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Primary and Secondary Subnational Debt Markets

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PRIMARY AND SECONDARY SUBNATIONAL DEBT MARKETS

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PRIMARY AND SECONDARY SUBNATIONAL DEBT MARKETS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

U.S. state and local (subnational) governments issue municipal bonds in the capital markets to finance infrastructure projects such as schools, roads, and bridges. These securities are first sold in the primary municipal bond market and subsequently resold in the secondary market. This dissertation explores the primary and secondary subnational debt markets and their impact on state and local governments. The first chapter provides background information on the municipal bond market. The second chapter estimates the market-implied marginal tax rates associated with tax-exempt debt. The third chapter estimates the effect of the secondary municipal bond market on future cost of borrowing for debt-issuing governments. The fourth chapter explores why some securities trade thousands of times in the secondary market while most never trade. The fifth chapter concludes the dissertation and discusses relevant policy implications.

The size of the subnational debt has surpassed $3.8 trillion as of the third quarter of 2017 [1]. Understanding the primary and secondary municipal bonds markets and the impact of these markets on issuers can allow thousands of debt-issuing state and local governments to save billions of dollars in borrowing costs. This is important because reducing borrowing costs, in turn, can free up funds for other public services such as education and health care. Debt is a crucial part of public finances. As such, this dissertation contributes to the public finance literature, particularly in the area of public financial management research.

Chapter 1: Background. The majority of state and local governments in the U.S. have debt-issuing capacity. There is quite a bit of heterogeneity in the types of issuers[1] and financial products that are issued in the municipal bond market. The variety of market participants (underwriters, dealer-brokers, etc.) add further complexity to the debt performance outcomes of issuers. The main feature that sets the muni market apart from other capital markets is the tax exemption of interest income - most municipal bonds are exempt

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[1]There are over $90,000$ government entities of which about $40,000$ are general purpose governments and the rest are special and school districts. See Section 1.1.

from federal, state, and certain local income taxes.

Chapter 2: Primary Market. Eliminating or limiting tax exempt-status of municipal bonds becomes a potential policy alternative in periods of budgetary distress, given that taxes foregone due to exemption amount to billions of dollars per year to the federal government. This chapter estimates the implied marginal tax rates associated with tax-exempt munis to understand the tax-reduction benefits accrued to state and local governments. In this analysis, tax-exempt munis are matched to near-identical taxable munis, which creates a unique quasi-experimental design. Results of the Random Coefficients Model (RCM), which accounts for issuer- and issuance-level unobserved effects, show significant heterogeneity in implied marginal tax rates across issuer types (e.g. counties vs. school districts) and over time. The longstanding muni puzzle, the finding that interest on tax-exempt bonds is higher than the theory would predict, disappears for general purpose governments, once the nested structure and the product and issuer heterogeneity of the municipal bond market are taken into account. Results imply that municipal forms of government benefit the most from the tax exemption, while special districts benefit the least.

Chapter 3: Effect of the Secondary Market On the Primary Market. The primary market for state and local government borrowing receives great attention yet researchers as well as subnational debt-issuing governments tend to ignore the secondary municipal bond market. However, if the primary market rewards the performance of the issuer's outstanding debt in the secondary market, then state and local governments are neglecting an important piece of the puzzle and the potential to reduce future borrowing costs. This study combines large proprietary databases of primary and secondary market information to test whether the performance of existing debt in the secondary market affects future cost of borrowing for state and local governments. Results show that fluctuations in the secondary market prices and yields impact future borrowing costs. Further, the effect of the secondary market varies significantly by issuer. Findings imply that the secondary market contains an additional layer of real-time quality information not captured by other lagged metrics such

as credit ratings.

Chapter 4: Secondary Market. The municipal bond market is full of peculiarities. One such puzzling fact is that some securities trade thousands of times in the secondary market while most do not trade at all. Studies have shown that these differences in trading frequency cannot simply be attributed to transaction costs - actively traded bonds are not necessarily less expensive to trade. Understanding what accounts for such distinct patterns of trading activity can inform investors and issuers about market demand and potentially improve government debt issuance outcomes and household portfolio allocation decisions. This paper examines the dispersion of trading activity of municipal securities in the secondary market using large databases of security- and transaction-level information. Results show that safer and high quality securities tend to be taken off the market quickly and most likely absorbed into the portfolios of buy-and-hold type investors. Further, the call complexity hypothesis reveals distinct trading patterns for different trade types (interdealer trades vs. retail customer trades) as the call date approaches. Finally, there is some evidence of speculative trading in the secondary market which further contributes to the wide dispersion in trading activity among various securities.

Chapter 5: Conclusion. The first set of findings show that the effect of the municipal bond tax exemption policy are substantial. Smaller municipalities benefit the most from the ability to issue tax-exempt munis. Second, I find that the secondary market contains an additional layer of real-time quality information not captured by other lagged metrics such as credit ratings. This information contained in the secondary market performance of the issuer's existing debt has a direct impact on future borrowing costs for state and local governments. Finally, hyper-trading in secondary market for municipal bonds is explained using several conceptual frameworks, such as portfolio absorption, speculative trading, and call complexity.

CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1 SUBNATIONAL GOVERNMENTS

The decentralized nature of the U.S. government creates significant heterogeneity in types of governments as well as debt issued by these governments. In addition to the 50 states, five territories, and the District of Columbia (DC), there are 3,031 counties, 35,879 municipalities (cities, town, townships, villages, boroughs), 38,266 special districts (such as utilities, port authorities, etc.), and 12,880 independent school districts in the United States according to the most recent 2012 U.S. Census of Governments. Debt issued by state and local governments is commonly referred to as subnational or municipal debt. City and county governments are usually the largest both in population size and expenditure among subnational governments. Special districts, on the other hand, are usually the smallest entities with a singular operational purpose such as treating waste or providing electricity. While states receive most of their revenues from income taxes, most cities, counties, and school districts rely on property taxes. Special districts, on the other hand, are generally funded through user fees. State governments enjoy a certain level of autonomy from the federal government, while local governments are creatures of their parent state governments.

1.2 MUNICIPAL SECURITIES/MUNICIPAL BONDS

Municipal bonds or municipal securities (munis) characterize debt issued in the capital markets by state and local (subnational) governments to fund various capital infrastructure projects such as roads, bridges, schools, hospitals, and parks. Most municipal bonds are issued in multiple increments at different prices with different par amounts, maturity dates, coupon payments, and CUSIP numbers. Bonds issued in multiple increments are called serial bonds. Bonds that are comprised of a single maturity are called term bonds. Each maturity/security is assigned a 9-digit CUSIP number, a unique security identifier issued by the Committees on Uniform Securities Identification Procedures (CUSIP) Bureau. The first

six digits of the CUSIP number identify the issuer and the last three digits/letters identify a specific maturity.

Figure 1.1 provides a visual example of a structure of a municipal debt issuance. The excerpt from the 2010 Official Statement (OS) of the State of New York (NY) shows a single debt issuance. Within this one debt issuance, the State of New York issued five term bonds and three different serial bonds - Series 2010A, Series 2010B, and Series 2010C. The first term bond in the amount of $3,560,000 with a 4.125% coupon is due March 1, 2032 at a yield of 4.3000%. Each of the serial bonds have multiple maturities while term bonds have a single maturity. Series 2010A at the top of the Figure 1.1 is comprised of 20 different maturities (10 on the right side of the top panel and 10 on the left side of the top panel) that were issued simultaneously and mature between 2011 and 2030 with various par amounts,[1] interest (coupon) rates,[2] and offering yields.[3] In Figure 1.1, each CUSIP is referred to as a security/maturity, each series is referred to as a bond (including term bonds), and the entire table is referred to as an issuance in the remainder of this dissertation. For example, the first half of the first row of the first panel in Figure 1.1 identifies CUSIP 649791AY6. Notice that all of the securities share the base CUSIP number 649791.

