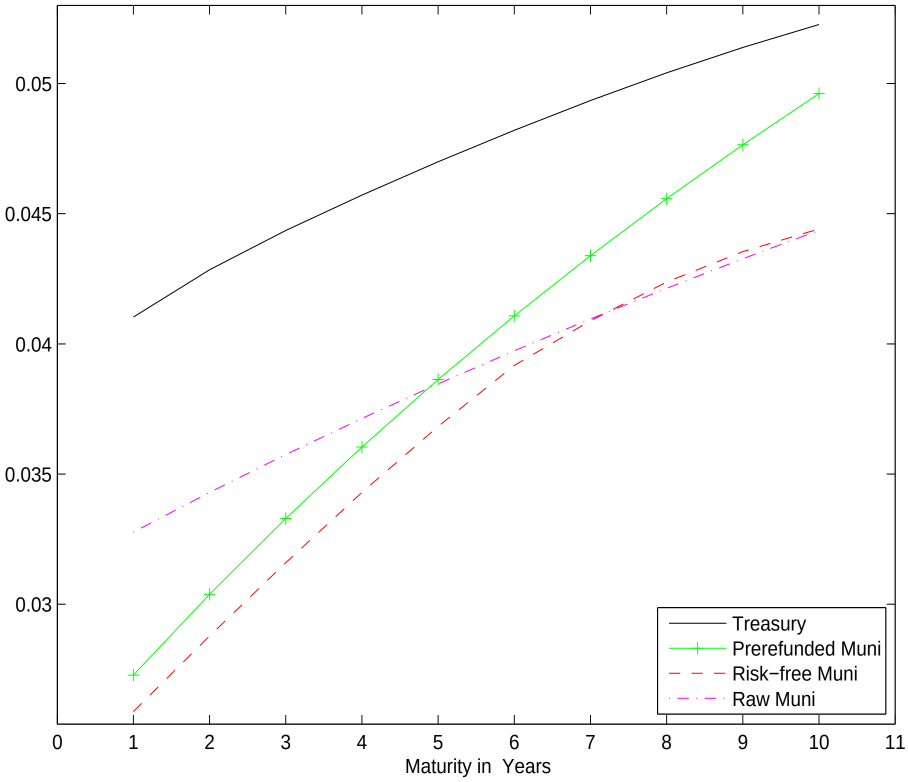


Note to Figure 1

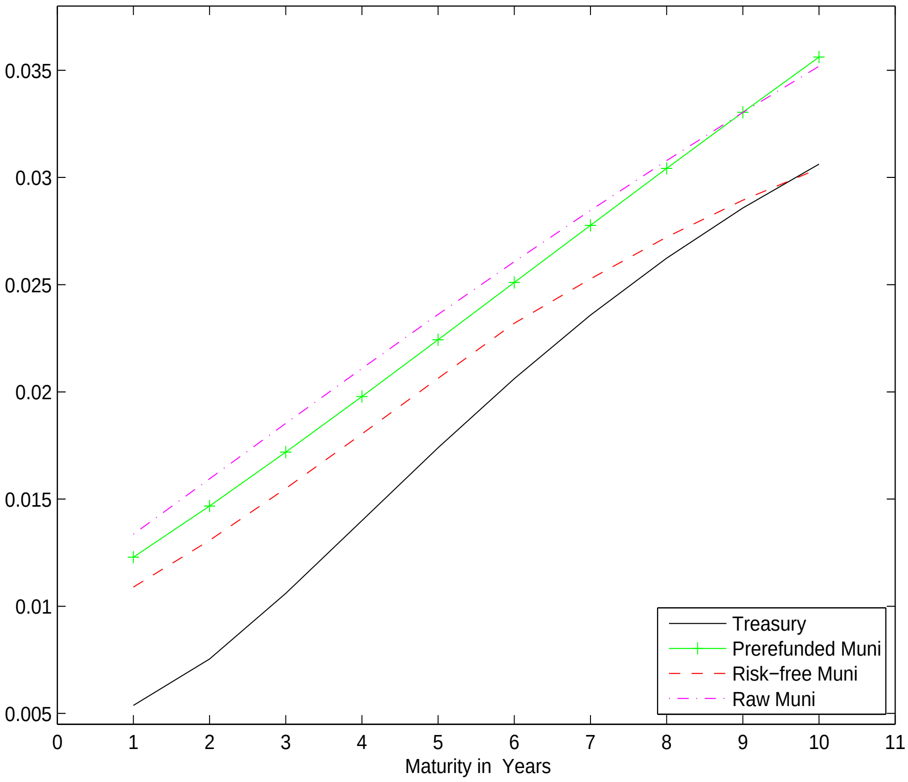
The figure plots muni zero curves averaged over September 2008, following the method of Nelson-Siegel (1987) fitted to straight bonds every trading day. In Panel A, we plot spot rates for the full set of regular munis and regular munis with the same liquidity characteristics as prerefunded munis ("liquidity-matched" munis). The latter have high price impact and lower turnover than regular munis. We refer to the difference between the liquidity-matched zeros and the regular muni zeros as the "liquidity adjustment." In Panel B, we apply the liquidity adjustment to the prerefunded muni zero curve. We adjust the prerefunded muni zeros downward by the liquidity adjustment to form the "risk-free muni" zero curve.

