Maturity Clienteles in the Municipal Bond Market: Term Premiums and the Muni Puzzle

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ABSTRACT

This paper finds empirical support for the idea that term premiums arise when an excess supply of long-term bonds forces shorter holding period investors to bear price risk. The empirical support comes from the tax-exempt (municipal) bond market where an ex-ante measure of the expected excess return on long maturity bonds is significantly and negatively related to the size of the positions held by long holding period investors (property and casualty insurance companies) and hence negatively related to the extent that short holding period investors are required to hold long-term bonds. The required excess returns on longer term bonds (term premiums) would cause implied marginal tax rates to decline with maturity and thus are a new potential explanation for at least part of the "muni puzzle" (Chalmers, 1998).

JEL Classifications: E43, G12, G22

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I. Introduction

A sufficient condition for the existence of term premiums is that prices reflect interest rate risk borne by short horizon investors that plan to liquidate their positions in long-term bonds for consumption prior to maturity. This interest rate risk is potentially priced when the supply of long-term bonds exceeds the demand by investors with long holding periods and short horizon investors are the marginal investor in long-term bonds. Further, increases in the supply of long-term bonds or decreases in demand by long-term investors should increase the term premium by forcing either short horizon investors or risk arbitrageurs to hold more long-term bonds (Greenwood and Vayanos, 2010).

Our analysis of data from 1982-2011 of the tax-exempt bond market shows that proxies for the expected return premium on long-term tax-exempt bonds vary with the extent to which short horizon investors or arbitrage capital are required to hold long-term tax-exempt bonds as a result of changes in the demand for long-term bonds. Thus, our analysis complements the analysis of D'Amico and King (2013) that find evidence of a "local supply" effect around changes in the supply of Treasury bonds associated with the Federal Reserve's 2009 large scale asset purchase program: yields on bonds of maturities closest to maturities repurchased were more impacted by the supply shock.

The tax-exempt market is uniquely suited for examining how maturity-specific supply-demand imbalances impact bond pricing. Proxies for exogenous changes in maturity-specific demand exist since data are available on tax-exempt bond holdings by insurance companies (liability-driven long holding period investors) versus shorter holding period investors and arbitrage capital (Tender Option Bond (TOB) programs). The exogenous variations in insurance company demand can be identified by fitting the relationship between insurance company municipal bond holdings and insurance company profitability. Finally, the maturity mix of tax-exempt bonds supplied is largely exogenous due to institutional constraints on issuers.

Proxies for the expected excess return on long-term tax-exempt bonds also exist. We show that the ratio of the municipal bond forward rate to a taxable bond forward rate (the *forward rate ratio*) depends on (a) the expected excess return on long-term tax-exempt bonds, and (b) the expected future (or forward) marginal tax rate. Thus, the forward rate ratio, controlling for expected future marginal tax rates, provides an ex-ante measure of the expected excess return on long-term tax-exempt bonds.[1]

Our central finding is that the exogenous component of insurance company demand is significantly and negatively related to the forward rate ratio controlling for expected future tax rates. Long-term municipal bond prices rise relative to long-term taxable bond prices when long maturity buyer demand rises. Finding that demand by long holding period investors is negatively related to the forward rate ratio is consistent with the term premiums declining as less short horizon investors are forced to hold long-term bonds. If there is ample demand for long-term bonds or short horizon investors are not averse to price risk, then changes in insurance company holdings would not impact the forward rate ratio.

We also examine the role of arbitrage capital by including the supply of arbitrage capital (Tender Option Bond program positions) in the empirical analysis of term premiums. We find that (a) the exogenous variation in insurance company demand retains its statistically significant impact on term premiums and (b) the amount of arbitrage capital is negatively related to expected term premiums. The negative relationship between arbitrage capital and term premiums suggests an exogenous variation in the amount of arbitrage capital rather than changes in the amount of arbitrage capital reflecting greater profit opportunities in the trade.

The evidence consistent with term premiums in the tax-exempt market provided in this paper are a new potential explanation for at least part of the pervasive tendency for implied marginal tax rates to decline with maturity – the muni puzzle.[2] A required excess return on long-term bonds would cause the marginal tax rate implied from bond

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[1] As discussed in detail later, the forward rate ratio potentially depends on the yield compensation for forward credit risk, tax-timing options, liquidity, embedded call options and tax policy uncertainty in tax-exempt bond prices.

[2] Important papers that provide evidence of the muni puzzle include Trzcinka (1982), Ang, Peterson, Peterson (1985), Jordan and Pettway (1985), Green (1993), Chalmers (1998), and Longstaff (2011).

yields to decline with maturity even though expected future tax rates are not expected to decline. Ferry (2006) describes practitioners' views of two potential reasons for the steeper slope of the tax-exempt curve: declining marginal tax rates. The first is uncertainty about investor's future tax rates or the tax treatment of municipal bonds.[3] The second is the chronic excess supply of long-term tax-exempt bonds. The relationship between the steepness of the tax-exempt curve and the demand by long tax-exempt investors documented here supports the idea that this chronic long-term bond supply is priced.

The remainder of this paper proceeds as follows. In Section II we derive a relationship between the term premium and supply and demand at various maturities and motivate the empirical analysis in the context of the tax-exempt market. Section III presents the empirical analysis and Section IV concludes.

II. Term Premiums: Maturity-Specific Supply and Demand

This section provides a simple model of the pricing of municipal bonds relative to taxable bonds with maturity-specific investors in the municipal bond and arbitrage capital that profits from the expected term premium in the tax-exempt market and hedges the interest rate risk with taxable market interest rate swaps. The relationship between maturity and expected bond returns (i.e. term premiums) in the municipal bond market depend on the supply of and demand for different maturity bonds. The model is a simple formalization along the same lines of Vayanos and Vila (2009) of the intuitive preferred habitat ideas of Culbertson (1957) and Modigliani and Sutch (1966).

The novel aspect of the model is the presence of two partially segmented markets. We show that the forward rate in the tax-exempt market relative to the forward rate in the taxable market (the *forward rate ratio*) is an ex-ante empirical proxy for expected excess returns in the tax-exempt market. We also provide testable implications of hedge fund behavior that relate the forward rate ratio to hedge fund positions. Finally, we provide a discussion of investors, issuers and arbitragers in the

[3] See Brooks (2002) for evidence on the impact of tax policy uncertainty on the tax-exempt yield curve.

tax-exempt market that motivates the measurement of maturity-specific supply relative to demand used in the empirical analysis.

A. Model Set Up

The simple two-market set up is described by the riskless, zero-coupon one period rate, the expected future one period rate in one period, and the two period rate in the taxable and tax-exempt markets.