There is significant heterogeneity in the municipal bond market both in terms of issuers as well as products. Municipal bonds can be short or long-term, general obligation or revenue-backed, with different call features, credit ratings, and other security characteristics. There are also various market participants in the muni market. The main regulatory agency in the municipal bond market, the Municipal Securities Rulemaking Board (MSRB) created by Congress in 1975, operates with a mission to protect investors, the public, and, since 2010, state and local governments. The next sections discuss the role of financial intermediaries and the types of investors in the municipal bond market.

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[1] Par amount is also referred to as par, face value, or the principal. This is the amount to be paid back to the investor at maturity.

[2] Coupon rate determines the fixed interest payments each period. For example, a 2% **annual** coupon rate means that the investor gets a coupon payment equal to 2% of the par amount of the maturity every year.

[3] See Equation 2.1 for the price/yield relationship formula.

$181,255,000 Series 2010A Tax-Exempt Bonds
(Base CUSIP Number†: 649791)

Amount	Maturity (March 1)	Interest Rate	Yield/ Price	CUSIP #†	Amount	Maturity (March 1)	Interest Rate	Yield/ Price	CUSIP #†
$14,990,000	2011	2.000%	0.330%	AY6	$2,155,000	2021	3.125%	3.210%	BJ8
$15,290,000	2012	2.000%	0.750%	AZ3	$2,215,000	2022	3.250%	3.350%	BK5
$15,595,000	2013	2.000%	1.000%	BA7	$2,290,000	2023	3.375%	3.450%	BL3
$15,905,000	2014	2.000%	1.300%	BB5	$2,365,000	2024	3.500%	3.550%	BM1
$16,225,000	2015	3.000%	1.690%	BC3	$2,455,000	2025	3.500%	3.650%	BN9
$16,710,000	2016	3.000%	2.130%	BD1	$2,025,000	2026	3.625%	3.750%	BP4
$17,215,000	2017	3.000%	2.450%	BE9	$2,105,000	2027	3.750%	3.850%	BQ2
$ 8,250,000	2018	4.000%	2.700%	BF6	$2,180,000	2028	4.000%	3.950%	BR0
$ 8,580,000	2019	3.000%	2.890%	BG4	$2,265,000	2029	4.000%	4.050%	BS8
$ 8,840,000	2020	0.000%	3.450%	BH2	$2,360,000	2030	4.000%	4.070%	BT6

$3,560,000 4.125% Term Bonds due March 1, 2032, at a yield of 4.300%
(CUSIP†: 649791BU3)
$5,925,000 4.375% Term Bonds due March 1, 2035, at a yield of 4.500%
(CUSIP†: 649791BV1)
$11,755,000 4.500% Term Bonds due March 1, 2040, at a yield of 4.580%
(CUSIP†: 649791BW9)

$50,980,000 Series 2010B Taxable Bonds
(Base CUSIP Number†: 649791)

Amount	Maturity (March 1)	Interest Rate	Yield/ Price	CUSIP #†	Amount	Maturity (March 1)	Interest Rate	Yield/ Price	CUSIP #†
$4,610,000	2011	1.000%	0.698%	BX7	$5,080,000	2016	3.250%	3.257%	CC2
$4,655,000	2012	1.250%	1.228%	BY5	$5,245,000	2017	3.600%	3.507%	CD0
$4,710,000	2013	2.000%	1.961%	BZ2	$5,435,000	2018	3.750%	3.707%	CE8
$4,805,000	2014	2.600%	2.538%	CA6	$5,635,000	2019	4.100%	4.042%	CF5
$4,935,000	2015	3.000%	2.938%	CB4	$5,870,000	2020	4.250%	4.242%	CG3

$216,860,000 Series 2010C Build America Bonds
(Base CUSIP Number†: 649791)

Amount	Maturity (March 1)	Interest Rate	Yield/ Price	CUSIP #†	Amount	Maturity (March 1)	Interest Rate	Yield/ Price	CUSIP #†
$ 9,475,000	2018	4.090%	4.090%	CH1	$12,860,000	2025	4.890%	4.890%	CQ1
$ 9,860,000	2019	4.290%	4.290%	CJ7	$13,490,000	2026	5.190%	5.190%	CR9
$10,285,000	2020	4.340%	4.340%	CK4	$14,190,000	2027	5.290%	5.290%	CS7
$10,730,000	2021	4.440%	4.440%	CL2	$14,940,000	2028	5.390%	5.390%	CT5
$11,205,000	2022	4.540%	4.540%	CM0	$15,745,000	2029	5.440%	5.440%	CU2
$11,715,000	2023	4.690%	4.690%	CN8	$16,600,000	2030	5.540%	5.540%	CV0
$12,265,000	2024	4.840%	4.840%	CP3					

$23,125,000 5.590% Term Bonds due March 1, 2035, at a yield of 5.590%
CUSIP†: 649791CW8
$30,375,000 5.620% Term Bonds due March 1, 2040, at a yield of 5.620%
CUSIP†: 649791CX6

Figure 1.1: Excerpt from The Official Statement of The State of New York (2010)

1.3 DEBT ISSUANCE PROCESS

Once a subnational government decides to issue a bond or a set of bonds, a financing team consisting of various professionals such as municipal advisors, bond counsel, rating agencies, trustees, underwriters, etc. is assembled to start the underwriting process.[4] Underwriters are one of the most important market participants in the debt issuance process. Typically, the underwriting investment bank(s) purchase(s) the entire bond issuance from the issuer at a discount and sell(s) these securities to the investors at the offer price. The difference between the offer price paid by the investors and the price paid by the underwriter, also known as the gross spread, compensates the underwriting group for their services. In a competitive sale, the issuer requests bids from underwriters and accepts the best bid, whereas in a negotiated sale, the issuer works with a single underwriter or underwriting syndicate to structure and price the debt.

1.4 PRIMARY AND SECONDARY BOND MARKETS

The debt issuance process between the issuer and the underwriter and the first transaction between the underwriters and the initial investor take place in the primary municipal bond market. The new debt issuance is accompanied with an official statement (OS) which contains important information about the bonds and the issuer. The OS serves as the main source of information for potential investors. Any subsequent sale of municipal securities following the initial sale take place in the secondary market. The MSRB supplies the OS and other relevant primary and secondary market trade information to the public on its website at `www.emma.msrb.org`.

The secondary municipal bond market is an over-the-counter, dealer market with no central exchange. Most municipal securities rarely trade in the secondary market given that most investors buy and hold munis until maturity. However, if an investor chooses

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[4]The Municipal Securities Rulemaking Board (MSRB) describes the role of each team member on the MSRB website: http://msrb.org/msrb1/pdfs/Financing-Team.pdf.

Table 1.1: Holders of U.S. Municipal Securities ($ Billions)

2017	Individuals/ Households	Mutual Funds[6]	Banking Institutions[7]	Insurance companies[8]	Other [9]	Total
Q1	1,646.4	912.9	580.7	517.0	172.4	3,829.3
Q2	1,626.6	925.3	585.3	522.9	176.9	3,837.0
Q3	1,561.5	934.7	584.2	530.2	192.6	3,803.2
Q4	1,569.5	948.7	593.7	543.7	195.1	3,850.7

Note: Data is obtained from SIFMA.[10]

to sell their municipal bond holdings, she will generally do so through a broker-dealer. According to the MSRB, there were 1,312 broker-dealers registered with the MSRB as of February, 2018. These broker-dealers have to report all trades to the regulator.[5] The municipal securities dealer will purchase the security from the current investor and sell it to a new investor or another dealer. There are generally two types of investors in the secondary municipal bond market: individual retail investors and institutional investors. Retail investors are not the minority in this market. Table 1.1 shows that the majority of holders of municipal debt are individuals and/or households. These individuals tend to be high-net-worth investors in the highest marginal tax brackets looking to reduce their tax burden.