Figure 2: Risk-Free Muni and Treasury Zero-Coupon Term Structure

Panel A: Average Yield Curves 1996-2007



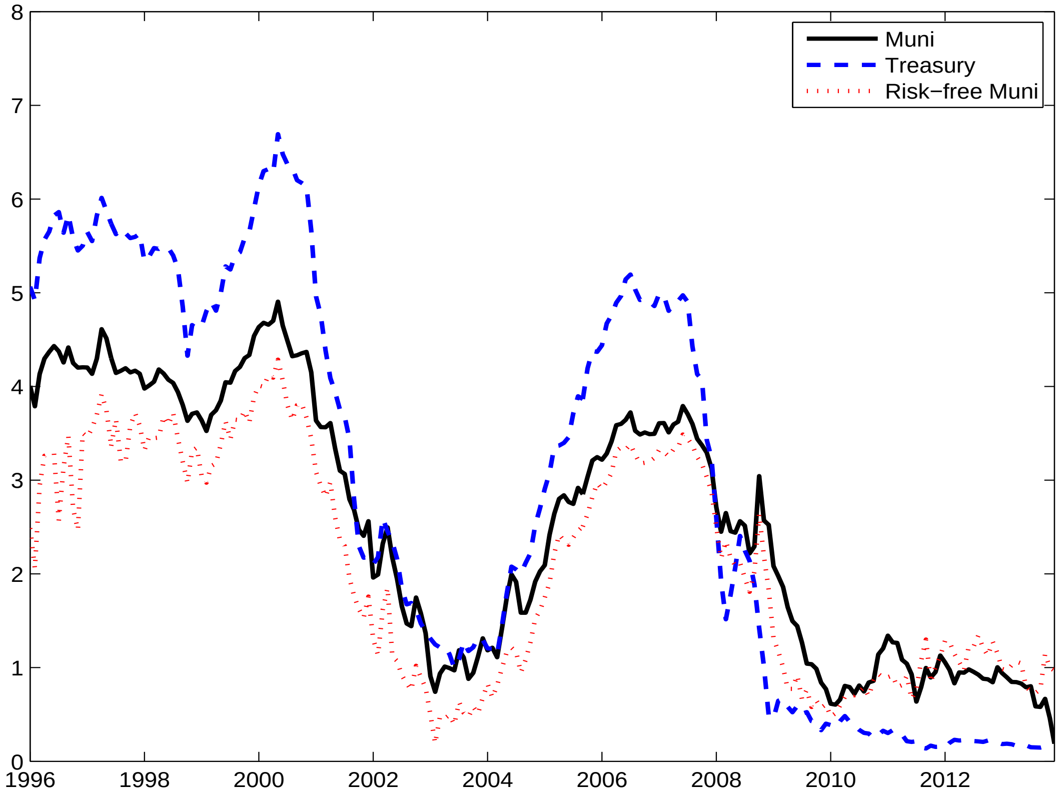
Panel B: Average Yield Curves 2008-2013



Note to Figure 2

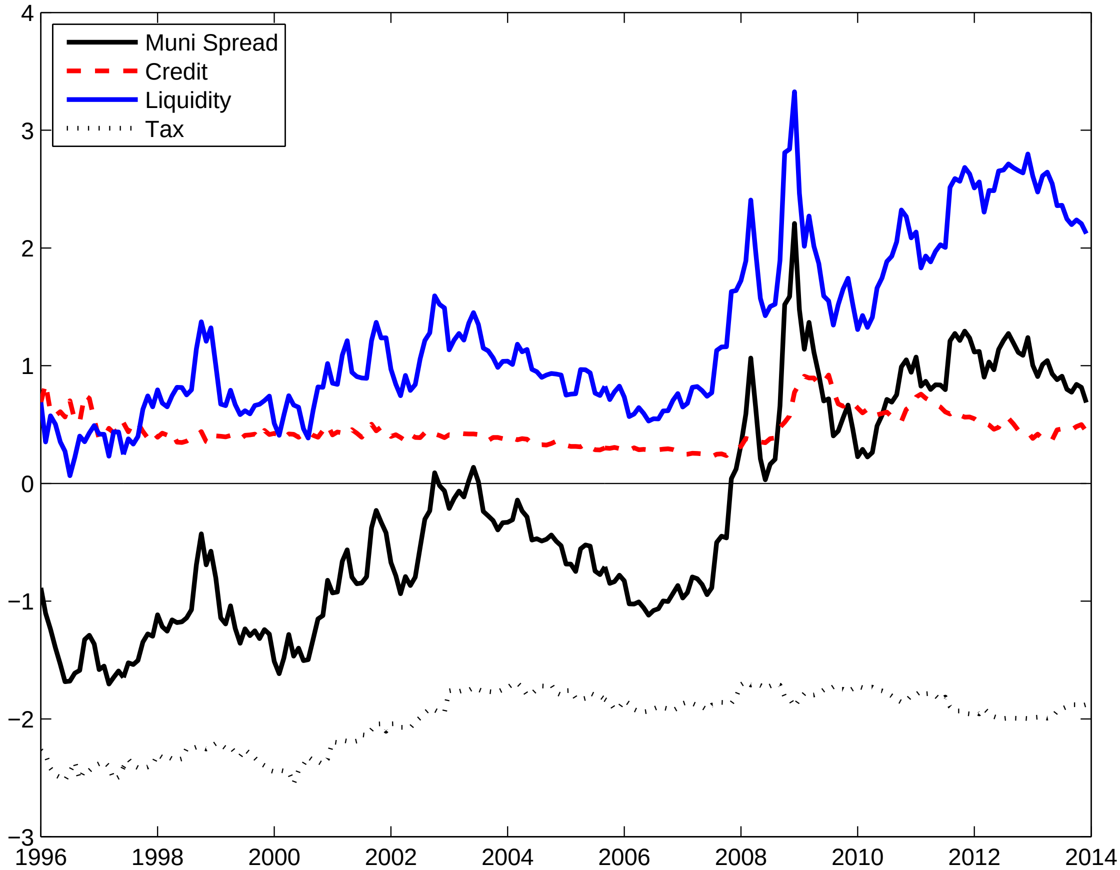
We plot the average zero-coupon curve for Treasuries, munis, prerefunded munis, and risk-free munis for two subsamples: 1996-2007 and 2008-2013 in Panels A and B, respectively. The Treasury zeros are updated from Gürkaynak, Sack, and Wright (2007). The zero yields for regular munis and prerefunded munis are computed following Nelson and Siegel (1987) using transaction-level data. We compute different zero curves for each trading day. The risk-free muni discount curve is computed with Nelson and Siegel (1987) applied to prerefunded muni transactions with a liquidity adjustment to account for their greater illiquidity, as detailed in Section 3.2.