Notation

r_{1T}	One Period Taxable Rate
$E(r_{1T})$	Expected Future One Period Taxable Rate in One Period
r_{2T}	Two Period Taxable Rate
r_{1M}	One Period Municipal Rate
$E(r_{1M})$	Expected Future One Period Municipal Rate in One Period
r_{2M}	Two Period Municipal Rate

The one period taxable rate (r_{1T}) and expected future one period taxable rate in one year ($E(r_{1T})$) are exogenous. Two assumptions are made for simplicity of exposition. First, there are no term premia in the taxable bond market. Thus, $r_{2T} = [(1+r_{1T})*(1+E(r_{1T})]^{1/2} - 1$. Second, investors in the tax-exempt market have a marginal tax rate of τ and will have a marginal tax rate of τ next period. Investors in the taxable market have a tax rate of zero. Assuming that there are investors with a continuum of marginal tax rates would allow for some long horizon investors in the taxable market to "crossover" to the tax-exempt market and capture term premiums. However, this would not qualitatively change the results of the analysis. Under the second assumption, $r_{1M} = (1-\tau)*r_{1T}$ and $E(r_{1M}) = (1-\tau)*E(r_{1T})$.

B. Maturity-Specific Supply and Demand

An investor in the municipal bond market that plans to liquidate her portfolio for consumption purposes in one period is subject to price risk if she holds a two period bond. Thus, a one period investor only purchases a two period bond when it has an expected one period return that is greater than r_{M1} as compensation for bearing this price risk.

The following simple example shows how the magnitude of the term premium as compensation for price risk varies with maturity-specific supply and demand. The exogenous supply of debt at each maturity i is denoted S_i. Investors are characterized by their holding period n and their degree of price risk aversion RA_k, which denotes the additional required return on a two-period bond. $RA_k \geq 0$ for investors with a one period holding period and $RA_k = 0$ for investors with a two period holding periods. Each investor has one dollar to invest and the total amount available to invest by investors with an n-year holding-period is D_n. Arbitrage capital is considered later. Consider the case where the supply and demand by maturity are as depicted in Table 1.

Table 1. Maturity-Specific Supply and Demand

The table below depicts the demand and supply for each maturity. D_n represents the demand from investors with a holding period of n periods. S_n represents the supply of municipal bonds with n periods to maturity. We examine the case where the net demand is greater than supply for 1-period bonds and supply is greater than demand for 2-period bonds.

Period of Bond	**Investor Demand**	**Municipal Supply**	**Net**
1	D_1	S_1	$D_1 > S_1$
2	D_2	S_2	$D_2 < S_2$

In this case, the supply of long-term (two periods to maturity) bonds exceeds the demand for long-term bonds by investors with long holding periods. Thus, $S_2 - D_2$ bonds are held by investors with a one period holding period. The marginal investor in the two period bonds is a one period investor. The one period expected return on a two period bond is higher than the expected return on the one period bond in order to compensate the marginal investor for price risk.

More importantly, the size of the term premium is an increasing function of $S_2 - D_2$. The least price risk averse one period investors are the natural holders of the two period bond. If $S_2 - D_2$ equals one dollar, then one period investor with lowest RA_k is the price setter in the two period bonds. If $S_2 - D_2$ grows to two dollars, then the investor with the next lowest RA_k is the marginal investor in the two-year bonds and the required expected return premium on the two-year bond increases.

C. *Ex-Ante Term Premium Measures*

Under the assumptions of this model, an ex-ante measure of the municipal bond market term premium (RA_k) is easily extracted from tax-exempt and taxable yields. Specifically, our ex-ante term premium measure is related to the ratio of the municipal bond forward rate to a taxable bond forward rate (the forward rate ratio).

Given the term premium required to hold a two period municipal bond is $RA > 0$, the two year municipal bond rate, r_{M2}, solves

$$(1 + r_{M2})^2 = (1 + r_{M1}) \times \left(1 + E\,(r_{M1})\right) \times (1 + RA) \tag{1}$$

Since no term premium is required to hold a two period taxable bond, the two-period taxable bond rate is

$$(1 + r_{T2})^2 = (1 + r_{T1}) \times \left(1 + E(r_{T1})\right) \tag{2}$$

The one period taxable bond forward rate in one year (F_T) and the one period tax-exempt bond forward rate in one year (F_M) are as follows:

$$F_T = \left[\frac{(1 + r_{T2})^2}{1 + r_{T1}}\right] - 1 = \frac{E_1(r_{M1})}{1 - \tau} \tag{3}$$

$$F_M = \left[\frac{(1 + r_{M2})^2}{1 + r_{M1}}\right] - 1 = E_1(r_{M1}) \times (1 + RA) \quad (4)$$

Ex-ante information about excess expected returns in the tax-exempt market are contained in the "forward rate ratio,"

$$\frac{F_M}{F_T} = (1 + RA) * (1 - \tau \quad) \quad (5)$$

The forward rate ratio depends on the expected excess return from holding a longer-term tax-exempt bond and the future expected tax rate. Thus, controlling for the expected tax rate, the forward rate ratio is a compelling ex-ante measure of the term premium in the tax-exempt market or expected excess return from holding a longer-term bond tax-exempt bond.

The forward rate ratio warrants some discussion on a couple of dimensions. First, the notion that the forward rate ratio depends only on (a) the expected excess return in the tax-exempt bond market and (b) the expected tax rate relies on simplifying assumptions that are probably not empirically valid. The most compelling taxable bond curves to obtain data on taxable bond forward rates are in the Treasury bond and the LIBOR interest rate swap market. Tax-exempt bonds are less liquid that Treasury bonds and have more default risk than Treasury bonds, even though our analysis examines AAA-rated tax-exempt bonds. Thus, the forward rate ratio is likely to contain time varying premiums in the promised tax-exempt bond yields for credit risk and liquidity (Wang, Wu and Zhang, 2008). Finally, the assumption that term premiums in the taxable bond market are zero may not hold, and there may be term premiums in Treasury bond prices or interest rate swap rates.

However, the goal of this analysis is not to provide expected return premiums that are as accurate as possible. Rather, our empirical analysis examines whether there is a statistically significant relationship between the forward rate ratio and the demand relative to supply for long-term tax-exempt bonds. Other factors that influence the forward rate ratio would simply create noise in the forward rate ratio as a measure of expected excess returns and bias against a finding.

Second, the forward rate ratio variable is a compelling ex-ante measure of expected excess returns in the tax-exempt bond market relative to the taxable bond market. This occurs because the markets are sufficiently segmented because of the tax treatments that term premiums could be greater in the tax-exempt but short-term rates and expected short-term rates remain related by the marginal tax rate.

Arbitrage capital that tries to capture the term premium in the tax-exempt market is an important player in the tax-exempt market. As discussed in detail in Bergstresser, Cohen and Shenai (2010), Tender Option Bond (TOB) programs purchase long-term municipal bonds that are held in a trust. The trust is largely financed by issuing tax-exempt floating rate bonds. Thus, the owners of the trust own long-term bonds and financed by short-term bonds which results in an expected profit equal to the size of the term premium RA_k.