1.5 INSTITUTIONAL CONTEXT: TAX EXEMPTION

Most municipal securities are exempt from federal, state, and certain local income taxes while some munis are taxable if the federal and/or state governments deem the use of bond proceeds to be of insignificant public value. Such triple tax exemption[11] allows subnational

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[6]Includes mutual funds, money market funds, closed-end funds and exchange traded funds.

[7]Includes U.S. chartered depository institutions, foreign banking offices in the U.S., banks in U.S. affiliated areas, credit unions, and broker dealers.

[8]Includes property-casualty and life insurance companies.

[9]Includes non-financial corporate business, non-financial non-corporate business, state and local governments and retirement funds, government-sponsored enterprises and foreign holders.

[10]Securities Industry and Financial Markets Alliance (SIFMA) Research and Data. www.sifma.org/resources/archive/research.

[5]Municipal Securities Rulemaking Board. http://www.msrb.org/BDRegistrants.aspx.

[11]Tax status of municipal securities is determined at the time of issuance.

governments to borrow at a lower cost compared to other borrowers (e.g. corporations) and provides investors, especially local residents, with attractive tax-exempt investment options. Municipal bonds are attractive to various market participants, especially investors in the highest marginal tax brackets, who are looking to reduce their tax burden.

Tax-exempt securities yield lower gross-of-tax interest earnings to investors. However, investors are willing to accept lower interest in return for reduction in their income taxes. Therefore, issuers are able to offer lower interest and save on borrowing costs. As an example, Morgan Stanley's website provides a simple calculator on its website to find the taxable equivalent yield for tax-exempt securities.[12] Based on this calculator, the investor can estimate that a 5% tax-free yield for a Georgia resident in the top federal income bracket is equivalent to a 8.81% taxable yield. This is a simple calculation and does not take into account many other important factors. Nonetheless, tax exemption implies a significant interest cost savings for most debt issuers.

Proponents of the muni tax-exemption policy argue that the federal government has an incentive to provide federal income tax exemptions for subnational debt given that the state and local government investment in public infrastructure fosters economic growth. Such positive economic activity is likely to generate spill-over effects and benefit the national government. The logic for state income tax exemption is the same. States may want to forgo taxes on debt issued by cities and other subsidiary governments, in addition to their own debt, to boost the local economy. The opponents of tax exemption, on the other hand, argue that the economic benefits are either small, non-existent, or better achieved through other means, such as direct subsidies to issuers.

The 1988 Supreme Court case *South Carolina v. Baker* ruled that the federal government can tax the interest earned on municipal bonds [2]. Therefore, eliminating or limiting the tax exemption of municipal bonds becomes a potential policy alternative in periods of budgetary distress. For example, President Obama's 2017 budget proposal included

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[12]Morgan Stanley. `morganstanley.com/wealth-investmentsolutions/municipalbonds`.

capping the exemption of interest earnings and President Trump's 2017 tax reform plan alluded to such limitations, which were later abandoned.[13] The outcomes of such a policy intervention, however, are not immediately clear. Proponents of similar tax expenditure elimination/reduction policies argue that the federal and state governments forgo billions of dollars due to lost taxes, and that tax collection on earned interest from municipal securities would be enough for the federal government to subsidize these public projects without state and local governments falling back on debt financing. On the other hand, the opponents argue that eliminating or changing the exemptions may divert investors who currently purchase and trade municipal bonds to other assets, thereby leaving issuers of municipal debt in a precarious position. Consequently, state and local governments would either incur significantly higher costs of borrowing or lose debt financing as an option. Even if the federal government did subsidize public projects as proponents have suggested, the opponents argue that distortions from such a policy change may potentially outweigh the gains from increased income tax revenues.

Since the adoption of the Sixteenth Amendment in 1913 and resulting creation of the federal income tax, the law has allowed interest on municipal securities to be tax exempt.[14] There is, however, significant variation in the tax-exempt status of munis at the state level. With a few exceptions of reciprocity, double exemption at both the federal and state levels applies only to debt issued within the state of the investor's residence. Theoretically, this local flavor encourages resident investors to invest in municipal securities issued in their own states. On the other hand, some states tax certain municipal securities only. Such discriminatory tax policy complicates the analysis of the net effects of the tax exemption policy on the issuers as well as the investors. Denison et al. (2009) provide estimates of the revenue loss if the selected group of states were to exempt all municipal bonds from tax calculations along with the potential revenue gains if the selected states instead were to tax all munis [3]. The authors further analyze what might happen if all municipal bonds

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[13]The 2018 tax reform eliminated private-activity bonds and advance refunding.
[14]Technically, munis were exempt before, the exemption just was not relevant until 1913.

are either exempt from state taxes in all states or taxable in all states. This type of analysis focuses on revenue gains and losses and ignores investor decisions. A rational investor will likely re-calibrate her portfolio if the tax treatment of municipal securities is changed or eliminated, thereby potentially invalidating these revenue loss/ gain estimates.

State and local governments can issue taxable municipal bonds, such as private activity bonds (PABs), by paying relatively higher interest to investors compared to exempt munis. Forgoing the tax-exempt status gives the issuers more autonomy and frees them from administrative and financial burden of abiding by numerous SEC regulations and IRS rules. In recent years, given more stringent regulations, incentives to issue taxable bonds have increased [4]. Issuing taxable rather than tax-exempt bonds, although more expensive, gives the issuer a certain level of freedom in terms of private use and reporting which may be especially valuable to smaller issuers with less administrative resources. Further, if the issuer is not completely certain about the use of proceeds in a project with many components, some of which may not be of public value, that issuer may opt in for a taxable status as a precaution.

It may seem surprising that investors choose taxable municipal bonds over tax-exempt securities, especially given that the muni market is dominated by high-net-worth retail investors in the top income tax brackets. However, the muni market is rather diverse on the demand side as well as the supply side. Some investors in the market gain little to no benefit from the tax-exempt status. These include, but are not limited to, pension funds, international entities, individual IRA accounts, etc. These investors simply utilize taxable munis as a means to diversify their portfolios. To such investors, munis represent an alternative asset class to Treasuries, U.S. agency bonds (Freddie, Fannie), corporate bonds, etc. Although federally taxable, most taxable munis are generally exempt from state and local income taxes. Furthermore, taxable munis should, at least theoretically, offer higher interest than tax-exempt munis. Another appealing feature for some taxable munis is the stronger protections from early redemptions compared to tax-exempt bonds through the

make-whole call feature.[15]

Cost (i.e. lost tax revenues) and benefits (i.e. growth of public infrastructure) of tax exemption of municipal securities to federal and state governments and tax benefits accrued to investors are not simple to estimate. Long-term and short-terms goals of the policy, as well as the multifaceted impact on variety of stakeholders, both private and public, complicate the analysis. Nevertheless, the importance and the size of the municipal market in the U.S. capital markets warrants a closer look at the municipal bond market.

1.6 MARKET SHORTCOMINGS

The municipal bond market suffers from several shortcomings such as the lack of a centralized exchange and shorting and less transparency compared to other capital markets, such as the equity markets. Municipal bond trading is more expensive, transaction costs have economies of scale in trade size, and trade frequencies for municipal securities do not significantly affect transaction costs. Finally, most municipal bonds rarely trade in the secondary market. Some researchers and analysts argue that these features are partially to blame for the peculiarities and numerous puzzling phenomena observed in the market. These unique aspects of the municipal bond market deserve some attention in this section in order to provide context for the rest of the dissertation. An important characteristic of the municipal bond market is that there is no centralized exchange or trading hours as in the equity markets. Instead, trades are completed over the counter and investors trade municipal securities through the brokers. The broker-dealers then purchase and sell these securities among themselves in the inter-dealer market in addition to trading with retail and institutional investors.