Figure 3: Five-Year Zero-Coupon Rates



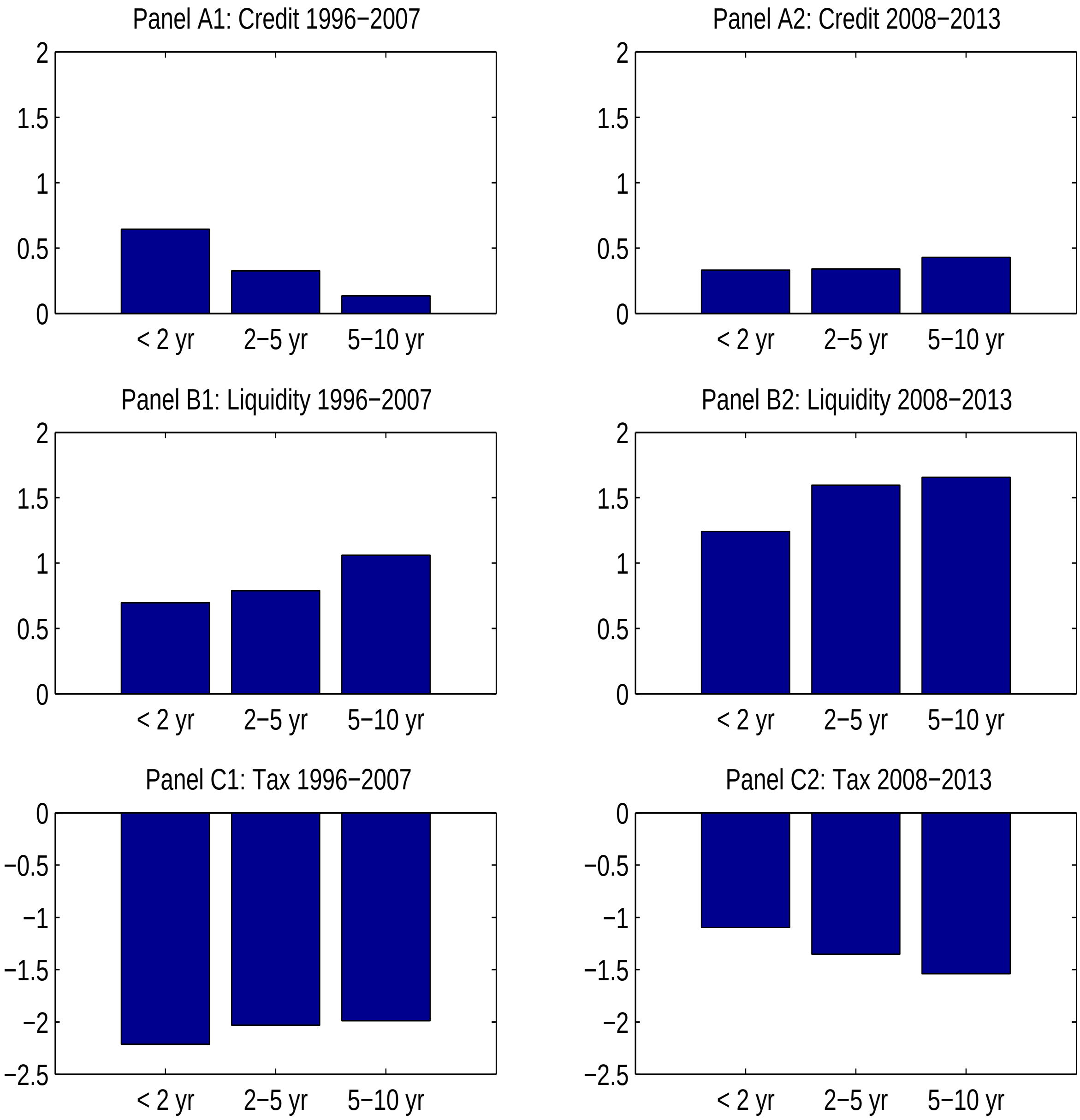
We plot regular muni zero-coupon rates, risk-free muni zero-coupon rates, and Treasury zero-coupon rates, all for the five-year maturity. Our sample is from January 1996 to December 2013. Units on the y-axis are in percentages.

Figure 4: Muni Spreads: Credit, Illiquidity, and Tax Components



We plot the time series of the muni spread, and its constituent components: credit, liquidity, and tax from January 1996 to December of 2009. The three components sum to give the muni spread. Units on the y-axis are in percentages.