The TOB programs can effectively hedge much of the interest rate risk in the position without giving up expected profits by taking interest rate derivative positions in the taxable market where the term premiums are lower or zero. Table 2 depicts the payoffs to the investors in a TOB in the context of our two period setting.

Table 2. Stylized TOB Program Payoffs

In this example the TOB program is funded by borrowing one dollar of two period floating rate tax-exempt debt where the floating rate adjusts each period and invests the proceeds in a two period tax-exempt bond. The position is hedged by entering into a two period pay fixed taxable interest rate swap with a notional amount of one dollar. The one period tax-exempt rate is denoted as r_{T1}*(1-τ)

Position	**First Period Payoff**	**Expected Second Period Payoff**
Two Period Tax-Exempt Bond	r_{M2}	$r_{M2} + 1$
Swap Payment	r_{T2}	r_{T2}
Floating Rate Debt	$-r_{T1}*(1-\tau)$	$-E(r_{T1})*(1-\tau) - 1$
Swap Receive	r_{T1}	$E(r_{T1})*(1-\tau)$

The expected profit per dollar position in this strategy over two periods is RA_k. The risk to this strategy comes about from basis risk in the hedge (a change in the marginal tax rate) and credit risk in the long bond position rather than exposure to an increase in interest rates in the carry trade in Vayanos and Villa (2009). However, this risk materialized in late 2008 when tax-exempt bond yields increased while Treasury yields and swap rates actually fell. This created margin calls and forced many TOB programs to unwind.

C. Municipal Bond Market Segmentation and Maturity Preferences

The empirical analysis relates the supply relative to demand of long-term tax-exempt bonds to ex-ante measures of term premiums in the tax-exempt market. Such a relationship requires (1) an excess supply of long-term bonds, otherwise price risk is not priced, and (2) some exogenous variation in the supply relative to demand.

The supply of long-term municipal bonds is considerable and exogenous (Brown, 2011; Poterba, 1989) due to institutional constraints. Put another way, tax-exempt issuers issue long-term bonds in spite of a potentially higher cost for the following reasons. First, in order to maintain a high-quality credit rating and manage investor credit risk concerns, tax-exempt issuers must meet certain coverage ratios. Thus, tax-exempt issuance is often a serial structure (multiple bonds of various maturities simultaneously issued) so that the annual debt service does not exceed a certain percentage expected tax revenues (general obligation bonds) or expected cash flows from the project being funded with a revenue bond. Coverage ratio constraints limit the ability of tax-exempt entities to issue short-term debt: tax-exempt entities do not generally issue short-term debt to fund long-term projects. Further, transaction and administrative costs of rolling over debt are substantial for local governments, especially small townships. Interest rate risk can cause uncertainty in future debt payments, which can impede budgeting and possibly create situations where tax revenues do not cover interest expenses.

Second, while the level debt service constraint is decreasing function of maturity, the maturity of the issuance typically cannot be much longer than the length of the project being financed. These two constraints together ensure that most of the municipal debt issued will match the length of the project being financed and will thus be exogenous: not driven by the slope of the yield curve.

The tax-exemption feature of municipal bonds induces clientele effects on the demand side because demand is limited to investors that fall in high tax-brackets (Dvbig and Ross, 1985). The dominant investors in the municipal bond market are households that own bonds directly or through mutual funds, and insurance companies (property and casualty insurance companies and life insurance companies). See Figure 1 for a breakdown of the percentage ownership of tax-exempt bonds.

Individuals are price risk averse and have a strong preference for short-term bonds. P&C insurance companies have a preference for long-term tax-exempt bonds due to the nature of their claim structure. P&C insurance companies are widely recognized as the major buyers of long-term bonds (specifically, maturities of 17-22 years).[4] The following excerpt from the Municipal Market Comment, issued by Citi Smith Barney in December of 2008 describes how pricing in the tax-exempt market was influenced by the absence of P&C insurance company buying:

> *"Part of the 'good news' for investors with cash to spend in the muni market was the extreme supply/demand imbalance that had occurred, keeping yields abnormally high... The lack of institutional demand had generated a supply/demand imbalance. This continues to be the case, with crossover buying still limited, property and casualty companies facing profit concerns that limit their capacity to own munis, and bond funds facing severe outflows."*

The above quote also points out that P&C insurance company buying is influenced by P&C insurance company profits. As shown in the following section, P&C demand for tax-exempt securities is strongly tied to profitability, which can often be influenced by insurance premium cycles and natural disasters. This means that at a potentially identifiable portion of P&C demand is exogenous to interest rate levels.

The model and description of investors in the tax-exempt bond market form the basis for a test of whether changes in the demand for long-term tax-exempt bonds impact term premiums in the tax-exempt market. As the demand for long-term bonds

[4] Feldblum (1989) discusses asset-liability matching for property/casualty insurance companies.

by long horizon investors (insurance companies) increases, less short horizon investors are required to hold long-term bonds and the term premium is expected to decline. The forward rate ratio is shown to be an ex-ante measure of the term premium in the tax-exempt market.

III. Empirical Analysis

A. Data Description

Descriptive statistics of all data used in our analysis are listed in Table 3. The Yields on AAA-rated General Obligation municipal bonds and Treasury bonds are retrieved from the fourth quarter of 1982 to the second quarter of 2011 from the Thomson Municipal Market Monitor (TM3). As a robustness check, we run our analysis omitting data after the recent financial crisis beginning in the last quarter of 2007. Bond yields are available for 1-, 5-, 10-, 15-, 20-, and 30-year maturities.

Panel A of Figure 2 shows the simple time series of the municipal bond yield as a percentage of the Treasury yield for 5-year and 20-year maturities from 1982 to 2011. As shown in numerous previous studies, the municipal bond yield curve is steeper than the Treasury bond yield curve as the municipal bond yield is much closer the taxable bond yield for 20 year bonds. Panel B of Figure 2 depicts the municipal bond yield/Treasury bond yield relationship as the implied tax rate at various maturities. Again, as shown in the previous literature, the implied tax rates at longer maturities are systematically lower than those of shorter maturities.

Total tax-exempt bonds outstanding and P&C holdings of tax-exempt bonds are obtained from the Federal Reserve's Fund Flows database. Unfortunately, the Fund Flows data does not differentiate among maturities or credit rating. Profitability measures, market value weighted average return on assets and pretax income as a percentage of assets of P&C insurance companies (SIC code 6331) are calculated using return on assets (NIQ/ATQ)[5] and pretax income over total assets (PIQ/ATQ)[6] in the Compustat database.