Shorting or short-selling is defined by the Securities and Exchange Commission (SEC) as "the sale of securities that an investor does not own or has borrowed." Shorting is rather

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[15]The make-whole-call feature of a security eliminates the interest costs savings of refinancing for the most part. Instead of being callable at par, for securities with this feature, investors are compensated at a price which equals the present value of future interest payments. This is punitive for the issuer who would otherwise benefit from early redemption.

difficult and almost impossible in the muni market given the buy-and-hold nature of the market, which makes most munis hard to come by. An alternative to shorting is to use credit derivatives, such as the credit default swaps.[16] This type of artificial shorting, however, is very small in the muni world compared to other derivatives markets. Nonetheless, local government officials worry that such speculation from shorting will affect the investor perception of their creditworthiness.

Over the last decade, the municipal bond market has innovated to move toward a model that is as transparent and real-time as the equity markets. Although the municipal bond market has not yet reached this goal, significant improvements have occurred over the years. The SEC requires all transactions on corporate bonds and equities to be reported almost instantaneously. The MSRB has implemented various rules and regulations to bring the reporting on municipal transactions as close to this metric as possible. Since 2005, all transactions (with a few exceptions) related to municipal bonds must now be reported within fifteen minutes from the time of trade. These unique aspects of the muni market present an interesting research environment.

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[16]Credit default swap is a contract in which the issuer of a bond insures the buyer's potential losses.

CHAPTER 2

TAX EXEMPTION OF STATE AND LOCAL DEBT: HAS THE MUNI PUZZLE DISAPPEARED?

ABSTRACT

Most municipal securities (munis) are exempt from federal, state, and certain local income taxes. Eliminating or limiting tax-exempt status of municipal bonds becomes a potential policy alternative in periods of budgetary distress, given that this tax expenditure costs billions of dollars per year to the federal government. This chapter estimates the implied marginal tax rates associated with tax-exempt munis to understand the tax-reduction benefits accrued to state and local governments. In this analysis, tax-exempt munis are matched to near-identical taxable munis, which creates a unique quasi-experimental design. Results of the random coefficients model (RCM), which accounts for issuer- and issuance-level unobserved effects, show significant heterogeneity in implied marginal tax rates across issuer types (e.g. counties vs. school districts) and over time. The longstanding muni puzzle, the finding that interest on tax-exempt bonds is higher than the theory would predict, disappears for general purpose government debt, once the nested structure and the product and issuer heterogeneity of the municipal bond market are taken into account. Results imply that municipal forms of government benefit the most from the tax exemption, while special districts benefit the least.

Keywords: federal tax expenditure, subnational debt, municipal bonds, muni puzzle, tax exemption policy, implied tax rate.

JEL codes: G12, G14, H5, H70, H71, H74.

2.1 INTRODUCTION

Most municipal securities (munis) are exempt from federal, state, and certain local income taxes.[1] Such triple tax exemption allows subnational[2] governments to borrow at a lower cost compared to corporations and other institutional borrowers. On the other hand, tax-exempt municipal securities are attractive to various market participants, especially investors in high marginal tax brackets looking to reduce their tax burden. Given that the federal and state governments forgo large sums of tax revenue due to the exemption policy, a common concern is that issuers are not recouping the full benefits of the exemption. One of the main concerns policy makers often express is that these benefits are accruing to high-net-worth investors who dominate the muni market rather than sufficiently reducing borrowing costs for debt-issuing governments.

Academic researchers have identified an inconsistency in what the theory predicts about the interest costs on tax-exempt securities (in comparison to other taxable fixed-income asset classes) and what is observed in the muni market. This longstanding finding that the interest cost on longer-term tax-exempt municipal securities seems too high is commonly referred to as the "muni puzzle." The muni puzzle literature estimates that the implied marginal tax rate associated with tax-exempt securities is about $20 - 25\%$, while theory predicts an implied tax rate of about $35 - 39.6\%$, given the current highest corporate and individual income tax rates.

This study tackles the muni puzzle in a novel way and estimates the market-implied marginal tax rates associated with municipal securities. This estimate, in turn, can identify interest cost reductions accrued to state and local issuers and tax reduction benefits accumulated to investors. In this analysis, tax-exempt munis are matched to their near-identical taxable counterparts, accounting for underlying idiosyncratic risks, investor preference for

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[1]Some munis are taxable if the federal and/or state governments deem the project to be of insignificant public value.

[2]Subnational governments are subsidiaries of the national government, i.e. all state and local (sub-sovereign) governments. Debt issued by subnational governments is commonly referred to as municipal debt. Tax-exemption status of municipal securities is determined at the time of issuance.

municipal securities over other fixed-income asset classes and potential preference for debt issued by specific issuers. Using the Random Coefficients Model (RCM) to account for issuer- and issuance-level unobserved effects, my results indicate large heterogeneity in implied marginal tax rates across issuers (e.g. school districts vs. counties) and issuances (large vs. small, general obligation vs. revenue debt, etc.). The muni puzzle disappears under more careful scrutiny, implying that borrowing costs for general purpose governments would increase if the tax-exemption policy were eliminated or even capped.

This research is important for at least three reasons. First, the municipal securities market, with $3.8 trillion in outstanding debt, is a significant portion of the U.S. capital markets. Second, tax exemption of municipal securities is often on the chopping block by Congress due to the mere size of the corresponding tax expenditures. Poterba and Verdugo (2011) estimate that the federal government alone forgoes $14 billion in revenue annually due to the exemption of interest income [5]. The muni puzzle implies that the federal and state governments are wasting tax dollars by subsidizing subnational borrower's interest costs and that the benefits of the policy may be mostly accruing to investors. Thus, understanding the effect of the policy on borrowing costs through implied reductions in interest costs (implied marginal tax rates) is a crucial next step. Third, the muni puzzle implies that state and local governments may be paying too much in interest costs. Addressing the puzzle, therefore, strengthens the stance that the subsidy (in the form of tax exemption) significantly lowers borrowing costs for state and local governments and encourages investment in public infrastructure rather than only helping the rich [investors] get richer.

Contributions of this study are as follows: First, this study addresses the longstanding "muni puzzle" for general purpose governments. Implied marginal tax rate is consistent with the marginal tax bracket of a typical muni investor at around 33%. Results indicate that the tax-exemption policy is effective in that it reduces interest costs significantly, consistent with theory. Second, results show that there is significant heterogeneity in yields for different types of issuers. School and special districts tend to get less interest cost reduc-

15

tions on exempt debt compared to general purpose governments such as cities, towns, and townships. Previous studies have not accounted for such issuer-type effects.

2.2 REVIEW OF THEORY AND LITERATURE

Access to tax-exempt debt financing by state and local governments is purely an American phenomenon. One of the benefits of this policy is encouraging investment in essential infrastructure and public projects in the spirit of fiscal federalism. Due to this tax exemption, state and local governments pay lower interest when issuing debt in the capital markets compared to corporations and other institutional borrowers. Investors, in turn, are willing to accept lower returns on exempt securities because interest income is not taxable. Traditional asset pricing theory suggests that, in equilibrium, a marginal investor should be indifferent between a taxable and an identical tax-exempt security if the following equation holds:

$$y_{Exempt} = (1 - \tau)y_{Taxable} \tag{2.1}$$

where y_{Exempt} is the yield to maturity[3] for a tax-exempt security, $y_{Taxable}$ is the yield to maturity for a taxable security, and τ is the marginal tax rate for the marginal investor. Therefore, if we observe that an investor is indifferent between tax-exempt security, $y_{Taxable}$, and taxable security, $y_{Taxable}$, then this investor's marginal tax rate is equal to tau, τ.

