Default Risk Cannot Explain the Muni Puzzle: Evidence from Municipal Bonds That Are Secured by U.S. Treasury Obligations

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Fama (1977) and Miller (1977) predict that one minus the corporate tax rate will equate after-tax yields from comparable taxable and tax-exempt bonds. Empirical evidence shows that long-term tax-exempt yields are higher than theory predicts. Two popular explanations for this empirical puzzle are that, relative to taxable bonds, municipal bonds bear more default risk and include costly call options. I study U.S. government secured municipal bond yields which are effectively default-free and noncallable. These municipal yields display the same tendency to be too high. I conclude that differential default risk and call options do not explain the municipal bond puzzle.

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The muni puzzle refers to the unexplained relation between the yields of tax-exempt and taxable bonds. More specifically, long-term tax-exempt bond yields appear to be too high relative to yields on taxable bonds, while short-term tax-exempt yields are generally consistent with financial theory. The following excerpt from *The Wall Street Journal* describes a typical comparison between long-term tax-exempt yields and long-term taxable yields:

> [S]ome seven-year tax-free bonds with high credit ratings now yield about 4.5%. Seven-year Treasury notes yield about 5.3%. But for an investor in the 36% federal tax bracket, that 5.3% on the Treasury note shrinks to only 3.4% after taxes—or about one full percentage point less than the muni issue offers.[1]

Obvious differences between tax-exempt and taxable bonds provide a natural starting point for an investigation into the muni puzzle. One clear difference between municipals and Treasuries is that while municipal defaults are possible, U.S. government bond default is unthinkable. Not surprisingly, a widely cited explanation for high relative municipal yields is that municipal default risk exceeds the default risk of corporate and U.S. Treasury bonds [e.g., Fama (1977), Trzcinka (1982), Yawitz, Maloney, and Ederington (1985), Scholes and Wolfson (1992), Stock (1994)]. Another common explanation relies upon differences in the standard call provisions included in taxable and tax-exempt bond issues. Municipal bonds usually provide the issuer the option to call bonds 10 years from the date of issue, while government bonds are normally noncallable. Because differences in default risk and call options have the potential to raise required municipal yields relative to comparable maturity Treasuries, these explanations have received considerable attention and to varying degrees are used to explain the muni puzzle.

I document the relative yields of U.S. Treasury bonds and municipal bonds that are secured by U.S. government bonds, referred to as prerefunded, advance refunded, or defeased municipal bonds. This sample of prerefunded bonds allows me to document the relative yields of taxable and tax-exempt bonds that do not differ with respect to default risk or the call provisions attached to the bonds. The muni puzzle is still present in these data. I find that the yield spread between tax-exempt prerefunded bonds and taxable government bonds decreases as term to maturity increases. I conclude that differences in risk or call provisions do not explain the long-standing puzzle posed by the relative yields of high-quality taxable and tax-exempt bonds.

[1] "Municipal Bonds Blossom Under New Tax Law," *The Wall Street Journal*, November 5, 1993, C1.

The results of this article exclude two commonly mentioned explanations for the muni puzzle, but the question remains: What explains municipal bond yields? A brief description of some possible explanations at the outset provides useful perspective. A popular hypothesis, supported by Mussa and Kormendi (1979) and Kidwell and Koch (1983) implies that investors in different marginal tax brackets have distinct maturity preferences, or "preferred habitats." The marginal tax rates of the clientele at each maturity lead to implied tax rates that decline with maturity. Alternatively, Constantinides and Ingersoll (1984) develop a theory of the relation between tax-timing options and the relative yields. Empirically Jordan and Jordan (1990) find that the basic features of a tax-timing option are potentially important factors in explaining the relative yields. Another explanation considers the U.S. government's option to rescind the tax-exemption feature of municipal bonds. In 1988 the Supreme Court ruled in *South Carolina v. Baker* that the U.S. government has a right to tax interest on municipal bonds [see Poterba (1989) for details]. In principle, the characteristics of the government's option are consistent with the observed relative yields. Most recently, Green (1993) argues that dealer arbitrage activities *within* the market for *taxable bonds* substantially reduce the impact that taxes have on long-maturity taxable bond prices. Empirical evidence in Green (1993) and Chalmers (1995) finds that Green's model cannot be rejected.

Continued effort to understand the pricing of tax-exempt bonds is worthwhile for at least two reasons. First, municipal bonds comprise a significant segment of the U.S. capital markets. In 1995 there was $1.3 trillion in outstanding municipal debt. For a point of reference, outstanding marketable U.S. Treasury debt totaled $3.3 trillion in 1995. Second, the role of taxes in asset pricing is unresolved. Unlike tests for tax effects in the equity markets, tax-exempt and taxable bonds provide the opportunity to study the valuation of certain rather than expected before-tax cash flows. Theoretically, after-tax cash flows arriving at the same time should be discounted at identical after-tax discount rates. Calculating the tax effect with fixed cash flows appears straightforward. The fact that economists cannot explain the role of taxes in such a simple case underscores the complexity that taxes introduce to asset pricing. A more complete understanding of the simple case of tax-exempt and taxable bonds is likely to provide insight into the role taxes play in the pricing of other assets.

This article is organized as follows: Section 1 reviews the literature on the muni puzzle. Section 2 describes prerefunded bonds and institutional details of the tax-exempt bond market. Section 3 describes the data. Section 4 shows that the muni puzzle persists with municipal yields calculated from default-free municipal bonds. Section 5 concludes. The Appendix describes details concerning the estimation of the municipal and government term structures.

1. Review of Theory and Evidence

The intuitive notion behind comparisons of relative yields is that investors, who have decided to purchase a bond, will choose the bond that provides the largest after-tax return. This idea suggests an equilibrium like Equation (1):

$$y_{M,t}(N) = (1 - \tau)\, y_{G,t}(N). \tag{1}$$

That is, $y_{M,t}(N)$, the municipal par-bond yield at date t for maturity N, is given by one minus the tax rate of the marginal bondholder, $1 - \tau$, times $y_{G,t}(N)$, the taxable government par bond yield for maturity N, where a par bond yield is defined as the coupon rate that enables a bond to sell at par. As Green (1993) notes, par-bond yields are convenient because they allow direct comparisons of cash flows from taxable and tax-exempt bonds. Furthermore, if held to maturity, par bonds will never realize capital gains or losses which simplifies issues related to differences in the tax treatment of capital gains and losses for taxable and tax-exempt bonds. Given that $y_{M,t}(N)$ and $y_{G,t}(N)$ are observable, an implied tax rate $\tau_t^i(N)$, can be calculated:

$$\tau_t^i(N) = 1 - \frac{y_{M,t}(N)}{y_{G,t}(N)}. \tag{2}$$

Under the simplifying assumption that the tax rate on equity returns is zero, Miller (1977) hypothesizes that the corporate capital structure decision between debt and equity will force equilibrium levels of corporate interest rates to follow Equation (1), where τ is the highest marginal corporate tax rate. Fama's (1977) bank arbitrage model also predicts that Equation (1) should hold with τ equal to the top marginal corporate tax rate. Fama argues that, because banks were legally able to deduct interest expense incurred to carry municipal bonds from taxable income, banks would borrow at an effective rate of $(1 - \tau_c)y_{G,t}(N)$ and invest in tax-exempt bonds earning $y_{M,t}(N)$. Thus arbitrage activity by banks would ensure that Equation (1) holds. The Tax Reform Act of 1986 eliminated this arbitrage opportunity for banks.[2] However, the tax code continues to allow all nonfinancial U.S. corporations to hold up to 2% of their assets in tax-exempt bonds

[2] Interest expense a bank incurs to buy "bank eligible" bonds remains deductible. However, bank eligibility is limited to public purpose issuers (cities, states, or school districts) issuing less than \$10 million per year.

and simultaneously deduct the interest on attributed debt from their taxable income.[3] In aggregate, this implies that substantial arbitrage opportunities for corporations exist if the implied tax rate is less than the highest marginal corporate tax rate.