[5] NIQ: Net Income (Loss), ATQ: Assets – Total

Annual data for 1995 through 2009 on the amount of capital raised in TOB and the amount of capital withdrawn from TOB program closures are obtained from Bergstresser, Cohen and Shenai (2010). The difference between capital raised and withdrawn (net TOB flows) is used as a measure of TOB investments in long-term bonds.

The analysis includes control variables that are expected to influence the demand for tax- exempt bonds: stock market volatility as measured by the VIX of the S&P 500 is from the CRSP database and the percentage change in personal income is provided by the Bureau of Economic Analysis (BEA). The most important control variable is tax rates since they directly impact the forward rate ratio. We collect the top marginal personal tax rates from the Tax Policy Center.[7]

B. Methodology

We construct a methodology to empirically test the relationship between changes in maturity-specific supply/demand conditions and term premiums. The empirical proxy for the term premium is the forward rate ratio derived from the municipal and Treasury yield curves. The extent of long horizon investors is measured by a variable derived from the holdings of tax-exempt bonds by P&C companies relative to the supply of municipal bonds. If P&C demand reduces priced price risk, it will have a negative effect on the forward rate ratio.

Before examining the relationship between P&C demand and the forward rate ratio, a variable is constructed that reduces potential endogeneity problems with P&C company holdings of tax-exempt bonds. P&C company holdings of long-term tax-exempt bonds potentially varies as a result of (a) increases (decreases) in profitability which result in larger (smaller) asset holdings and holdings tilted towards (away from) tax-exempt bonds – a shift in demand for tax-exempt bonds - and (b) changes in the implied marginal tax rate on longer term bonds – movement along the demand curve for tax-exempt bonds. Movement along the demand curve for tax-exempt bonds is the nature of the endogeneity problem.

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[6] PIQ: Pretax Income

[7] Tax Policy Center: http://www.taxpolicycenter.org

In order isolate the exogenous component of P&C company demand, we regress P&C Share on an exogenous aggregate P&C profitability measure and use the fitted values of P&C share as our demand/supply proxy. We calculate our profitability measure as the aggregate return on assets of the property and casualty insurance company industry (i.e., firms with SIC code equal to 6331). We then estimate the following regression:

$$PCShare_t = \alpha + \beta * Profitability_t + r_t \tag{6}$$

The estimated models of Equation (6) are presented in Table 4. There is a statistically significant positive relationship between P&C Share and profitability. The fitted (i.e., predicted) value $\widehat{PCShare}_t$ represents the P&C Share due to P&C profitability at time t, which is exogenous to the slope of the yield curve, and the residual r_t captures variation in P&C share not due to profitability. These fitted and residual values are used in the models that used to predict implied tax rates and additional term premium. Figure 3 presents the time series of the fitted P&C Share and the residual P&C Share in Panels A and B, respectively. Panel A displays the forward rate ratio and the fitted P&C Share, which captures exogenous insurance industry demand for municipal bonds. Panel B displays the Muni-Treasury Slope Differential and the residual P&C Share, which captures insurance industry demand not resulting from changes in profitability. The muni-Treasury slope differential is computed as the 20-year and 5-year Municipal Bond slope minus the 20-year and 5-year Treasury slope (i.e., slope of the term structure).

C. The Forward Rate Ratio and Exogenous P&C Demand Shocks

We estimate the effect of P&C demand on the forward rate ratio by running the following regression using Newey-West standard errors:

$$PR_t = a + b_1 * \widehat{PCShare}_t + b_2 * Residual_t + \mathbf{c_t V_t} + \epsilon_t \tag{7}$$

The vector $\mathbf{V}$ contains control variables, which includes the individual top marginal tax rate, change in personal income, and a volatility measure of the S&P 500 (VIX). We expect b_1 to have a negative sign because greater P&C demand should lead to lower long-term municipal bond yields, resulting in less of a forward rate ratio.

Panels A & B of Table 5 provides the estimation results of Equation (7). Panel A utilizes the 5- and 20-year maturities and Panel B considers the 1- and 30-year maturities for robustness. We first run Equation (7) without the control variables and then again with the control variables. We also adjust the time period to include and exclude the time period of the financial crisis. In all cases, Table 5 reports b_1 as negative and statistically significant. This indicates that positive P&C demand shocks have a negative impact on the term premium in the municipal bond yield curve. This is consistent with the idea that as P&C insurance companies demand more of the long-term bonds supplied by municipalities, fewer short horizon investors are required to hold long-term bonds.

Another result is that the b_2 coefficient is positive in sign in all regressions. This is expected since the residual P&C Share picks up the P&C demand that moves endogenously with the slope of the yield curve. The percentage change in personal income measures individual investor demand for tax-exempt bonds, which we expect to be negatively related to the forward rate ratio since individual investors value tax-exempt bonds when income is high.

D. Forward Rate Ratio and Arbitrage Capital

Tender Option Bond (TOB) programs are the most compelling mechanism to capture expected return premiums in the tax-exempt market as they are allowed to finance positions in long maturity tax-exempt bonds by issuing tax-exempt floating rate debt. We examine the relationship between the forward rate ratio and the net flows into TOB programs by including net TOB flows as an explanatory variable in the model estimated in Equation (7). The model is estimated over the 1995 to 2009 time period where net TOB flows are available. The net TOB flows data are annual and thus the value of the net TOB flow is the same for each quarter in a particular calendar year. Clearly, this creates some noise in the measurement of quarterly flows.

There are two non-mutually exclusive potential relationships between TOB net flows and the forward rate ratio (i.e., forward rate ratio, which directly affects the profitability of the trade). The first potential relationship arises when one assumes that changes in the profitability of the trade arise from exogenous shocks to the demand for long-term bonds and that arbitrage capital reacts to the trade. In this case, when long maturity tax-exempt bond investors withdraw capital, the profitability of the trade increases, which attracts arbitrage capital. This case is consistent with the Vayanos and Villa (2010) model where additional risk-averse arbitrage capital requires a larger expected return before committing capital to the trade. In this case, there is a positive relationship between net TOB flows and the forward rate ratio. We refer to this as the *endogenous* arbitrage capital case.

The opposite relationship between net TOB flows and the forward rate ratio from the endogenous arbitrage capital case occurs when the arbitrage capital flows are *exogenous*. For example, suppose that arbitrage capital flows into this trade because of an increased investor appetite to invest in arbitrage/hedge fund type investments in general, or arbitrage capital exits because hedges backfire.

The results presented in Table 6 show a negative and significant relationship between net TOB flows and the forward rate ratio. The finding is not consistent with the endogenous arbitrage capital thesis. Rather, it suggests that the significant movement of capital into TOB funds around the 2005-2007 reduced the forward ratio while the rapid unwinding of these programs in 2008 caused the forward rate ratio to increase.