Almost all of the previous studies compare tax-exempt municipal securities to (taxable) corporate bonds or Treasuries to estimate the implied tax rates associated with exempt munis. However, municipal, corporate, and Treasury bonds have different underlying risk

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[3]Given price, coupon rate (and therefore, coupon payments), and face value, the yield to maturity (the offering yield), y, is determined based on the following formula:

$$Price = \sum_{t=1}^{T} \frac{\text{Coupon Payments}_t}{(1+y)^t} + \frac{\text{Face Value}}{(1+y)^T} \tag{2.2}$$

where $T - t$ is the time remaining until maturity and T is the maturity date. The offering price is set by the underwriters.

16

and reward properties. Therefore, this type of apples to oranges comparison can introduce serious bias. In general, taxable munis are considered to be less risky than corporate bonds and other taxable securities. Munis also have a much lower default rate than corporate bonds. The federal government, on the other hand, has never defaulted on its debt, whereas subnational governments have very small but non-zero historical default rates.

A crucial observation for this paper is that state and local governments have the option to issue taxable municipal bonds. Forgoing the tax exempt status gives the issuers access to foreign and tax-exempt investors and frees them from administrative burden of abiding by numerous SEC and IRS rules and regulations associated with issuing exempt securities.[4] The IRS also regularly audits tax-exempt municipal bonds to assure compliance with the Code. The IRS conducts about 400 audits per year, 25% of which results in non-compliance and "taxability." [5] In recent years, given more stringent regulations, incentives to issue taxable bonds have increased. For example, many universities have shifted toward issuing more taxable securities. The Bond Buyer (2016) article on Ohio State University debt issuance presents an example [4]. Issuing taxable rather than tax-exempt bonds, although more expensive, gives the issuer a certain level of freedom in terms of private use and reporting, which may be especially valuable to smaller issuers with less administrative resources. Further, if the issuer is not completely certain about the use of proceeds in a project with many components, some of which may not be of public value, that issuer may choose to issue a portion of the proceeds in the form of a taxable bond as a precaution.

It may seem surprising that investors choose taxable municipal bonds over tax-exempt securities, especially given that the muni market is dominated by high-net-worth retail investors in the highest income tax brackets. However, the muni market is rather diverse on the demand side as it is on the supply side. Some investors in the market gain little to no benefit from the tax exemption of interest income. These include, but are not limited to,

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[4]See the Post-issuance Compliance section of the IRS Publication 4079: `https://www.irs.gov/pub/irs-pdf/p4079.pdf`. Accessed on: 01/26/2018.

[5]See the Treasury report at https://www.treasury.gov/tigta/auditreports/2012reports/201210087fr.pdf. Accessed on 02/27/2018.

pension funds, international entities, individual IRA accounts, etc. These investors utilize taxable munis as means to diversify their portfolios or as an alternative asset class to Treasuries, U.S. agency bonds (Freddie, Fannie), corporate bonds, etc. Furthermore, taxable munis should, at least theoretically, offer higher interest than the tax-exempt munis.[6]

Additionally, municipal securities are more likely to have a "local flavor." First, investors may have a preference for the state they live in and especially if they only benefit from state income tax-exemption if they reside in the issuer's state.[7] Therefore, investors have an incentive to buy and hold tax-exempt munis issued in their state to recoup the full tax benefits of triple tax exemption (federal, state, and local, where applicable). Second, individuals may have different preferences for municipal securities than for corporate bonds or Treasuries. They may feel more loyal to the locality they live in or be more confident in that locality's credit quality and wish to invest in local projects. Moreover, if the investor has a preference for smaller forms of government, she may prefer her town's bonds to state-issued bonds. The caveat is that finding a credible identification strategy for the investor behavior is difficult without information on investors' portfolio composition. Nevertheless, if investors in fact do perceive munis, corporate bonds, and Treasuries as different asset classes, which is very plausible, then identifying the value of tax-exemption using the yield spreads between Treasuries (or corporate bonds) and municipal securities is an invalid approach. Further, if investors have preferences for specific issuers (levels of government) within the muni world, then state-issued bonds may not be the best comparison group for debt issued by smaller municipalities.

Several studies have attempted to estimate the total monetary costs of the municipal tax exemption policy accrued to the national government. Poterba and Verdugo (2011) es-

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[6]Another appealing feature for some taxable munis is the stronger protections from early redemptions compared to tax-exempt bonds through the make-whole call feature. The make-whole-call feature of a security for the most part eliminates the interest costs savings of refinancing. Instead of being callable at par, for securities with this feature, investors are compensated at a price which equals the present value of future interest payments. This is punitive for the issuer, who would otherwise benefit from early redemption. Taxable munis with the make-whole-feature are not common and are excluded from the final sample in this study.

[7]Local income taxes rarely apply to municipal bond interest income. It is not possible to identify the local income taxes without a zip-code level investor portfolio data.

timate that the federal government forgoes approximately $14 billion in revenue annually due to the tax exemption policy [5]. Marlowe (2015) estimates that in the absence of the tax exemption program, state and local governments would have paid an additional $714 billion in interest expense between 2000 and 2014 (or $48 billion per year) [6]. Marlowe (2015) also shows that state and local governments invested approximately $400 billion in various capital projects in 2014, and that nearly 90 percent of subnational government *capital* spending is debt-financed [6]. These studies imply that benefits of the tax-exemption policy outweigh the costs to the federal revenue stream. However, these types of analyses focuses on revenue gains and losses at the government level and ignores investor decisions. A rational investor will likely re-calibrate her portfolio if the tax treatment of municipal securities is changed or eliminated, thereby potentially invalidating these revenue loss/gain estimates.

The Build America Bond (BAB) program, part of the American Recovery and Reinvestment Act (ARRA) of 2009, presented an interesting experiment. The BAB program subsidized state and local governments for issuing taxable rather then tax-exempt municipal bonds. Issuers received a subsidy in the amount of 35% of interest payments on their taxable bonds issued within the 20-month period, although the subsidy was for the life of the bond. Liu and Denison (2014) match BABs and general taxable bonds to tax-exempt municipal bonds issued in California and find that the implied marginal tax rate for the marginal investor is 25% [7]. Similarly, Luby (2012) estimates an implied tax rate of 24% using two BAB transactions issued by the State of Ohio in 2010 [8]. However, California or Ohio may not be representative of the entire muni market, and BABs may be perceived as a special asset class by investors.

Given that BABs were a special asset class, I exclude these securities from my sample and analyze issues spanning a 15-year period rather than the 20-month period when BABs were in effect. My data captures issuers across the country of different types (states, cities, counties, districts, etc.) rather than a single state issuer. Further, Liu and Denison (2014)

use True Interest Cost (TIC) at the serial bond level rather than offering yields at the maturity level as the dependent variable, losing an important level of granularity [7]. Further, studies have shown that issuer and issue size affect TICs. Therefore, large issuers, such as California, may fare differently than smaller and local government issuers in the market. Finally, Section 2.3.2 describes why Ordinary Least Squares (OLS) and fixed effects panel regressions pose econometric issues when unobserved and time-varying issuer-level effects are suspect.