Consistent with the Fama (1977) and Miller (1977) prediction, Jordan and Pettway (1985), Poterba (1986), and Jordan and Jordan (1990) show that *short-term* tax-exempt bond yields are, on average, equal to one minus the highest marginal corporate tax rate times the short-term taxable yield.[4] However, Arak and Guentner (1983), Poterba (1986), and many others find that *long-term* municipal bond yields tend to be much higher than predicted by Fama (1977) and Miller (1977). This is the muni puzzle.

Figure 1 illustrates the muni puzzle. As described, the yield spread between tax-exempt and taxable yields decreases with maturity. Alternatively, if the yield spread narrows with maturity, implied tax rates calculated from the taxable and tax- exempt yields decline with maturity. Depicting the muni puzzle as a declining term structure of implied tax rates is a convenient way to view the puzzle over time. Using data from Poterba (1986), Figure 2 plots the term structure of implied tax rates from 1973 to 1983. Figure 2 shows that the declining term structure of implied tax rates is present in every year from 1973 to 1983. The muni puzzle is a pervasive empirical fact.

Several hypotheses suggest that properties of municipal bonds increase the required rate of return of long-term tax-exempt bonds relative to long-term taxable bonds. This article addresses the differential default risk and differential call option hypotheses. Fama (1977) suggests and Trzcinka (1982), Yawitz, Maloney, and Ederington (1985), and Stock (1994) support the hypothesis that municipal default risk is an important factor in determining the relative yields, even when yields from high-quality municipal bonds are analyzed. Trzcinka's hypothesis is that municipal bond ratings are not directly comparable to corporate bond ratings. Trzcinka (1982) cites three reasons why municipal bonds have higher default premiums than corporate debt of the same rating. First, Hempel (1972) argues that municipal assets may be more difficult to seize in bankruptcy. Second, Zimmerman (1977) suggests that information costs are higher for municipal bondholders than for corporate bondholders because municipal financial statements are less informative. Third, Fama (1977) points out that

[3] See Scholes and Wolfson (1992, p. 337, footnote 4). In 1995 Congress considered eliminating the 2% rule for all corporations.

[4] Rabinowitz (1994) examines 7-day tax-exempt yields relative to 7-day LIBOR and argues that they do not conform to the Fama and Miller benchmark. Nonetheless, the effect is much more pronounced in longer-term bonds.

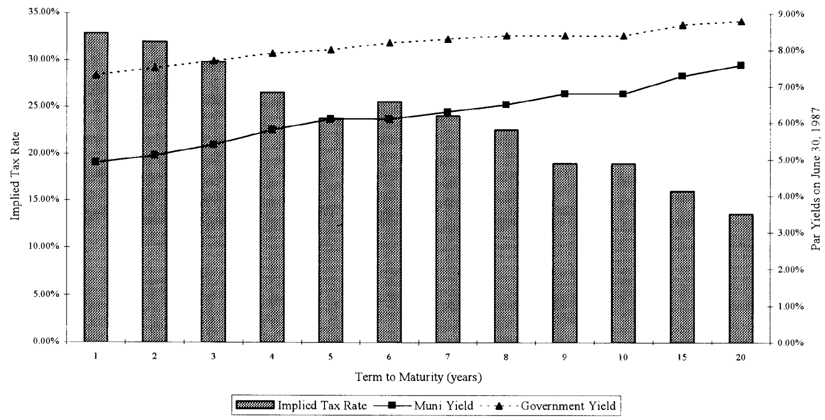

Figure 1
Two perspectives on the muni puzzle: relative yields and implied tax rates
Term structure estimates from June 30, 1987, provide a representative set of par bond yield curve estimates for the government and prerefunded municipal bond samples. Implied tax rates are calculated from the par bond yield estimates.

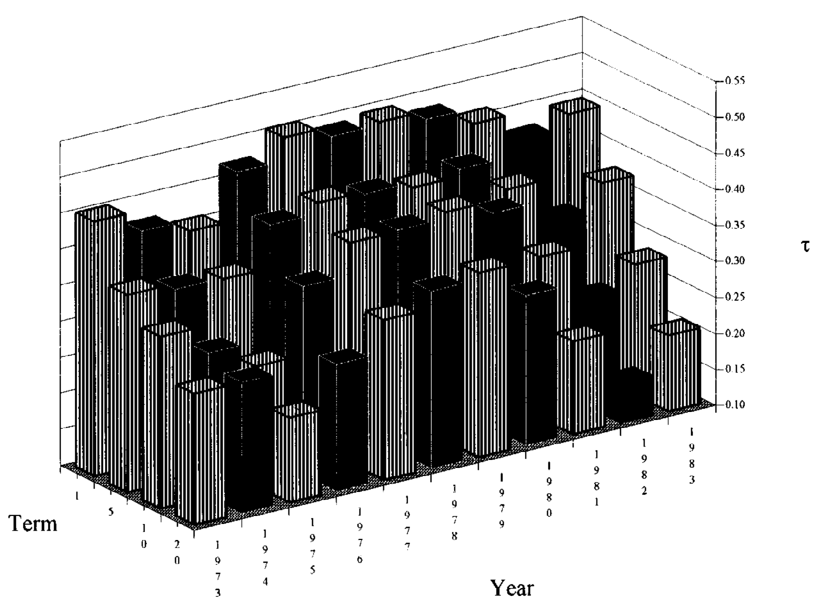

Figure 2
Historical term structure of implied tax rates: 1973–1983
Annual average implied tax rates for 1, 5, 10, and 20 year par bond maturities calculated by Poterba (1986) using monthly par bond yields from Salomon Brothers' *Analytical Record of Yields and Yield Spreads*.

the political objective function is far more difficult to understand than corporate profit maximization.

Trzcinka tests the differential default risk hypothesis using Equation (3):

$$y_{M,t}(N) = \lambda_t(N) + \beta y_{G,t}(N). \tag{3}$$

The parameters in Equation (3) are estimated separately for various maturity and rating pairs using Cooley and Prescott's (1976) procedure. $\lambda_t(N)$ is interpreted as a time-varying default premium which is paid on municipal bonds of maturity N, with time indexed by t. The estimates are compared across maturities and ratings. Trzcinka finds that none of the estimated β's are significantly different from $(1 - \tau_c)$ at the 5% significance level. Furthermore, the estimates of $\lambda_t(N)$ are generally greater for longer-maturity bonds and lower-grade bonds. Trzcinka (1982) cites this result as support for the hypothesis that differences in default risk explain the declining term structure of implied tax rates.

Three studies, Gordon and Malkiel (1981), Skelton (1983), and Ang, Peterson, and Peterson (1985), dispute the interpretation of Trzcinka's results. The first two articles study bonds with similar issuers but different tax status in order to control for default risk. Gordon and Malkiel (1981) examine five bond issues where a single issuer offered tax-exempt and taxable issues on the same day with roughly similar terms. Ang, Peterson, and Peterson (1985) match corporate taxable and tax-exempt bond pairs by similar issuers, with similar characteristics. Both studies reject the hypothesis that the implied marginal tax rate was equal to the corporate tax rate for bonds of all maturities. Skelton (1983) addresses the relative risk question by comparing the returns of an equally weighted index of 20 frequently traded municipal bonds to the returns of a high-quality corporate bond index. Skelton finds that corporate and municipal bond returns have similar standard deviations and similar covariances with stock returns. Skelton concludes that relative risk differences are small between corporate and municipal bonds. The results from these three articles are inconsistent with the differential default risk explanation.

Despite the results from these three studies, municipal default risk remains a popular explanation. Recent studies, including Yawitz, Maloney, and Ederington (1985), Scholes and Wolfson (1992), and Stock (1994), cite risk differences as a part of the explanation for the behavior of relative yields on taxable and tax-exempt bonds.[5] Yawitz,

[5] For example: "This [decline in the term structure of implied tax rates] might be due, in part, to differences in risk and differences in the call features associated with long-term municipal bonds compared to taxable bonds" [see Scholes and Wolfson (1992, p. 368)].