V. Conclusion

This paper provides an explanation for the muni puzzle based on supply/demand characteristics unique to the tax-exempt bond market. We develop a simple model that shows when the supply of long-term bonds exceeds the demand of investors with an equally long holding period, the yield curve carries an additional forward rate ratio. We use the model to show why the tax-exempt forward rate ratio is consistently greater than that of the Treasury curve.

The demand side of the tax-exempt bond market is dominated by investors with short-term preferences. The supply of tax-exempt bonds is segmented by maturity due to institutional constraints in such a way that the supply of long-term bonds often exceeds the demand by investors with long-term preferences. The excess supply must be bought by investors with short-term preferences, which drives up the yields at long maturities. Using the ratio of forward rates implied in the municipal and Treasury markets from 1982 to 2007, we show that the municipal forward rate ratio gets closer to the Treasury forward rate ratio as property and casualty insurance companies demand more tax-exempt bonds. This explains low implied marginal tax rates at the long end of the yield curve. Our findings complement existing explanations of the muni puzzle, such as systematic risk and liquidity risk, and help to shed light on the complex problem of relating taxable and tax-exempt yields.

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Figure 1. Ownership Percentages of Municipal Bonds

The following chart shows the percentage ownership of municipal bonds through time. Data is from the Federal Reserve's Fund Flow database from 1982 to 2011.

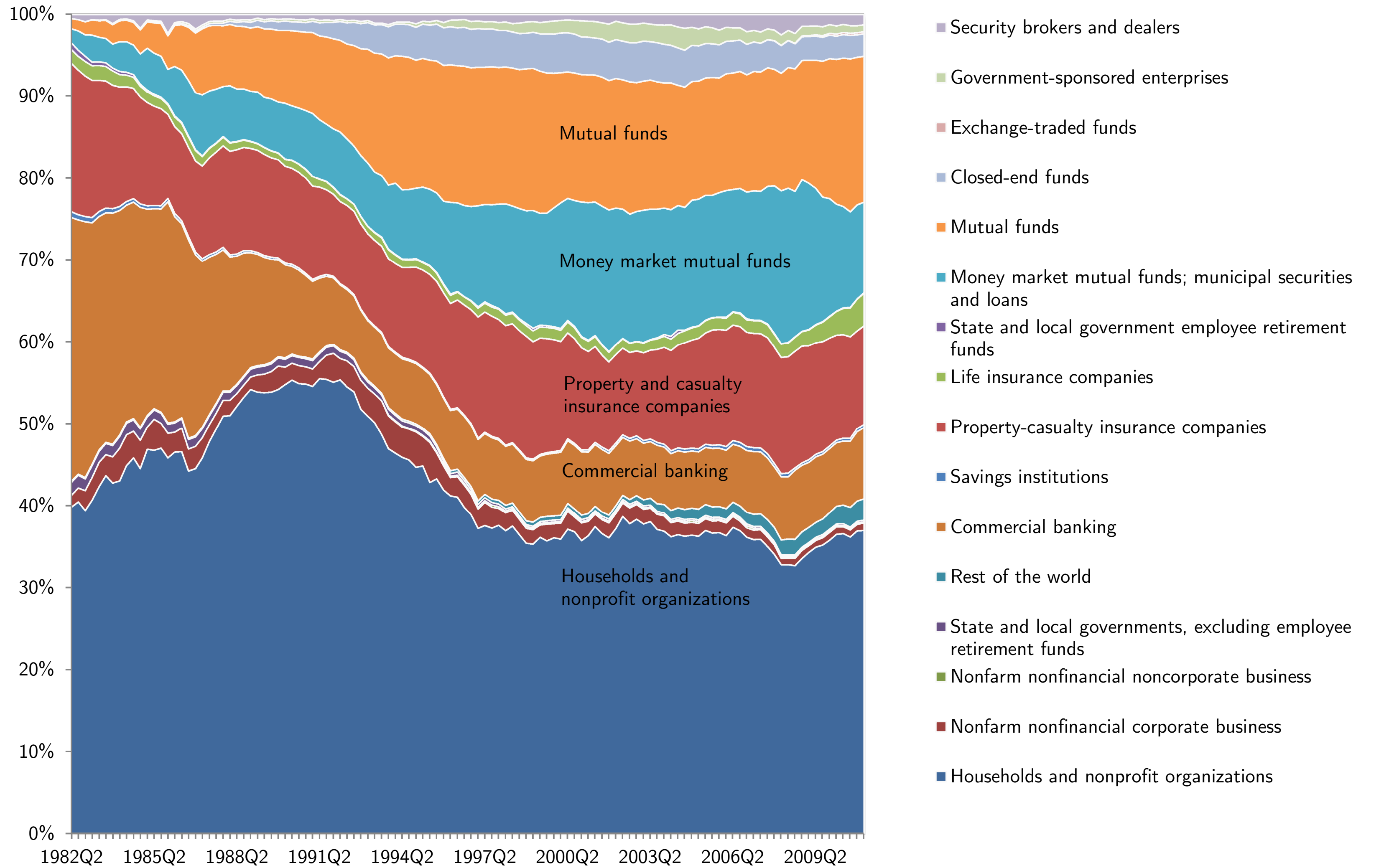
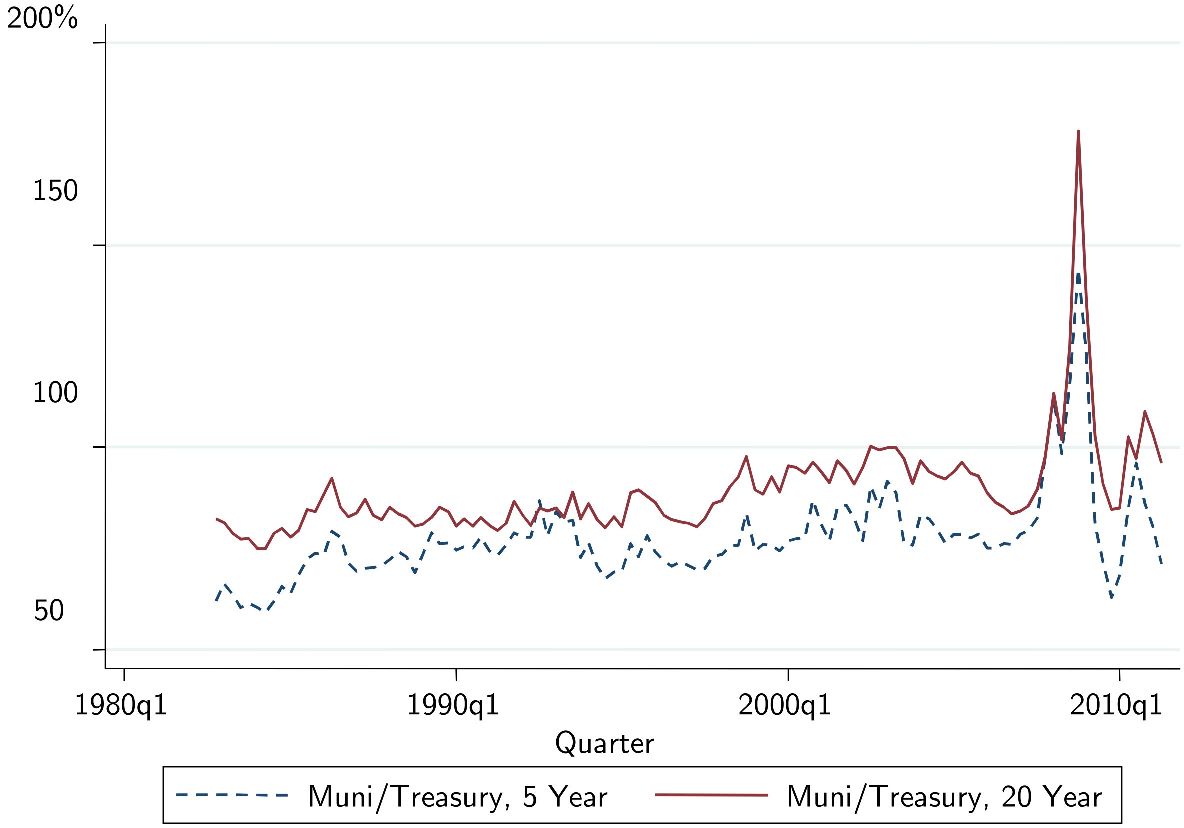