The debate that interest rates on tax-exempt municipal bonds seems too high (the muni puzzle) has been ongoing for decades. The finance literature has identified and attempted to address this puzzle for a long time. To reconcile the higher than predicted yields on exempt securities with financial theories, studies have explored default risk [9], call options [9], low liquidity, tax-timing options [10], and systematic risk [11], among others as possible culprits. The puzzle seems to persist in each of those studies. Only Wang et. al. (2008) find marginal tax rates of about $32 - 33\%$, after examining the effect of liquidity, default, and personal taxes on the relative yields of Treasuries and municipal bonds [12]. These estimates are consistent with my results.

Atwood (2003) compares munis subject to AMT with tax-exempt municipal securities and finds $25-30\%$ implicit tax rate, asserting that the AMT system affects asset prices [13]. The author also compares a small sample of (less than 50) taxable municipal securities to tax-exempt munis issued on two separate days (July 20, 2001 and May 1, 2002), matching only based on maturity, and finds an implied tax rate of $34 - 35\%$. This approach has the usual small and non-representative sample concerns (a few issuers, two days). Further, because taxables are matched to tax-exempt securities only based on maturity lengths, the taxable sample has different features (average credit ratings, call option, etc.) than the tax-exempt muni sample. Merely controlling for specific features does not eliminate bias concerns due to unobserved issuance- and issuer-level effects.

The investor profile and income tax rates have changed since the Atwood (2003) study

[13]. Bergstresser and Cohen (2015), using the Surveys of Consumer Finances, show that municipal debt holdings of households have changed significantly over time [14]. Despite the increase in the size of municipal debt, ownership has shifted to portfolios of more concentrated investors. Further, the highest marginal income tax bracket was revised from 35% to 39.6% in 2013, which is captured in my 2001-2017Q2 sample. Finally, taxable munis are not a perfect benchmark for tax-exempt munis unless they have the same public benefit features and same backing (general obligation verses revenue). Investors may behave loyally to their community by investing in their local government or prefer debt issued for a specific purpose (stadium bonds vs. higher education bonds) or a specific type of debt (general obligation vs. revenue bonds).

2.3 RESEARCH DESIGN

2.3.1 Matching Taxable Munis to Tax-exempt Munis

Almost all of the existing research exploits the spreads between tax-exempt municipal bonds and either Treasuries or corporate bonds to isolate the tax benefits of municipal bonds accrued to investors.[8] This study argues that such comparison is an apples to oranges comparison and introduces serious concerns for bias. Methodology used in this paper utilizes a near-identical matching of taxable and tax-exempt municipal bonds. Recall that not all municipal securities are exempt from income taxes - a subset of the municipal bond universe does not have the typical tax exemption feature. Further, state and local governments periodically issue taxable and tax-exempt munis with near-identical characteristics simultaneously. Comparisons within the same asset class (the muni world) yield a more accurate estimate than comparisons to corporate bonds or Treasuries. The intrinsic difference between munis and other fixed income securities, at least through tax preference, strengthens the justification for this matched comparison approach.

Furthermore, the matching technique takes advantage of bonds issued by the same gov-

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[8]See Poterba and Verdugo (2011) for an example of this [5]

	$560,525,000 State of Georgia General Obligation Bonds 2015A Maturity Schedule			
Maturing February 1,	Principal Amount	Interest Rate	Price or Yield	CUSIP (a)
2016	$28,740,000	5.000%	0.190%	373384Y59
2017	30,555,000	5.000	0.560	373384Y67
2018	32,085,000	5.000	0.960	373384Y75
2019	33,695,000	5.000	1.250	373384Y83
2020	35,375,000	5.000	1.470	373384Y91
2021	20,405,000	5.000	1.720	373384Z25
2022	21,425,000	5.000	1.930	373384Z33
2023	22,495,000	5.000	2.070	373384Z41
2024	23,615,000	5.000	2.210	373384Z58
2025	24,800,000	5.000	2.340	373384Z66
2026	23,350,000	5.000	2.450*	373384Z74
2027	24,515,000	5.000	2.560*	373384Z82
2028	25,740,000	5.000	2.660*	373384Z90
2029	27,030,000	5.000	2.760*	3733842A3
2030	28,380,000	3.000	3.250	3733842B1
2031	29,230,000	4.000	3.260*	3733842C9
2032	30,400,000	4.000	3.310*	3733842D7
2033	31,615,000	4.000	3.350*	3733842E5
2034	32,880,000	4.000	3.390*	3733842F2
2035	34,195,000	3.500	3.580	3733842G0

*Priced to February 1, 2025 optional redemption date.

	$447,830,000 State of Georgia General Obligation Bonds 2015B (Federally Taxable) Maturity Schedule			
Maturing February 1,	Principal Amount	Interest Rate	Price or Yield	CUSIP (a)
2016	$30,050,000	0.300%	0.300%	3733842H8
2017	30,345,000	2.250	0.760	3733842J4
2018	30,805,000	1.250	1.250	3733842K1
2019	31,420,000	1.750	1.750	3733842L9
2020	32,050,000	2.050	2.050	3733842M7
2021	20,880,000	2.420	2.420	3733842N5
2022	21,405,000	2.670	2.670	3733842P0
2023	22,045,000	2.780	2.780	3733842Q8
2024	22,710,000	2.980	2.980	3733842R6
2025	23,390,000	3.130	3.130	3733842S4
2026	15,450,000	3.625	3.320*	3733842T2
2027	15,960,000	3.875	3.570*	3733842U9
2028	16,510,000	4.125	3.770*	3733842V7
2029	17,100,000	4.250	3.900*	3733842W5
2030	17,725,000	4.250	4.000*	3733842X3
2035	99,985,000#	4.150	4.150	3733842Y1

* Priced to February 1, 2025 optional redemption date.
# Term bonds subject to mandatory redemption as described herein. See "DESCRIPTION OF BONDS – *Mandatory Redemption of 2015B Bonds*" herein.

Figure 2.1: Excerpt from The Official Statement of The State of Georgia (2015)

ernment at the same time with the same features to identify the implicit tax rates. This results in a final sample with a variety of debt products issued by a variety of issuer types across the country. Such matching on security characteristics that are known to affect yields provides a more accurate estimate of the relationship between taxable and tax-exempt yields expressed in Equation 2.1 and removes underlying risk differentials and demand differential for specific securities. In essence, this set-up approximates an experimental design where the taxable munis are the control/comparison group. Another important advantage of such identical matching is that it guards the estimates against bias due to model misspecification and allows to directly test the relationship in Equation 2.1.

Figure 2.1 provides a visual example of and justification for the matching technique used in this study. The excerpt from the Official Statement (OS) of the State of Georgia shows the parallel between taxable and tax-exempt maturities. Note that both Series 2015A and Series 2015B are general obligation (GO) bonds with the same issue date (July 9, 2015), interest payment frequency (semiannual), credit rating (Moody's - Aaa, S&P - AAA, Fitch - AAA), and maturity dates. As an example, consider the tax-exempt CUSIP[9] 373384Y67 maturing on February 1, 2017 with the taxable CUSIP 3733842J4 also maturing on February 1, 2017. The tax-exempt security has a principal amount of $30,555,000, a 5% coupon rate, and 0.56% offering yield. The taxable counterpart of this security has a principal amount of $30,345,000, a 2.25% coupon, and 0.76% offering yield. Notice that both of these securities are discount coupons (yield is lower than the coupon rate) and neither is callable. These securities are therefore, identical in every way except for coupon rate, maturity size, offering yields, and of course the tax status. Using Equation 2.1, the offering yields on the matched pair maturing in 2017 imply a tax benefit of $[1 - \frac{0.56}{0.76}] = 26.32\%$. However, such simple calculation does not account for coupon and price differentials or issuer- and issuance-level unobserved effects and warrants a more rigorous empirical analysis.

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[9]CUSIPs are unique security identifiers issued by the Committees on Uniform Securities Identification Procedures (CUSIP) Bureau.