Maloney, and Ederington (1985) imply that default probabilities are critical in the valuation of high-grade municipal bonds. For prime grade municipals they estimate implied default probabilities are between 1.5 and 3%. Furthermore, there are theoretical reasons to believe that default risk will cause the term structure to have a steeper slope. For example, Kim, Ramaswamy, and Sundaresan (1993) argue that credit spreads for high-quality coupon bonds increase with maturity because longer bonds have more coupons subject to default risk. This relation between term to maturity and the credit spread is consistent with long-term municipal yields being higher than predicted by the Miller or Fama models of relative yields.

My tests control for default risk in the spirit of Gordon and Malkiel (1981), but utilize a larger sample of municipal securities over an extended sample period. The evidence in this article implies that default risk and differences in call provisions do not help to explain the observed relative yields. This confirms the suspicions of Poterba (1986), Kochin and Parks (1988), Jordan and Jordan (1990), and Green (1993), who have noted that if municipal default risk is to explain this puzzle the implied default probabilities for municipals would have to be unreasonably large. My results are also consistent with the paucity of municipal defaults. During the period from 1940 to 1994 the Public Securities Association reports that 2,020 of 403,152 long-term municipal bond issues, or 0.5%, experienced a technical or actual default.

2. Description of Prerefunded Bonds

The Fama (1977) and Miller (1977) prediction may not be observed in the data unless differences between taxable and tax-exempt bonds are controlled. To fully control for differences in taxable and tax-exempt bonds the following six conditions must hold:

(i) Risks are similar.
(ii) Bonds are not callable, so the maturity date and maturity price are certain.
(iii) Liquidity and transaction costs are similar.
(iv) Federal tax applies to one bond and tax payments are due when coupons are received.
(v) State tax treatment is the same for all bonds.
(vi) Capital gains and losses have the same tax treatment and both bonds are currently selling for the same price.[6]

[6] Condition 6 is moot if both bonds are selling at par and bonds are priced as if they are to be held to maturity.

This section discusses how these six conditions apply to U.S. government bonds and prerefunded municipal bonds.

2.1 Risk of default

Both government bonds and prerefunded bonds are nominally riskless. Prerefunded municipal bonds are tax-exempt bonds that have been defeased by an escrow of noncallable U.S. government securities. In legal terms, defeased means that the debt has been paid, even though the debt has not been retired. The defeasance escrow is structured in a manner such that principal and interest payments received from the escrowed portfolio of U.S. government securities meet or exceed (without reinvestment) the payments required over the remaining life of the refunded municipal bonds. Structuring a defeasance portfolio is a linear programming problem. The constraints are the payments due on the bonds that are being refunded. The objective is to minimize the cost of the portfolio of government securities that will provide cash flows greater than or equal to the cash flows of the bond that is being refunded and comply with investment restrictions in the tax code. Given that defeased bonds are secured by U.S. government securities, it is reasonable to assume that defeased municipal bonds are nominally riskless.[7]

2.2 Call features

Most U.S. government securities are issued without any call options. By selecting only those securities that are noncallable, the government bonds in my sample have a certain maturity date and maturity price. Most long-term municipal bonds include a 10 year call provision when they are issued. Another advantage of studying prerefunded bonds is that they are effectively noncallable bonds. This is because the option component of the call is extinguished at the refunding date. Usually the escrow trustee is instructed to exercise the call option at the first available call date; any resulting call premium is included in the cost of the refunding escrow. Therefore at the refunding date the call date becomes the bond's effective maturity date and the redemption price (par plus the call premium) is the defeased bond's new maturity price. If a bond is escrowed to maturity, the maturity date and maturity

[7] There exists one case in Wedowee, Alabama, in which a defeased municipal bond was placed in technical default. The *Bond Buyer* (the municipal bond industries daily paper) reported on March 14, 1994 that two related defeased issues in Wedowee, Alabama, were in default. It can be argued that the entire default precipitated because of a mistake made by the escrow trustee. The trustee incorrectly alleged that Laventhol and Horwath (a defunct accounting firm) had incorrectly verified the cash flows from the refunding escrow and placed the $5.7 million bond issue in default. This isolated case of a technical default illustrates that there is some uncertainty beyond that which you would incur if you held direct investments in U.S. Treasury bonds.

Table 1
Relative size and components of the U.S. bond market (1995)

Security Type	Par Value (billions)	Daily Volume (billions)	Outstanding Issues	Number of Issuers
U.S. Treasury bills, notes & bonds	$3,292	$193.2	208 Notes and Bonds 32 Bills	1
Municipal bonds	$1,301	$3.0	1.2 Million CUSIPS	50,000
Corporate bonds[a]	$1,823	NA	40–50,000 (c)	4,500(c)
Mortgage backed[b]	$1,570	$45.0	NA	3

[a]Includes U.S.-based and non-asset-backed corporate issues.
[b]Includes only GNMA, FNMA, and FHLMC mortgage-backed securities.
[c]Rough estimates by Moodys' Investor Services.

Sources: Public Securities Association, Monthly Statement of the Public Debt, Moodys' Investors Services, Federal Reserve Board, Fabozzi and Fabozzi (1995, p. 155).

payment maintain the original terms of the bond, with the exception that any call options are canceled on the date of the defeasance.[8]

2.3 Bond market liquidity

Liquidity issues are relevant for two reasons. First, liquidity differences between the taxable and tax-exempt market may help to reconcile the observed relative yields with the Fama (1977) and Miller (1977) hypotheses. Table 1 presents data to support the presumption that the Treasury bond market is more liquid than the municipal bond market. Average daily trading volume of Treasuries is $193 billion, while for the entire municipal bond market trading volume is estimated at $3 billion per day. At least as important, the trading volume for Treasuries is spread over only 230 different issues of bills, notes, and bonds. Contrast the structure of the Treasury market with the municipal bond market which is comprised of an estimated 1.2 million distinct bonds with vast heterogeneity in terms of security, maturity, and applicable tax rules. As a result, the muni market is a thin market where most bonds are unlikely to trade at all on a given day. Furthermore, the costs of adverse selection may be substantially higher in the municipal bond market.[9]

The second liquidity issue concerns the relative liquidity of prerefunded municipal bonds and municipal bond yields used by prior researchers. If prerefunded bonds are less liquid than the highly rated municipal bonds that Salomon Brothers uses to determine its yield

[8] In 1986, Kansas City attempted to exercise unused call provisions in an escrowed to maturity issue and extract excess escrow funds by redeeming bonds early, but this transaction never transpired. Despite new contracts that explicitly cancel call provisions in escrowed to maturity issues, municipal bond traders suggest that some investors remain wary of escrowed to maturity issues [see Fabozzi, Fabozzi, and Feldstein (1995 p. 36)].

[9] For example, see *Wall Street Journal*, "Municipal Bondholders Need More Information," March 27, 1987.

estimates, then it is possible that tests of the differential default risk hypothesis are confounded. However, anecdotes from market participants allay this concern. Without exception, municipal bond traders have told me that prerefunded bonds are among the most liquid of all municipal bonds due to their homogeneous collateral.[10] For example, traders have suggested that a 7 to 8 year maturity prerefunded bond trades with a spread of one-eighth of a dollar for institutional trades and up to three-quarters of a dollar for retail customers.

2.4 Federal taxes

The coupons and capital gains received from investments in U.S. government bonds are subject to federal taxation. The coupons and amortized original issue discount received from an investment in municipal bonds are not subject to federal taxation; however, capital gains earned on municipal bonds are subject to federal taxation.

2.5 State taxes

Interest from U.S. government bonds is excluded from income for state tax purposes in every state of the United States. However, interest earned on municipal bonds is not necessarily excluded from state income taxes. In 1986 all but five states (Illinois, Iowa, Kansas, Oklahoma, and Wisconsin) exempted municipal bond interest from state income tax provided that the bonds were issued within the state of the bondholder's residence [see Andrew (1987, Appendix 3)]. In 32 states, interest from out-of-state municipal bonds is taxed as income. In 13 states and the District of Columbia, there is no income tax on interest income from a tax-exempt bond issued by any authority. Interest earned from tax-exempt bonds issued by territories of the U.S. (Puerto Rico, Guam, and Virgin Islands) is exempt from state taxes in every state. In most states, the capital gains tax is applied to gains on municipal bonds whether issued in state or out of state. As a result, differences exist in the pricing of bonds depending on their state of issue. For example, high-quality Puerto Rico bonds tend to sell at premium prices relative to other issues because of their exemption from state taxes in every state in the United States. However, anecdotal evidence in Green (1993) implies that while state tax differences induce small parallel shifts in municipal yield curves, state taxes do not affect the slope of the municipal term structure.