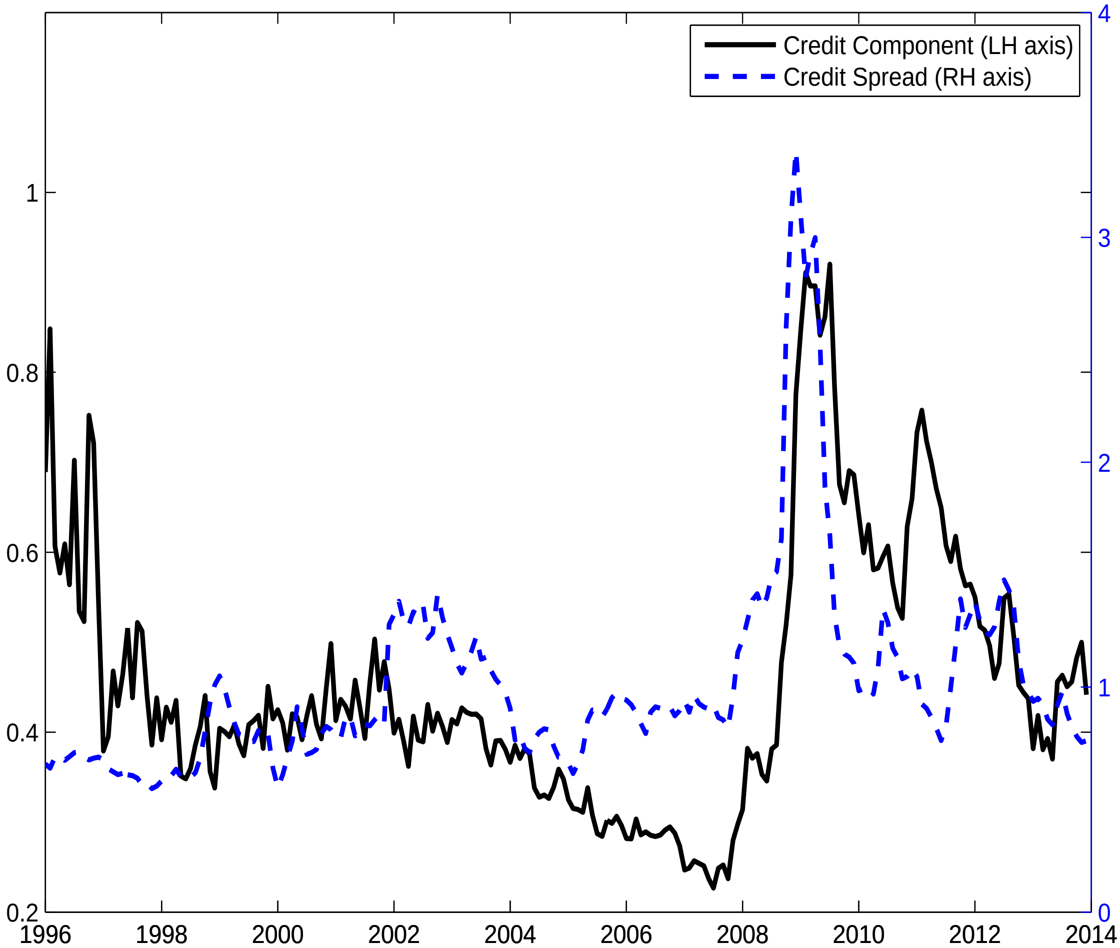
Figure 5: Term Structure of Muni Spread Components



Note to Figure 5

We plot the credit, liquidity, and tax components broken down by different maturity buckets. We divide all municipal bonds into three different maturity bins and compute the three components for each bin. Units on the y-axis are in percentages. Graphs in the left-hand and right-hand columns correspond to the subperiod 1996-2007 and 2008-2013, respectively.