Table 2.1: Matching Criteria for Tax-exempt and Taxable Muni Pairs

1	issuer	(name)
2	issue date	(day, month, year)
3	maturity date	(day, month, year)
4	coupon type	(par, discount, premium)
5	security type	(general obligation, revenue)
6	capital purpose	(new, refunding)
7	bank qualification	(bank-qualified, not bank-qualified)
8	call option	(callable, not callable)
9	sinking fund type	(sinking fund, no sinking fund)
10	insurance	(insured, uninsured)
11	use of proceeds	(see Table A.4)
12	credit rating	(0-21 scale, average of all ratings)
13	sale type	(competitive, negotiated)
14	state tax status	(exempt only)
15	interest frequency	(semiannual only)
16	debt type	(bonds only)

As the example in the previous paragraph suggests, in order to eliminate underlying idiosyncratic risks and demand differences across different types of securities, taxable and tax-exempt CUSIP numbers are matched based on the criteria described in Table 2.1. Matching on issuer name eliminates the need to match on issuer specific characteristics, such as state, region, issuer size, etc. Matching by issuer is important because it controls for unobserved investor preferences. For example, investors may prefer California (CA) bonds over New York (NY) bonds or city-issued bonds over state-issued bonds.Matching criteria 14-16 in Table 2.1 are null since there is only one category for each of these criteria in the final sample due to the exclusion criteria discussed in Section 2.4.2.

Note that matching utilized in this study is exact and one-to-one. If a taxable security is matched to multiple exempt securities, then the match with the closest maturity amount is kept. If the exempt security is matched to multiple taxable securities, again only the match with the smallest maturity amount difference is kept. Eliminating duplicate matches for taxable securities eliminates biased sample concerns.[10] The matching technique described

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[10]An alternate solution is to weigh the sample. However, identifying the correct sample weights presents

above would result in five matches for the issuance displayed in Figure 2.1 - securities maturing in 2017 and 2026-2029, highlighted in yellow. The rest of the maturities would drop out either because of differing coupon types or call features. For example, the 2019 exempt maturity is a premium coupon (coupon rate is greater than the offering yield) whereas the 2019 taxable maturity is a par coupon (coupon rate equals the offering yield).

In addition to coupon types (par vs. discount vs. premium), coupon rates matter as well. For example, anecdotal evidence suggests that investors have a preference for 5% coupons regardless of the yield. Unfortunately, matching on coupon rates is not feasible, as taxable and tax-exempt bonds tend to have different coupon rates. This level of restriction on matching would result in an extremely small sample. Similarly, maturity size and total offering size are not used as a matching criteria. Therefore, the difference in coupon rates, maturity size, and issue size are controlled in the model. Finally, the representativeness of this small matched sample in comparison to the full muni sample is addressed in the Appendix.

2.3.2   Model

The tax rate at which the marginal investor should be indifferent between taxable and tax-exempt municipal bonds is estimated using the Random Coefficients Model (RCM). The RCM has several advantages over traditional regression models. First, it accounts for dependency across observations - given that securities are clustered within issuances and issuances are clustered within issuers, there are multiple sources of correlation. Second, different issuers may have different idiosyncratic risks not captured by their issuance-level credit ratings. Further, these issuer-level effects may change over time. The RCM can test issuer heterogeneity and estimate issuer-specific effects. Finally, the RCM does not require that the panel data be balanced. The primary muni market data is not balanced - some subnational governments issue new debt every year whereas other issuers go to the market

its own challenges.

25

less frequently.

The RCM is a more appropriate empirical strategy to identify, model, and leverage unobserved, but important, heterogeneity in municipal securities. This modeling is, therefore, a leap forward from the traditional empirical strategies used in municipal finance. Random coefficient/ slope on the key variable allows the effect of this covariate to vary at multiple levels (by issuer and by issuance). The levels/dimensions in this study are defined as securities within issuances within issuers. The logic for this type of nesting, as explained in the previous paragraph, is driven by issuer- and issuance-level unobserved heterogeneity and dependency.

The RCM utilized in this study can be expressed as:

$$y_{ijkt}^E = (\beta_1 + \theta_j + \lambda_k)y_{ijkt}^T + \beta_2 X_{ijkt} + \beta_3 Z_{ijkt} + \epsilon_{ijkt} \qquad (2.3)$$

where y^E is the tax-exempt offering yield[11] for i^{th} security within j^{th} issuance for k^{th} issuer at time t and y^T is the offering yield for the taxable counterpart. The key variable of interest is the taxable yield, y^T, and the corresponding fixed and random coefficients at the issuer and issuance levels.

The model does not include any intercept (fixed or random) in order to uniquely capture the relationship described in Equation 2.1. The βs capture the fixed effects coefficients. These are the mean effects of each covariate in the population. The θ captures the unobserved effects at the issuance level and the λ captures the unobserved effects at the issuer level. Conditional on the covariates, these issuance- and issuer-level random effects are equal to zero in expectation. Consequently, we analyze the variance of the random effects by evaluating their point estimates and standard errors. Finally, Z is the vector of covariates used in matching[12] and X is the vector of additional controls.

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[11]Offering yield is equal to yield to maturity at the time of issuance. Offering yield is equal to yield to call for callable securities.

[12]Variables used in matching are included as covariates for several reasons. Matching on these covariates only eliminates the main effects of the Zs. If there are indirect effects on yield between the Zs and the tax/no-tax treatment, then there will likely still be a significant effect in the model. Further, note that I am not

2.4 DATA

2.4.1 Data Sources

The data for this study come from the Municipal Securities Laboratory at the Andrew Young School of Policy Studies at Georgia State University. The primary database is Mergent's Municipal Bond Securities Database (MBSD) and is not available to the public. This database contains the CUSIP numbers and issuance information, including issuance and maturity dates, debt type, coupon type, capital purpose, use of proceeds, credit rating and other enhancements, default information, original sale type, etc.[13] Mergent database includes a variety of information on more than 3.5 million securities. Issuer types are manually identified by the author using the issuer names as the data does not contain such classification.Variable descriptions, data sources, and covariate constructions are described in Table 2.2.

A second dataset is the Municipal Market Analytics's (MMA) market yield curve, also a proprietary data not available to the public.[14] The MMA's municipal bond index is created by surveying 38 institutions that represent dealer and investor opinion on daily muni yields. The MMA's median consensus yield scale is constructed for an AAA-rated, tax exempt, callable, 5% coupon, general obligation bond for each of the $1, 2, 3...., 30$ year maturities on a daily basis since 2001. The MMA's benchmark yield curve is used as a proxy for prevailing municipal bond market yields. A market yield variable is constructed by matching each CUSIP to the corresponding part of the MMA yield curve. Note that MMA is available for weekdays only. If the issue date (dated date) of a security falls on a Saturday, that observation is matched to the MMA yield from the day before (Friday). If

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matching on the tax status (taxable vs. tax-exempt). Rather, I am matching on tax-exempt and taxable yields which have significant between variation and matching only takes care of the within variation.

[13]Unfortunately, there is no information on credit upgrades/ downgrades in the database. It is plausible that recent upgrades/downgrades and/or credit watches may have an effect on offering yields. These effects are not known based on these data sets and are accounted for as unobserved issuer- and issuance-effects.

[14]I would like to thank Municipal Market Analytics, Inc., especially Tripp Kaiser, for allowing me to use the MMA yield curve in this research.

the dated date falls on a Sunday, that observation is matched to the MMA yield for the next day (Monday).

The unit of analysis is a CUSIP. The time frame overlap among the three data sets captures the 2001 through 2017Q2 period. In addition to data availability and overlap within datasets, this 16-year time period provides a sufficient time period before and after the Great Recession of 2008-2009.