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[10] Municipal bond traders also mention that bonds which sell at large premiums to par tend to sell at higher yields than bonds selling close to par. Because much of my sample includes premium bonds this issue is noteworthy.

2.6 Tax treatment of capital gains and losses

It is difficult to completely control for the different tax treatment of capital gains and losses in comparisons between government and municipal bonds. Both tax-exempt and taxable bonds purchased at a discount in the secondary market accrue taxable capital gains at the time of sale or maturity. However, the treatment of the premium bonds differs for taxable and tax-exempt bonds. The premium over par paid for a taxable bond may be amortized and taken as an annual tax deductible loss over the life of the bond.[11] While the purchaser of a premium municipal bond must amortize the bond's basis, the amortized premium *cannot* be taken as an expense for tax purposes. If the premium municipal bond is subsequently sold, the basis for computing capital gains or losses is the depreciated basis not the original purchase price. Constantinides and Ingersoll (1984) have pointed out that this difference in the tax treatment of premium bonds results in an inferior tax-timing option on municipal bonds selling at a premium.

2.7 Summary

There are several advantages to studying the prices of defeased municipal bonds. First, the payments on prerefunded bonds are nominally riskless because bond payments come from the U.S. government after passing through an irrevocable escrow account. Second, prerefunded bonds have a certain maturity date and maturity price because call options that exist in the refunded bonds are extinguished by the refunding process. Third, the liquidity of prerefunded bonds is comparable if not better than the liquidity of any other municipal bond in the secondary market. Fourth, prerefunded bonds maintain their status as tax-exempt bonds for federal tax purposes. Despite these benefits, problems common to most studies of municipal bond yields persist. State taxes are very difficult to control for because of the heterogeneity among issuers and investors involved with municipal bonds. Likewise, differences in the treatment of capital gains and losses may actually help to explain the pricing relations between taxable and tax-exempt bonds. However, because these problems apply equally to all tax-exempt bonds, there is no reason to expect that these imperfections will affect inferences related to the differential default risk or call option hypotheses.

[11] The premium on bonds issued prior to September 27, 1985, can be amortized on a straight-line basis. Bonds issued after September 27, 1985, must amortize the premium on a yield basis (i.e., geometrically at the yield to maturity). See Kramer (1986, section 27), *Fundamentals of Municipal Bonds* (p. 118), and Constantinides and Ingersoll (1984).

3. Data Description

3.1 Prerefunded municipal bond data

The defeased municipal bond data used in this study are provided by J. J. Kenny and Co., Inc. J. J. Kenny is one of the largest providers of municipal bond valuation services and the largest interdealer broker of municipal bonds.[12] Valuation clients include many of the largest tax-exempt mutual funds, bank trust departments, bank treasury departments, and financial publications. J. J. Kenny values municipal bonds with pricing grids. Grid prices are J. J. Kenny's estimates of a bond's value. There are several reasons to believe that grid prices will, on average, provide accurate pricing. First, grid prices have an economic impact on investors. On any given day, grid prices are used to value 75 to 80% of the bonds held by open-end municipal bond funds to determine net asset value. Given that open-end funds trade at net asset value, these grid data determine the prices at which fund shares are bought and sold. Second, the methodology used at J. J. Kenny to estimate grid prices makes extensive use of transaction prices collected through J. J. Kenny's municipal bond brokerage business. Finally, although unique errors in the pricing of a particular bond are likely to exist, as long as these errors are not systematic, any individual pricing error's impact on estimated yields will be diversified away in a large sample.

J. J. Kenny provides month-end price estimates for up to 1,400 prerefunded issues from January 1984 through August 1991. The sample changes over time as maturing bonds drop out of the sample, as newly refunded bonds are included in the sample, and because several short-term bonds are added to the sample in 1984–1985 to supplement the sample's short maturities. In addition, prerefunded transaction prices from J. J. Kenny's interdealer broker are included from June 1986 through June 1991. Although the transaction database contains 11,885 trades of prerefunded municipals, only 400 of these trades occur at month-end dates. This limits the transactions data to about 400 usable observations because government bond data are readily available only at month end.[13]

All of the bonds are rated AAA by Standard & Poor's or Aaa by Moody's investors service. The rating agencies check that proper procedures are used to ensure the irrevocability of the escrow and its investment in 100% U.S. government securities. Municipal capital ap-

[12] *Bloomberg: A Magazine for Bloomberg Users*, August 1993, vol. 2, no. 8, p. 66.

[13] A sense of the relation between the grid and transaction prices can be gleaned from 138 bond prices where a grid and transaction price are available for identical bonds on the same day. The mean grid price is 0.5% higher than the mean transaction price for those bonds.

preciation bonds, or zero coupon bonds, and issues sold at an original issue discount have very complicated tax rules and are eliminated from the sample. In addition, grid prices are deleted if less than 1 month remains to maturity for that particular bond. Table 2 provides detailed summary statistics for the sample of prerefunded municipal bonds. Panel A documents the large proportion of the sample that has maturities less than 10 years. Panel B shows that the vast majority of the municipal bond sample is made up of bonds selling at a premium to par. In both panels A and B time variation in the average number of municipal bonds in the sample is observed, from a low of 190 in 1984 to a high of 1,251 bonds in 1989. Panel C provides grand averages of prices, coupons, yields, and maturities as well as the average state corporate and personal tax rates applicable to the bonds in the sample. Note that the average corporate state tax rate is 4.95%. This gives an indication of the potential impact of the state tax exemption for this sample.

3.2 Salomon Brothers' municipal yields

The source of data for nearly all prior research examining tax-exempt and taxable yields is Salomon Brothers' *Analytical Record of Yields and Yield Spreads*. At the beginning of each month, Salomon Brothers' estimates the yields of *new issues* sold at par for various rating categories and maturities. In this article, 1, 5, 10, and 20 year prime grade general obligation par-bond yields are utilized. Prime grade general obligation bonds reflect the yields required to sell AAA-rated bonds that are secured by the taxing authority of the municipal borrower. These bond yields are representative of risky bonds that include standard municipal call options. Because the predominant source of yield data for municipal bond research is the Salomon Brothers' yield data, the Salomon yields provide an important benchmark to which the prerefunded yield data can be compared.

3.3 U.S. Government security prices

The government bond data come from the Center for Research in Security Prices (CRSP) 1993 government bond files.[14] Government notes and bonds are included in my sample if they are noncallable, have coupons that are fully subject to federal tax, and have no special estate tax status. These criteria ensure that the government bond universe has characteristics that are most comparable to the prerefunded tax-

[14] Coleman, Fisher, and Ibbotson (1992) and Warga (1992) have noted that ask prices are less dependable than bid prices in the CRSP database. I use midpoint prices.