Figure 2. Municipal / Treasury Yield Relationship and Implied Tax Rates

Panel A plots the municipal bond yield over the Treasury yield (as a percentage) for the 5- and 20-year maturities from 1982Q4 to 2011Q2. The data comes from the Thomson Municipal Market Monitor and consists only of AAA-rated general obligation bonds only. Panel B plots the implied tax rates based on the municipal / Treasury bond relationship for various maturities. The implied tax rate is defined as $\tau_i = 1 - r_{Mi}/r_{Ti}$. The yield rates are provided by the Thomson Municipal Market Monitor and span the time period 1982Q4 to 2011Q2.

Panel A. Municipal Yield over Treasury Yield



Panel B. Implied Tax Rates

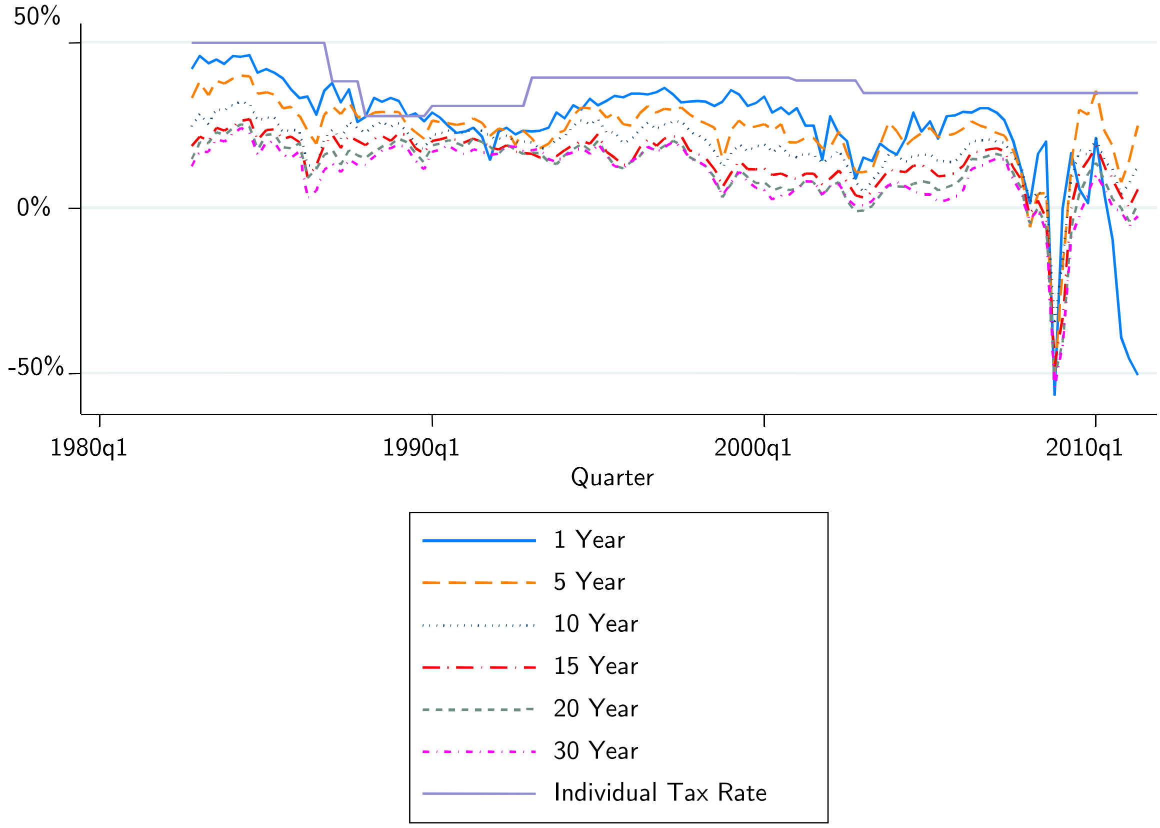
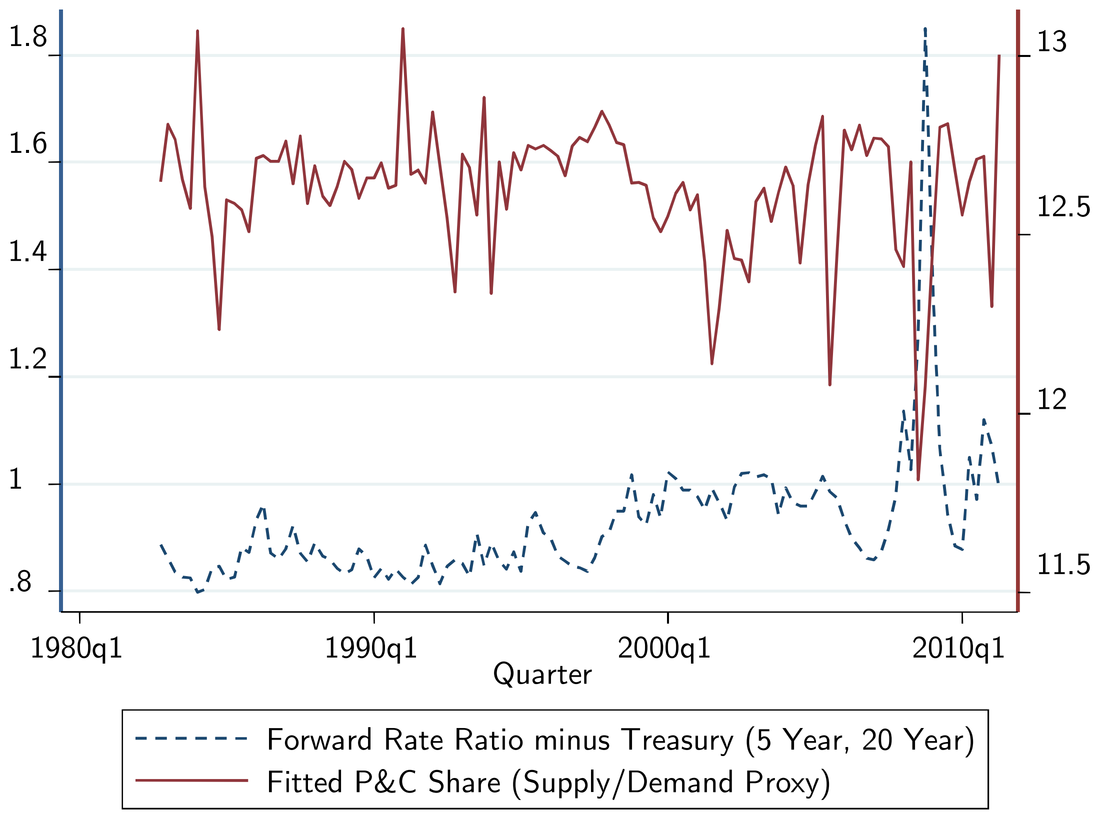