Figure 6: Credit Risk Comparison

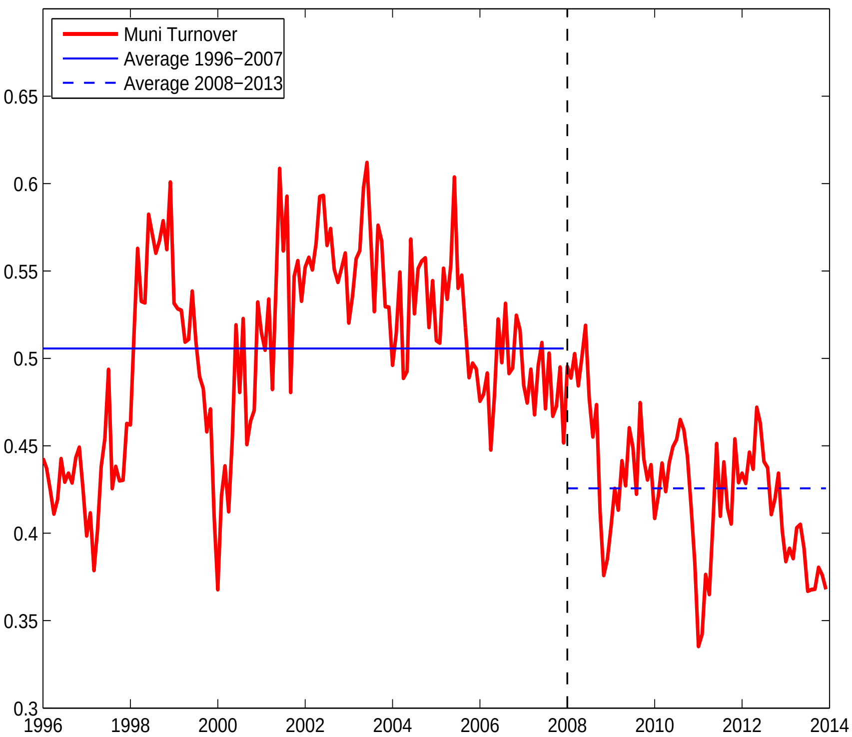


We compare the credit component (left-hand y-axis) with the credit spread (right-hand y-axis). Units on the left- and right-hand y-axes are in percentages.