Table 2
Municipal bond sample characteristics

Panel A: Municipal bond sample by maturity

Year	N_{obs}	0.5 yr	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr	15 yr	20 yr
1984	190	2.9%	6.4%	5.6%	4.4%	4.3%	3.2%	7.2%	13.0%	10.4%	2.5%	2.4%	22.1%	14.3%
1985	290	1.5%	3.7%	3.0%	2.9%	3.4%	10.2%	19.3%	19.5%	4.7%	4.8%	1.5%	16.3%	8.7%
1986	669	0.2%	0.9%	1.2%	3.6%	9.3%	15.9%	19.9%	13.0%	15.7%	7.4%	1.1%	8.3%	3.3%
1987	1112	0.4%	0.9%	2.7%	9.3%	12.0%	15.1%	14.4%	18.9%	16.0%	2.5%	1.7%	4.4%	1.5%
1988	1199	0.4%	2.8%	9.1%	11.6%	14.4%	15.0%	19.8%	16.6%	2.9%	1.7%	1.3%	3.3%	1.0%
1989	1251	1.9%	8.9%	11.5%	14.1%	15.1%	20.4%	17.9%	3.1%	1.7%	1.2%	0.5%	3.0%	0.7%
1990	1213	4.6%	12.1%	15.0%	16.0%	21.4%	19.3%	3.9%	2.0%	1.3%	0.5%	0.7%	2.7%	0.5%
1991	734	5.6%	15.8%	16.6%	23.7%	23.6%	5.6%	2.1%	1.7%	0.6%	0.9%	0.8%	2.6%	0.3%

Panel B: Municipal bond sample by price

Year	N_{obs}	$P < \$90$	$90 < P < 95$	$95 < P < 100$	$100 < P < 105$	$105 < P < 110$	$110 < P < 115$	$115 < P$
1984	190	42.7%	3.4%	3.6%	13.9%	8.6%	5.2%	22.5%
1985	290	27.1%	1.6%	2.8%	7.9%	7.8%	12.2%	40.6%
1986	669	2.4%	3.5%	4.3%	4.1%	4.6%	10.8%	70.4%
1987	1112	2.0%	2.5%	2.0%	3.6%	8.4%	19.6%	61.9%
1988	1199	1.4%	2.0%	3.4%	5.2%	13.2%	26.8%	48.1%
1989	1251	0.8%	1.7%	3.3%	11.7%	23.0%	33.0%	26.5%
1990	1213	0.7%	1.0%	3.5%	12.5%	28.5%	38.1%	15.6%
1991	734	0.3%	0.4%	1.4%	12.7%	25.4%	39.1%	20.8%

Table 2
(continued)

Panel C: Other municipal bond characteristics (N = 79,890)

Variable	Mean	Standard Deviation	Minimum	Maximum
Price	112.36	10.54	52.77	165.58
Coupon	9.64%	1.78%	3.25%	15.13%
Yield	6.40%	0.80%	3.85%	11.15%
Term (years)	5.25	3.53	0.08	27.85
State corporate tax rate	4.95%	3.84%	0.00%	12.00%
State personal tax rate	3.33%	4.24%	0.00%	16.00%

In panel A maturity buckets are labeled 0.5 yr for bonds with maturities between 1 day and 6 months, 1 yr for maturities 6 months to 1.5 years, 2 yr = 1.5–2.5 years, . . . , 10 yr = 9.5–10.5 years, 15 yr = 10.5–17.5 years, and 20 yr = 17.5–22.5 years. Each cell represents the percentage of bonds with a given maturity in a given year. In panel B price bucket labels describe the percentage of observations for the year that have a month-end bond price within the range described by the column label. N_{obs} is the average number of monthly bond observations for the year. 1991 contains monthly data from January to August. In panel C summary statistics are presented for the entire sample. State corporate (personal) tax is an average of the highest state corporate (personal) tax rates in the state in which each bond was issued.

exempt bonds. Table 3 details the composition of the government bond sample. Panel A provides the average number of U.S. government notes and bonds of various maturities in each year of the sample. The sample is concentrated in maturities less than 10 years, and on average there are about 160 bonds from which to estimate the term structure in each month. Panel B describes the prices of the bonds in the sample. In 6 of the 8 years, at least 56% of the sample is priced within \$5 of par. Given that interest rates declined during much of the sample period it is not surprising that there are some years where steep premium bonds comprise the majority of the sample. Panel C provides grand averages for coupons, prices, yields, and maturities of the sample of government bonds. In addition, panel C shows that 81% of the Treasury sample is composed of notes while 19% are bonds.

3.4 Estimating par-bond yields from the data

The CRSP government bond data and J. J. Kenny prerefunded municipal bond data provide the prices of coupon bonds, and from these prices I estimate par-bond yields. Par bond yields are convenient because if bonds are held to maturity, taxable and tax-exempt coupons can be used to calculate the tax rate at which an investor will be indifferent to the taxable and tax-exempt bond without considering capital gains tax issues. The objective of the par bond yield curve estimation is to extract reliable estimates of the coupons (which are equal to the yield for a par bond) required to sell various maturities of U.S. government and prerefunded municipal bonds at par on a given date. The par-bond yield estimation entails two steps. First,

Table 3
U.S. government bond sample

Panel A: Government bond sample by maturity

Year	N_{obs}	0.5 yr	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr	15 yr	20 yr
1984	137	8.5%	18.9%	15.4%	10.0%	8.6%	6.3%	5.1%	4.0%	3.5%	4.9%	3.5%	4.3%	6.8%
1985	146	8.4%	18.4%	15.0%	10.8%	8.1%	6.6%	5.1%	4.6%	4.6%	4.6%	3.7%	3.7%	6.3%
1986	154	8.5%	17.9%	15.8%	10.4%	8.5%	6.6%	5.8%	5.6%	4.4%	4.8%	1.2%	5.3%	5.1%
1987	156	8.2%	19.0%	15.7%	10.8%	8.6%	7.4%	6.9%	5.6%	4.7%	1.9%	0.9%	7.2%	3.0%
1988	159	9.0%	18.9%	15.8%	10.6%	9.3%	8.4%	6.8%	5.9%	1.9%	2.1%	1.3%	8.9%	1.2%
1989	161	8.7%	19.1%	15.6%	11.7%	10.5%	8.4%	7.1%	3.1%	2.1%	2.5%	1.2%	9.9%	0.1%
1990	164	8.9%	18.6%	16.7%	12.7%	10.2%	8.6%	4.3%	3.3%	2.4%	2.4%	1.6%	9.4%	0.9%
1991	171	8.5%	19.2%	17.1%	11.9%	10.1%	7.5%	4.3%	3.5%	2.3%	2.7%	3.2%	7.0%	2.8%

Panel B: Government bond sample by price

Year	N_{obs}	$P < \$90$	$90 < P < 95$	$95 < P < 100$	$100 < P < 105$	$105 < P < 110$	$110 < P < 115$	$115 < P$
1984	137	13.2%	12.3%	29.9%	31.3%	8.5%	3.5%	1.3%
1985	146	2.9%	3.9%	10.8%	46.3%	20.1%	7.9%	8.2%
1986	154	0.1%	0.2%	2.7%	35.8%	18.8%	12.2%	30.3%
1987	156	0.5%	4.6%	18.5%	32.0%	14.9%	10.0%	19.5%
1988	159	0.3%	5.2%	32.0%	30.2%	11.0%	7.9%	13.5%
1989	161	0.3%	3.9%	33.9%	33.2%	10.5%	7.4%	10.8%
1990	164	0.0%	1.8%	28.5%	45.5%	9.4%	4.4%	10.4%
1991	171	0.1%	0.2%	5.8%	57.5%	17.4%	5.9%	12.9%

Panel C: Other U.S. government security characteristics ($N = 14{,}260$)

Variable	Mean	Standard Deviation	Minimum	Maximum
Price	105.23	10.51	66.44	171.66
Coupon	10.18%	2.32%	6.13%	16.13%
Yield	8.52%	1.61%	0.74%	13.91%
Term (years)	4.59	4.58	0.04	24.96
Treasury notes	81%			
Treasury bonds (noncallable)	19%			

In panel A, maturity buckets are labeled 0.5 yr for bonds with maturities between 1 day and 6 months, 1 yr for maturities 6 months to 1.5 years, 2 yr = 1.5–2.5 years, . . . , 10 yr = 9.5–10.5 years, 15 yr = 10.5–17.5 years, and 20 yr = 17.5–22.5 years. Each cell represents the percentage of bonds with a given maturity in a given year. Price bucket labels describe the percentage of total observations for the year that have a bond price in a given month within the range described by the column label. N_{obs} is the average number of monthly bond observations for the year. 1991 contains monthly data from January to August. Panel C contains summary statistics for the entire sample of government notes and bonds utilized in this study.