Figure 3. Municipal Bond Yields and P&C Insurance Industry Demand

Panel A presents the time series of the forward rate ratio (the ratio of muni and treasury forward rates at the 5- and 20-year maturities) and the fitted values of the regression of the P&C Share on return on assets of the P&C industry. Panel B shows the time series of the muni-Treasury slope differential and the residual P&C Share. The slope differential is computed as: $(r_{M,20} - r_{M,5}) - (r_{T,20} - r_{T,5})$. The residual P&C Share are the residuals of the regression P&C Share on aggregate return on assets of the P&C insurance industry. All bond yields are retrieved from the Thomson Municipal Market Monitor website.

Panel A. Fitted P&C Share and the Forward Rate Ratio



Panel B. Residual P&C Share and the Muni-Treasury Slope Differential

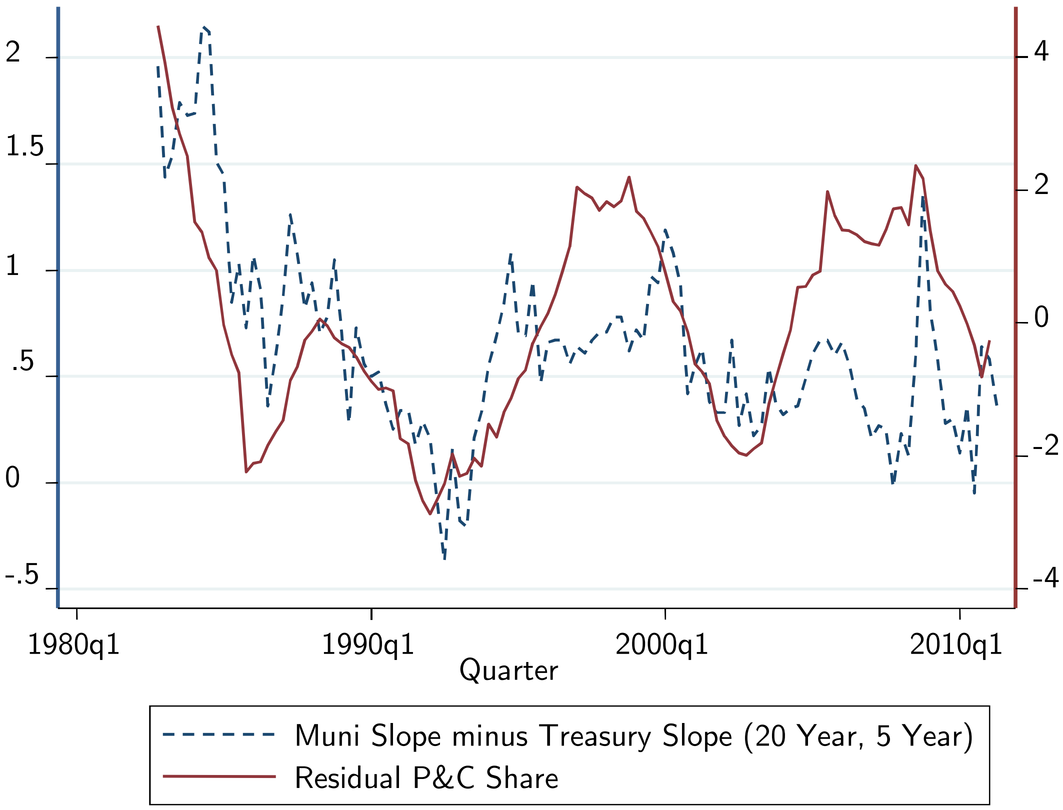


Table 3. Descriptive Statistics of Data Variables

This table provides the summary statistics of the variables used in this paper. The bond yields are retrieved from the Thomson Municipal Market Monitor. The Federal Reserve gathers the municipal bond holdings information of property and casualty insurance companies and total municipal bonds outstanding. The S&P 500 VIX comes from CRSP. Personal income growth is provided by the Bureau of Economic Analysis.

Variables	*Mean*	*Std. Dev.*	*Min*	*Max*	*N*
1-Year Muni/Treasury Relationship	76.31478	22.27053	54.5	250	115
5-Year Muni/Treasury Relationship	77.43739	11.70244	59.1	144.2	115
10-Year Muni/Treasury Relationship	82.40087	10.03639	67	146.5	115
15-Year Muni/Treasury Relationship	86.82522	11.6468	73.4	171.3	115
20-Year Muni/Treasury Relationship	89.39739	12.49227	74.9	178.2	115
30-Year Muni/Treasury Relationship	90.60783	12.31324	75.6	179.7	115
Total Munis Outstanding	1533361	647504.2	508049	2925324	114
Total P&C Muni Holdings	194756.9	91688.18	84742	381938	114
P&C Muni Holdings / Munis Outstanding (P&C Share)	12.62763	1.579209	9.966205	17.11803	114
Aggregate P&C Industry Return on Assets	0.594661	0.256912	-0.53732	1.21368	115
Fitted P&C Share (Demand/Supply Proxy)	12.63091	0.184919	11.81613	13.07647	115
Residual P&C Share	0.000000	1.568646	-2.86933	4.468332	114
Percent Change in Personal Income	0.013406	0.009129	-0.01501	0.03187	114
VIX of S&P 500	20.89515	7.793908	10.63	46.45	103
Municipal Bond Forward Rate (5-Year & 20-Year)	0.06328	0.016252	0.040331	0.111104	115
Treasury Bond Forward Rate (5-Year & 20-Year)	0.070082	0.022711	0.030421	0.138434	115
Forward Rate Ratio ($f_{M5,20}/f_{T5,20}$)	0.926562	0.126179	0.797432	1.849111	115
Forward Rate Ratio ($f_{M1,30}/f_{T1,30}$)	0.908416	0.1242	0.757037	1.805357	115

All variables are quarterly.