Figure 7: Municipal Bond Liquidity

Panel A: Price Impact

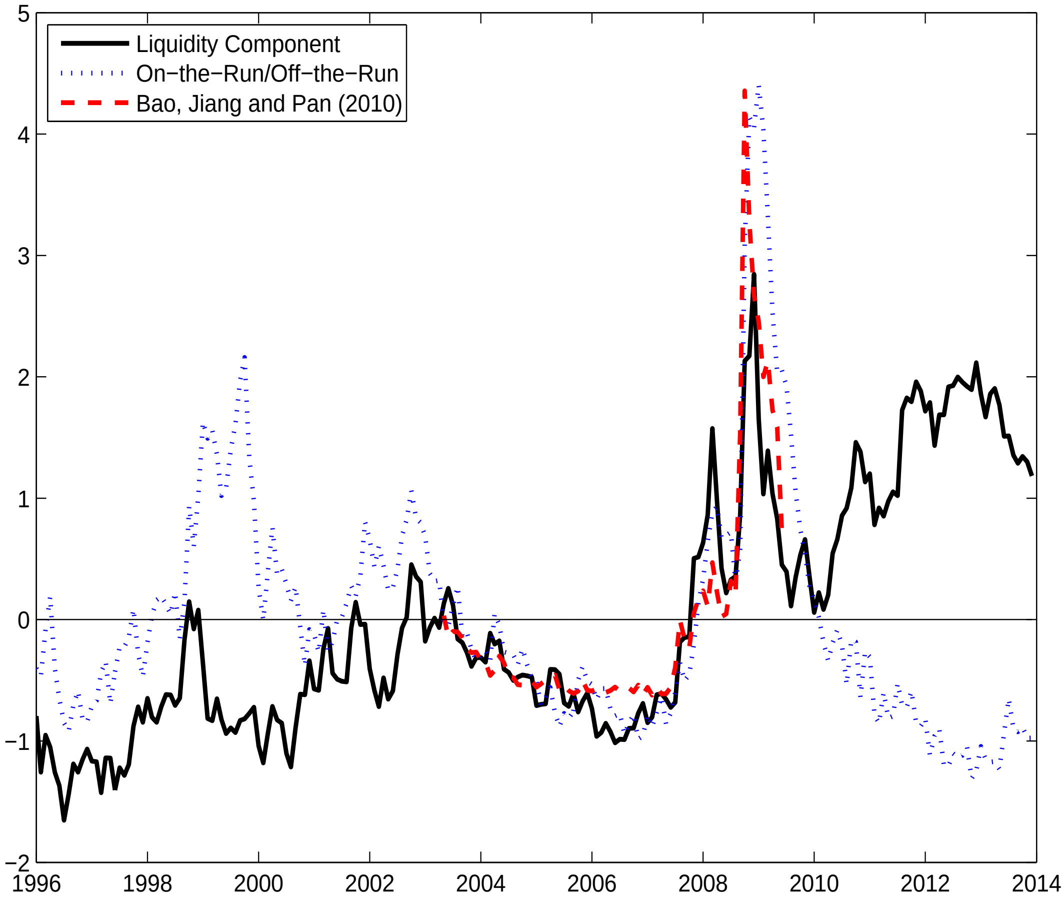
Panel B: Turnover



Note to Figure 7

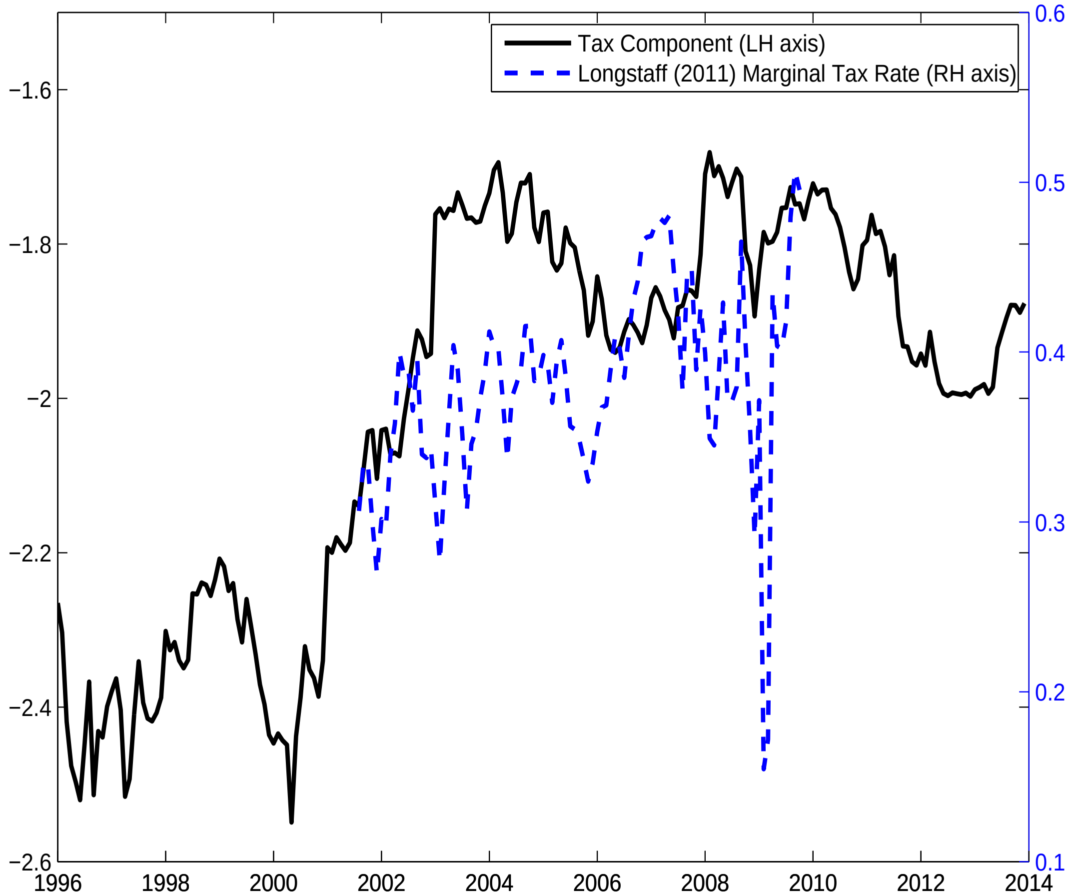
Panel A plots price impact and Panel B turnover in the muni market over 1996 to 2013. Following Amihud (2002), the price impact is defined as the absolute percentage price change between the last and current transaction divided by the par amount traded. We scale the measure by a factor of one million. Price impact is artificially low in the first two years because the MSRB data only counts interdealer trades during this time. The turnover statistic is defined as the average par value traded each month expressed as a fraction of total outstanding par value. It is expressed as a percentage. We draw a vertical dashed line to mark January 1, 2008 and then plot the average liquidity measures before and after this date in horizonal lines.

Figure 8: Illiquidity Risk Comparison



We compare liquidity component with On-the-Run liquidity premium, average percentage zero return in stock market and Bao, Jiang and Pan (2010) liquidity risk proxy. We normalize all variables to mean zero and unit standard deviation.

Figure 9: Tax Risk Comparison



We plot the muni tax component (left-hand y-axis) together with Longstaff's (2011) marginal tax rates (right-hand y-axis) estimated from muni swaps. Units on the left- and right-hand y-axes are in percentages.