I estimate zero-coupon discount rates for the government and municipal samples for each sample month using a technique similar to that of Coleman, Fisher, and Ibbotson (CFI) (1992). Second, using the estimated zero-coupon yield curve, I calculate the implied par bond yield curve.

While the details of the term structure estimation method are relegated to the Appendix, I note here that every alternative term structure estimation method attempted leads to qualitatively identical results. For example, the conclusions drawn from taxable and tax-exempt yields estimated with CFI are nearly identical to those that obtain if the discount rate function proposed by Nelson and Siegel (1987) is utilized to estimate the respective term structures.

4. Testing for Differential Default Risk

If differences in municipal default risk or call options explain the muni puzzle, I expect to observe no relation between default-free municipal yields and term to maturity after controlling for comparable maturity government bond yields. To examine this hypothesis, in Section 4.1 the default-free par yields are used to document the time series of the term structure of implied tax rates, and Section 4.2 documents the relation between the yields and term to maturity in a pooled time-series and cross-section framework.

4.1 The default-free term structure of implied tax rates

A time-series perspective on the degree to which the muni puzzle exists in the sample of prerefunded municipal bonds is an intuitive starting point. Figure 3 shows the degree to which the time series of implied tax rates has been downward sloping. More specifically, Figure 3 plots 92 monthly coefficient estimates from the OLS cross-sectional regression of the implied tax rate on term to maturity,

$$\tau^i(N) = \alpha + \beta_2 Term(N) + \varepsilon(N). \qquad (4)$$

Figure 3 plots the intercept term α the slope of term structure of implied tax rates β_2 and error bars $\pm$ two standard errors around β_2. In each cross-section regression the maturity N is equal to 1, 2, ..., 10, 15, and 20 years.

It is apparent from Figure 3 that the slope of the term structure of implied tax rates is consistently negative and significant. It is also notable that the slope has become less negative in the period following the Tax Reform Act of 1986. Furthermore, during economic downturn and times of tax law uncertainty it appears that implied tax rates are

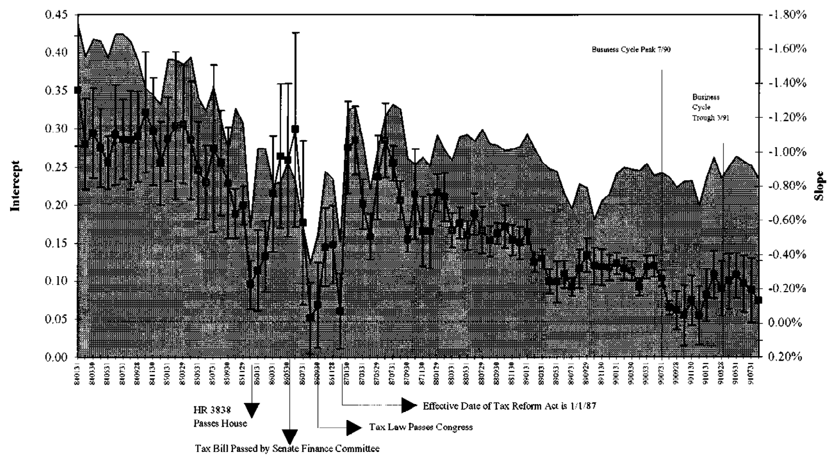

Figure 3
Shape of the term structure of implied tax rates
Equation (4) is estimated in 92 separate OLS cross-sectional regressions and the intercepts and slope coefficients are plotted above. Implied tax rates $\tau^I(N)$ are calculated with the prerefunded municipal and the government par bond yields. Each cross-sectional regression has 12 observations. The intercept α is shaded. The slope β_2 is plotted with boxes connected by a line and surrounded by error bars that mark ± 2 standard errors. The NBER business cycle peak and trough which fall in the time-series interval are noted, as are four important tax law events which occurred. (Note: right-hand scale refers to the estimated slope coefficients with the least negative slopes at the bottom.)

lower for all maturities and the differences across maturities are less pronounced. For example, periods of radical change in the tax law, such as December 1985 (House passes tax bill), May 1986 (Senate Finance Committee approves a tax bill), September 1986 (Tax Reform Act is passed into law), and December 31, 1986 (last day prior to effective date of Tax Reform Act), and the lone economic downturn during the sample period are months where the short-term implied tax rate estimate α is at its lowest levels and the slope estimate β_2 is more likely to be insignificantly different from zero. When uncertainty looms, the municipal yield curve appears to revert toward the shape and level of the taxable yield curve.

4.2 Pooled cross-section time-series tests of the differential default hypothesis

This section provides a more formal analysis of the relative yields of tax-exempt and taxable bonds in a pooled time-series cross-sectional framework. Equation (5) regresses $y_{M,t}(N)$, the municipal par-bond yield of maturity N at time t on the same maturity government par-bond yield $y_{G,t}(N)$, and the term to maturity of the yield pair *Term* (which is equal to N):

$$\begin{aligned} y_{M,t}(N) = \alpha &+ [\beta_{1:\mathrm{Pre}} 1_{\{\mathrm{Pre}\}} + \beta_{1:\mathrm{Post}} 1_{\{\mathrm{Post}\}}] y_{G,t}(N) \\ &+ [\beta_{2:\mathrm{Pre}} 1_{\{\mathrm{Pre}\}} + \beta_{2:\mathrm{Post}} 1_{\{\mathrm{Post}\}}] Term(N) + \varepsilon_t(N) \\ &\text{for } N = 1, 2, \ldots, 10, 15, \text{ and } 20 \\ &\quad\text{for } t = 1, 2, \ldots, 92. \end{aligned} \tag{5}$$

The indicator variables, $1_{\{\mathrm{Pre}\}}$ and $1_{\{\mathrm{Post}\}}$, take a value of 1 if the observation is pre-January 1, 1986, or post-January 1, 1986, respectively, and zero otherwise. The specification allows for the coefficients to be different during two important tax regimes that characterize this sample period. January 1, 1986, is chosen as the relevant effective date for the Tax Reform Act of 1986 which reduced the highest marginal corporate tax rate from 46 to 34%.[15]

Under a strict interpretation of the Miller or Fama theories the intercept term should be zero since variation in the municipal yields will be captured by a constant, $1 - \tau$ times the government yield. Trzcinka (1982) finds a positive intercept and interprets it as a default premium. Under the Fama and Miller null hypothesis, $\beta_{1:\mathrm{Pre}}$ and $\beta_{1:\mathrm{Post}}$ are equal to $(1 - \tau_c)$ where τ_c is the top corporate tax rate or $\beta_{1:\mathrm{Pre}} = 0.54 = (1 - 0.46)$ and $\beta_{1:\mathrm{Post}} = 0.66 = (1 - 0.34)$. Finally, the null is tested that the coefficients on *Term*, $\beta_{2:\mathrm{Pre}}$ and $\beta_{2:\mathrm{Post}}$, are equal to zero. β_2 estimates greater than zero imply that the term structure of tax-exempt bonds has a steeper slope than the term structure of taxable bonds. A logarithmic specification of the *Term* variable leads to nearly identical conclusions.

In the pooled cross-sectional time-series regression, the cross-sections are the par-bond yield estimates for each maturity, $N = 1, 2, \ldots, 10, 15, 20$, and the time series are the 92 month-end observations of the term structure, $t = 1, 2, \ldots, 92$. Estimating the coefficients in Equation (5) with OLS relies upon the standard OLS assumptions, which in this case imply that the cross-time and cross-term-structure errors are uncorrelated and homoscedastic. A likelihood ratio test rejects the pooled OLS model in favor of a model that allows cross-term-structure correlation for all maturities (N), and a single autocorrelation coefficient applied to the time series of yields for each maturity (N). A two-step GLS procedure is used to incorporate the cross-sectional

[15] The Tax Reform Act passed Congress on September 27, 1986, was signed by President Reagan on October 22, 1986, and took effect on January 1, 1987. Poterba (1989) documents market reaction to two earlier events: first, the passage of the House version, HR3838, in December 1985; second, the passage in May 1986 of the Senate Finance Committee's version of the bill.