Table 4. Demand for Municipal Bonds and Insurance Industry Profitability

This table analyzes the extent to which insurance industry demand for municipal bonds is affected by the industry's profitability. The dependent variable is P&C Share, which is calculated as total P&C municipal bond holdings divided by total municipal bonds outstanding and measures the overall demand for long-term munis relative to supply. The municipal bonds holdings data is provided by the Federal Reserve. An aggregate value-weighted return on assets of the property and casualty insurance industry is gathered from the net income and total assets variables of the Compustat database (including only companies with SIC code of 6331). The fitted P&C Share and the residual P&C Share are used in subsequent analysis.

Independent Variables	***Dependent Variable: P&C Share***
Return on Assets of P&C Industry	1.846**
	(0.729)
Constant	11.40***
	(0.474)
Observations	115
R-squared	0.061

The Newey-West standard errors are reported in parentheses.
Statistical significance indicated by: *** p<0.01, ** p<0.05, * p<0.1

Table 5. Municipal Bond Demand Shocks and the Forward Rate Ratio

The dependent variable is the forward rate ratio as calculated as the ratio of forward rates of municipal and Treasury bonds. We first regress the percentage of all municipal bonds outstanding owned by property and casualty insurance companies (P&C Share) on the value-weighted return on assets of the property and casualty insurance industry. The fitted P&C Share variable is used as the supply/demand proxy for the long-term municipal bond market in the regressions of Panels A and B below. The data spans 1982Q4 to 2011Q2 for regressions using all dates and 1982Q4 to 2007Q4 for regressions excluding the financial crisis.

Panel A. Regressions of the Forward Rate Ratio using the 5- and 20-year municipal and Treasury bond rates

	Dependent Variable: Forward Rate Ratio (1- and 20-year)			
	(1)	**(2)**	**(3)**	**(4)**
Independent Variables	*All Dates*	*All Dates*	*Excluding Financial Crisis*	*Excluding Financial Crisis*
Fitted P&C Share (Supply/Demand Proxy)	-0.345***	-0.223***	-0.145***	-0.133***
	(0.130)	(0.0688)	(0.0434)	(0.0374)
Residual P&C Share	0.0157	0.0327***	0.00269	0.0203***
	(0.0110)	(0.00791)	(0.00646)	(0.00696)
% Change in Personal Income		-3.107*		-0.253
		(1.698)		(0.646)
Top Individual Tax Rate		0.00141		0.00283***
		(0.00138)		(0.00100)
VIX of the S&P 500		0.00350***		0.00137
		(0.00133)		(0.00102)
Treasury Curve Slope (20y - 5y)		0.0519***		0.0405
		(0.0166)		(0.0250)
Constant	5.281***	3.636***	2.732***	2.438***
	(1.654)	(0.899)	(0.554)	(0.474)
R-Squared	0.28	0.56	0.13	0.40
Time Span	1982Q4-2011Q2	1985Q4-2011Q2	1982Q4-2007Q4	1985Q4-2007Q4
Observations	114	102	100	88

The Newey-West standard errors are reported in parentheses. Statistical significance indicated by: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Panel B. Regressions of the Forward Rate Ratio using the 1- and 30-year municipal and Treasury bond rates

	Dependent Variable: Forward Rate Ratio (1- and 30-year)			
	(1)	**(2)**	**(3)**	**(4)**
Independent Variables	*All Dates*	*All Dates*	*Excluding Financial Crisis*	*Excluding Financial Crisis*
Fitted P&C Share (Supply/Demand Proxy)	-0.328**	-0.208***	-0.122***	-0.132***
	(0.129)	(0.0682)	(0.0356)	(0.0368)
Residual P&C Share	0.0141	0.0319***	8.77e-05	0.00962
	(0.0113)	(0.0116)	(0.00633)	(0.00974)
% change in personal income		-3.510**		-0.702
		(1.637)		(0.518)
Top Individual Tax Rate		0.000805		0.00246**
		(0.00219)		(0.00112)
VIX of the S&P 500		0.00329**		0.000920
		(0.00142)		(0.00116)
Treasury Curve Slope (30y – 1y)		0.0199**		0.00211
		(0.00794)		(0.0114)
Constant	5.047***	3.459***	2.417***	2.454***
	(1.646)	(0.897)	(0.455)	(0.483)
Time Span	1982Q4-2011Q2	1985Q4-2011Q2	1982Q4-2007Q4	1985Q4-2007Q4
R-Squared	0.26	0.54	0.10	0.30
Observations	114	102	100	88

The Newey-West standard errors are reported in parentheses. Statistical significance indicated by: *** p<0.01, ** p<0.05, * p<0.1

Table 6. Arbitrage Capital and the Forward Rate Ratio

The dependent variable is the forward rate ratio as calculated as the ratio of forward rates of municipal and Treasury bonds. Arbitrage capital is measured through the activity of Tender Option Bond (TOB) programs. The variable TOB Net refers to the number of TOB program creations minus the number of TOB program liquidations. TOB data is provided by Bergstresser, Cohen and Shenai (2010). The variable Fitted P&C Share is equal to the fitted (i.e., predicted) value based on a regression of P&C Share on the value-weighted return on assets of the property and casualty insurance industry. The variable "Residual P&C Share" is the residual value of the regression. The data spans 1995Q1 to 2009Q4.

	Dependent Variable: Forward Rate Ratio (5- and 20-year)		
Independent Variables	(1)	(2)	(3)
TOB Net (Creations minus Liquidations)	-0.00219*	-0.00131*	-0.00281***
	(0.00122)	(0.000697)	(0.000822)
Fitted P&C Share (Supply/Demand Proxy)		-0.408***	-0.212**
		(0.144)	(0.0793)
Residual P&C Share		0.0228	-0.00337
		(0.0180)	(0.0109)
Constant	0.998***	6.121***	5.155***
	(0.0405)	(1.828)	(1.200)
Control Variables (Personal Income % Change, Tax Rate, VIX, Treasury Slope)	NO	NO	YES
Time Span	1995Q1-2009Q4	1995Q1-2009Q4	1995Q1-2009Q4
R-Square	0.084	0.38	0.61
Observations	60	60	60

The Newey-West standard errors are reported in parenthesis. Statistical significance indicated by: *** $p<0.01$, ** $p<0.05$, * $p<0.1$