Table 4
The relative slopes of the taxable and tax-exempt term structures: two-stage GLS cross-sectional time-series regressions

	α	$\beta_{1:\text{Pre}}$	$\beta_{1:\text{Post}}$	$\beta_{2:\text{Pre}}$	$\beta_{2:\text{Post}}$	ρ	N
Panel A: y_M estimated from U.S. government secured municipal bonds							
N = 1–10, 15, 20	.0091	.5537	.6361	.0011	.0003	.75	1104
t = Feb 1984–Aug 1991	(.0011)	(.0108)	(.0132)	(.00003)	(.00001)		
	[8.54]	[51.08]	[48.00]	[37.42]	[38.87]		
Panel B: y_M is Salomon Brothers' estimate of "prime" municipal par bond yields							
N = 1, 5, 10, 20	.0054	.5446	.6384	.0012	.0005	.33	368
t = Feb 1984–Aug 1991	(.0015)	(.0155)	(.0195)	.00004	.00002		
	[3.47]	[35.18]	[32.74]	[26.77]	[29.16]		
Panel C: Prerefunded yields minus Salomon yields							
N = 1, 5, 10, 20	.0040	.0201	.0029	−.00023	−.00017	.41	368
t = Feb 1984–Aug 1991	(.0013)	(.0132)	(.0166)	(.00003)	(.00003)		
	[3.12]	[1.53]	[.177]	[−7.27]	[−11.33]		

The prerefunded municipal par bond yields and Salomon Brothers' "prime grade" municipal par bond yield estimates are used in conjunction with the U.S. government par bond yield curve to estimate Equation 5. Generalized least squares estimates that incorporate corrections for cross-sectional and time-series dependence in the error term are presented. A model that incorporates cross-term structure correlation (values of N) and a common autocorrelation coefficient for each maturity cannot be rejected in favor of a less restrictive model that allows different autocorrelation coefficients for each term structure observation. In panel A, $y_{M,t}(N)$ is the 1–10, 15, and 20 year par bond yield estimated from prerefunded municipal bond prices. In panel B, $y_{M,t}(N)$ is the 1, 5, 10, and 20 year par bond yield estimated by Salomon Brothers. In both panels $y_{G,t}(N)$ is the U.S. par bond yield estimated from the CRSP U.S. government bond data. The bond yields are estimated using a procedure similar to the one described by Coleman, Fisher, and Ibbotson (1992). Twenty-year government par bond yields from February 1989 to January 1990 are estimated by McCulloch and Kwon. *Term* is the maturity of the municipal/government yield pair for a given observation. ρ is the average residual autocorrelation coefficient estimated in the GLS estimation. The last column in the table presents the total number of time-series and cross-sectional observations. The first time-series observation is lost to estimate the autocorrelation coefficients. The Pre and Post subscripts refer to whether the variable is nonzero for values prior to January 1, 1986 or post-January 1, 1986. Standard errors are in parentheses and t-statistics are in square brackets.

and time-series correlation into the estimation. The GLS estimates are presented in Table 4.[16]

If municipal default risk explains why municipal yields are relatively high at long maturities, one would not expect to observe a relation between default-free municipal yields and term to maturity in Equation (5). Panel A reports the coefficient estimates on *Term* where the prerefunded bond yields are utilized. The coefficients on $\beta_{2:\text{Pre}}$ and $\beta_{2:\text{Post}}$ are both positive and significantly different from zero with t-statistics of 37 and 39, respectively. In the pretax reform era $\beta_{2:\text{Pre}} = 0.0011$. This implies that a 10 year municipal par bond yield will have a premium of 110 basis points over the tax-adjusted yield on 10 year government bonds. Purchasers of long-term municipal bonds receive an economically large yield premium even when the tax-exempt bonds are secured by U.S. Treasury securities. The co-

[16] Although pooled OLS estimates provide slightly lower estimates of β_1, the qualitative description of the other parameter estimates and their significance are unchanged by the GLS procedure.

efficient on *Term* falls to $\beta_{2:\text{Post}} = 0.0003$ in the post-1986 period. Conjectural explanations for the decrease in this effect include the fact that tax brackets compressed and interest rates were substantially lower in the post-1986 period. Not reported in Table 4 is the result that removing the pre and post designation impacts the values of the coefficient estimates but not their sign or significance. The statistically and economically large coefficient estimates on *Term* lead me to conclude that differences in default risk or call options do not provide a comprehensive explanation for the muni puzzle.

A comparison of prerefunded municipal and Salomon municipal yields helps assess whether differential default risk provides any substantive explanatory power. Table 4, panel B details the coefficient estimates where the Salomon Brothers' municipal bond yields are utilized. As in panel A, the coefficients on $\beta_{2:\text{Pre}}$ and $\beta_{2:\text{Post}}$ are both positive and significantly different from zero, with t-statistics of 27 and 29, respectively. The coefficient $\beta_{2:\text{Pre}} = 0.0012$ is qualitatively identical to the coefficient in the sample of prerefunded yields. The coefficient on $\beta_{2:\text{Post}} = 0.0005$ is larger than the coefficient found in panel A. However, panels A and B are not directly comparable because panel A includes several maturities that are not available in the Salomon data.

To facilitate a direct comparison between prerefunded yields and Salomon yields, differences between the prerefunded and Salomon yields for the 1, 5, 10, and 20 year maturities are regressed on the independent variables in panels A and B. Reported in panel C, the coefficient estimates are the differences in the coefficient estimates for the prerefunded yields versus the Salomon yields. The slope of the Salomon municipal yield curve is 0.0002 per year of bond maturity steeper than the prerefunded yield curve; the intercept term is 0.0040 larger for the prerefunded sample.

It is unlikely that the Salomon yield curve's steeper slope represents the marginal impact of default risk and call options on the municipal term structure. Using the point estimates from panel C, 20 year prerefunded bond yields are predicted to be identical to the 20 year Salomon yield [$.0040 - 20(0.0002) = 0$]. This is surprising but consistent with Chalmers (1995) which documents that prerefunded yields are almost always higher than Salomon high-grade municipal bond yields. Given that default-free bonds have equal or higher yields than the Salomon bonds, it is implausible to explain the steeper slope to the Salomon term structure with differences in default risk and call options. Therefore, I conclude that differential default risk and call options in municipal bonds cannot help to explain why long-term municipal yields are so high relative to taxable yields.

Finally, it is noteworthy that the coefficient estimate on the government yield variables in Table 4 are consistent with the values predicted by Fama and Miller. The coefficient $\beta_{1:\mathrm{Pre}} = 0.55$ with a standard error of 0.011 is within 2 standard errors of the null hypothesis of 0.54. In addition, the coefficient $\beta_{1:\mathrm{Post}} = 0.64$ with a standard error of 0.013, is within 2 standard errors of the null of 0.66.[17] When conditioned by the maturity of the bond yields, the marginal impact of changes in government yields are transferred to municipal yields at the highest marginal corporate tax rate. This is consistent with the Fama and Miller hypothesis. The positive and significant intercept terms in panels A and B are inconsistent with the Fama and Miller hypothesis, but similar to Trzcinka's finding.

In sum, Figure 3 and Table 4 provide important evidence concerning the impact of default risk and call options on the relative yields of tax-exempt and taxable bonds. There is no evidence to suggest that default risk or call options can explain the muni puzzle. Of practical use, the similarity between the Salomon Brothers' and prerefunded bond results implies that researchers utilizing the "prime grade" yields can be reasonably certain that these yields are representative of very safe noncallable municipal bond yields. As mentioned, Chalmers (1995) documents that the AAA yields trade at lower yields than comparable maturity prerefunded bonds. This is a puzzling anomaly. However, it does underscore the fact that over this time period default risk and call features of AAA-rated municipal bonds do not have a measurable impact on the relative term structures. Finally, it is reassuring that the results using the Salomon data and the pre-refunded bond data are so similar. The robustness of the results implies that term-structure estimation procedures are not driving these results.

5. Conclusion

There are many periods in time where investors facing marginal tax rates of 5% or more would appear to be better off purchasing municipal bonds rather than taxable bonds. The consistently high level of long-term tax-exempt interest rates relative to taxable yields presents a conundrum to financial economists. In this article I reject differential default risk and differences in call options as explanations for the muni puzzle. While the rejection of these hypotheses does not provide researchers with an answer, it will hopefully redirect energy toward other promising explanations.

[17] This is the only result that is sensitive to the term structure estimation method or the logarithmic specification of *Term*. The Fama and Miller null hypothesis can be rejected in several of these alternative tests. However, from an economic perspective, the β_1 estimates are always within 0.10 of the null hypothesis.

The fundamental result is that effectively default-free noncallable taxable and tax-exempt yields display the same qualitative relation observed in yield comparisons that utilize riskier, callable municipal bonds. Controlling for default risk and call provisions by selecting a specialized sample of U.S. government secured municipal bonds, I find that the term structure of noncallable default-free municipal bonds is steeper than the U.S. Treasury term structure. That is, the tax rate that would make an investor indifferent between a taxable bond and a tax-exempt bond declines with term to maturity. Furthermore, this behavior is very similar to that observed in the risky Salomon yields. These results, combined with evidence provided by Gordon and Malkiel (1981) and Ang, Peterson, and Peterson (1985), imply that differences in default risk and call options do not explain the declining term structure of implied tax rates. For future researchers this implies that the effect that default risk or call options have on the Salomon Brother's prime grade par bond yield estimates are unlikely to affect results. Given that the Salomon Brothers data are widely used and easily available, it is useful to know that embedded call options and default risk in these data are very unlikely to contaminate empirical tests. Finally, conditional on maturity, the variation in municipal yields is explained by a coefficient on government yields that bears a striking resemblance to the value predicted by Fama (1977) and Miller (1977).

Appendix: Term Structure Estimation

To develop the intuition behind the par bond yield curve estimation, consider Equation (6). Equation (6) describes P_t, the bond price at time t, on a coupon payment date, with par equal to 100, annual coupon equal to C paid semiannually, and time to maturity N (in years):

$$P_t = \frac{C}{2}\left(\sum_{n=1}^{2N} \frac{1}{\left(1 + \frac{y_t^{spot}(n)}{2}\right)^n}\right) + \frac{100}{\left(1 + \frac{y_t^{spot}(2N)}{2}\right)^{2N}}. \qquad (6)$$

Equation (7) expresses the coupon necessary to sell a bond at par given the set of spot rates, $y_t^{spot}(1)$ through $y_t^{spot}(2N)$. To obtain Equation (7), set $P_t = 100$ in Equation (6) and solve for the coupon C. That coupon divided by 100 is $y_t(2N)$, the par bond yield for a bond with

Table A.1
Semiannual cash flow periods over which spot rates are defined

Semi-Annual Cash Flow Periods	Defined Spot Rate	Semi-Annual Cash Flow Periods	Defined Spot Rate
1–3	$y_t^{spot}(1)$	14–15	$y_t^{spot}(7)$
4–5	$y_t^{spot}(2)$	16–17	$y_t^{spot}(8)$
6–7	$y_t^{spot}(3)$	18–19	$y_t^{spot}(9)$
8–9	$y_t^{spot}(4)$	20–21	$y_t^{spot}(10)$
10–11	$y_t^{spot}(5)$	22–34	$y_t^{spot}(15)$
12–13	$y_t^{spot}(6)$	35–45	$y_t^{spot}(20)$

a maturity $2N$ semiannual periods from the current date:

$$y_t(2N) = \frac{C}{100} = 2\left[\frac{\left(1 - \frac{1}{\left(1+\frac{y_t^{spot}(2N)}{2}\right)^{2N}}\right)}{\sum_{n=1}^{2N} \frac{1}{\left(1+\frac{y_t^{spot}(n)}{2}\right)^{n}}}\right]. \tag{7}$$

Par bond yields are calculated with Equation (7) using estimates of the spot rates, $y_t^{spot}(n)$, for each semiannual coupon or principal payment date n.

To estimate the spot rate parameters, $y_t^{spot}(n)$, I use a method similar to Coleman, Fisher, and Ibbotson's (CFI) (1992) term structure estimation technique. CFI use nonlinear least squares weighted by the inverse of duration to estimate piecewise constant forward rates from prices of coupon bonds.

To use CFI's technique, I must assume that the spot rate is constant over various ranges. I estimate 12 unique spot rates, $y_t^{spot}(n)$, over 45 possible semiannual coupon or principal payment periods. The semiannual cash flow payment periods over which the spot rates are held constant are shown in Table A.1.

For example, $y_t^{spot}(2)$ discounts cash flows that arrive between 1.5 and 2.5 years from the date for which the term structure is being estimated. With two exceptions, the cash flow intervals are identical for the municipal and government term structure estimation procedures. The exceptions are that I estimate a 6 month spot rate for the government term structure for the cash flows arriving in the first period, and as a result the 1 year government spot rate discounts cash flows occurring in semi-annual periods 2 and 3. The municipal 6 month spot rate is not estimated because there are months in which there are no 6 month municipal bonds.

Using nonlinear least squares $\hat{y}_t^{spot}(n)$ is chosen, for $n =$ 1–10, 15, and 20 as defined above, to minimize the price errors in the objective function given by Equation (8):

$$\min_{\hat{y}^{spot}(n)\forall n} \sum_{i=1}^{I} \frac{(P_i - \hat{P}_i)^2}{Dur_i} \text{ with}$$
$$\hat{P}_i = \sum_{k=1}^{K} \frac{CF_k}{\left(1 + \frac{\hat{y}^{spot}(n)}{2}\right)^{\left(k-1+\frac{\text{Days from Settlement to Next Coupon}}{\text{Actual Days in Coupon Period}}\right)}}. \tag{8}$$

P_i is equal to the quoted price plus accrued interest. I is the number of bond price observations (P_i's). CF_k is the pretax cash flow for each payment period k on the ith bond. CF_k can be a semiannual coupon payment and/or a principal payment plus a call premium. K is the total number of cash flow dates. $K = 2N$ on coupon payment dates, where N is the term to maturity in years. The Securities Industry Association's (SIA) conventions for Government bonds are used to calculate predicted prices.[18] Although the convention for municipals is to use a 30/360 day basis, for consistency the predicted municipal prices and accrued interest are calculated on an actual day basis. Finally, in the objective function each observation is weighted by the inverse of duration, calculated using the yield to maturity. Weighting by duration places disproportionate weight on the pricing errors for short-term bonds. If the yield estimates are to be uniformly accurate, placing greater weight on the price errors at the short end of the term structure helps control for heteroscedasticity in the yield errors. Small price errors for a short-term bond translate into large short-term yield errors. However, large price errors on long-term bonds translate into relatively small errors in long-term yields.

Given bond prices from June 30, 1987, Figure 1 plots an example of the government and prerefunded term structure estimates and the associated implied tax rates. The CFI spot rate estimates are relatively insensitive to the duration weights and whether or not capital gains are incorporated into the estimation. However, the term structure of standard errors is much more uniform for the weighted spot rate estimates. The asymptotic standard errors estimated in the CFI procedure are in general less than 10 basis points and in the majority of cases in the range of 1 to 2 basis points. Finally, to fill in estimates from Febru-

[18] The SIA's convention for semiannual payments is $P = -(100 \cdot \frac{C}{2} \cdot \frac{A}{E}) + \sum_{k=1}^{N} \frac{CF_k}{(1+\frac{Y}{2})^{(k-1+\frac{DSC}{E})}}$, where C is the annual coupon, A is the number of accrued days, E is the number of days in the semiannual coupon period, N is the number of (partial and whole) semiannual coupon periods between settlement and maturity, CF_k is the semiannual coupon or maturity payment, DSC is the number of days from settlement to the next 6 month coupon date, and Y is the annual yield.

ary 1989 through January 1990 that could not be estimated using the CFI term structure estimation method, twelve 20-year government par bond yield observations are taken from McCulloch and Kwon (1993) and converted to semiannually compounded equivalents to use in this article.

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