2.4.2   Exclusion Criteria

The exclusion criteria are described in Table 2.3. These exclusions results in a 15% reduction in the original sample size. Reasons for excluding these securities are as follows. Section 2.2 explains why BABs are different and are therefore excluded. Variable rate securities[15] are complex and analyzing them is beyond the scope of this paper. Short-term securities, with less than one year until maturity, are of limited quantity and are excluded as a precaution. Further, the effect of tax-exemption on such short-term securities is likely to be absent or very small. Securities subject to state taxes are excluded to avoid the confounding effects between federal and state taxes. The last three exclusion criteria, criteria 6-8 in Table 2.3, do not have a significant effect on the sample size and are excluded as a precaution that demand may vary based on interest rate frequency and complexity features. After matching taxable and tax-exempt securities, the final sample has five below investment-grade security pairs that are also dropped as a precaution. These non-investment grade (referred to as "high yield" in the industry) securities tend to attract a specific investor pool. The final sample includes $6,472$ matched pairs or $12,944$ securities.

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[15]These are adjustable, deferred, floating auction, floating, floating at floor, inverse floater, index-linked, stripped, stripped convertible, stripped principal, stepped, or variable rate coupons.

Table 2.2: Variable Descriptions and Data Sources

Variable Name	Description and Measurement	Source
Dependent variable		
Tax-exempt Yield	Yield offered to the initial investor	Mergent
Independent variables		
Taxable Yield	Yield offered to the initial investor	Mergent
Issuer Type	Indicators for city, county, state, school district, special district, and town/township	Mergent[16]
Coupon Difference	Tax-exempt coupon rate - Taxable coupon rate	Mergent
Price Difference	Tax-exempt price - Taxable price	Mergent
Size Difference	(Tax-exempt issuance size - Taxable issuance size) / 100,000	Mergent
Market Spread	Tax-exempt offering yield - MMA yield	Mergent, MMA
Callable	Indicator for call feature	Mergent
Sinking Fund	Indicator for sink fund	Mergent
Credit Rating	Average credit rating based on Moody's, S&P, Fitch, converted to a $0 - 21$ scale with unrated $= 0$ and $21 =$ best possible credit rating	Mergent
General Obligation	Indicator for general obligation vs revenue debt	Mergent
Insured	Indicator for presence of insurance	Mergent
New	Indicator for new issuance vs. refunding	Mergent
Time to Maturity	Years remaining until maturity	Mergent

Table 2.3: Sample Exclusion Criteria

1	BABs and any other debt types that are not bonds (notes, derivatives, etc.)
2	Variable coupon rates
3	Maturity length < 1 year (notes)
4	Securities subject to state tax or with state tax status missing
5	Capital purpose other than new or refunding
6	Interest rate frequency other than semiannual or at maturity
7	Securities with make-whole-call feature
8	Debt issued by U.S. territories and their subsidiary governments

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[16]Coded manually based on Google searches of the issuer's name.

2.5 FINDINGS

2.5.1 Descriptive Results

Figure 2.2 and Figure 2.3 provide visual demonstrations of the matching results. The first panel of the Figure 2.2 shows that, with a few exceptions, as expected, the offering yield for the taxable securities is higher than that of the matched exempt yield and lies below the 45 degree line (dashed blue line). The exceptions above the dashed blue line capture the observations where the offering yield for the exempt security was higher than that for the taxable security. The observations above the 45 degree line imply a tax burden rather than a tax benefit associated with these maturity pairs. There is no theoretical reason why this should be the case. However, lack of market demand (under-subscription) for specific securities may push the spread between taxable and tax-exempt securities upwards. Coupon, price, and size differences may also contribute to the range of the spread.

The solid green line captures the theoretical indifference line for the marginal investor in the highest income bracket of 39.6%. Recall that, due to exclusion criteria, none of these securities are subject to state taxation. This indifference line corresponds to the following equation: $y_{Exempt} = 0.604 y_{taxable}$, where y_{Exempt} is the offering yield for the exempt security and $y_{taxable}$ is the offering yield for its taxable counterpart. If there were no other differences other than tax status (e.g. coupon differential, face value, issuer- and issuance-level unobserved effects, etc.), theory predicts that all observations would lie on this solid green line for the typical muni investor in the highest income bracket. If the average muni investor has a tax rate which is lower than the highest tax rate, then the observations would need be somewhere between the solid green and the dashed blue lines for these securities to clear the market. Finally, there are a significant number of observations below the solid green indifference line implying tax benefits above the rate in the highest tax bracket. This warrants a more rigorous analysis to see if these relationships remain after adjusting for coupon/size differentials and unobserved effects.
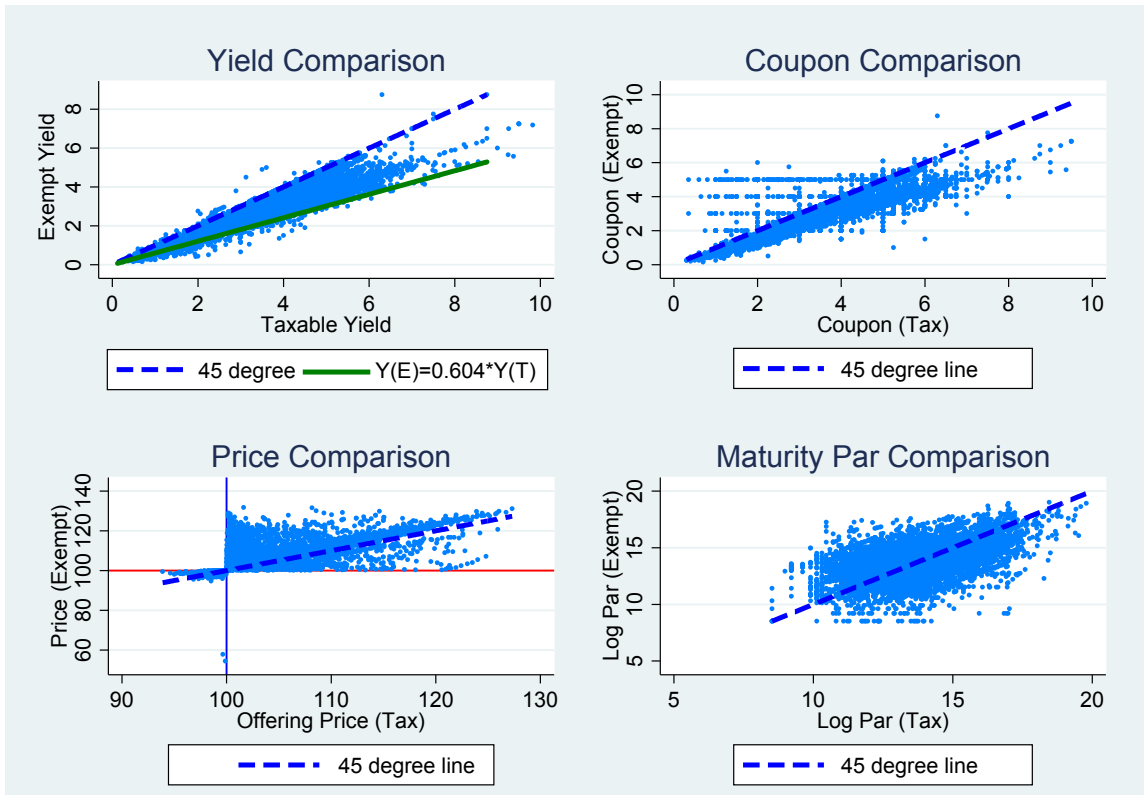
Figure 2.2: *Visual Representation of Matched Pairs*

The sample contains par, original issue discount, and original issue premium bonds. The maturity amounts for each pair are clustered in a relatively tight range as displayed in the bottom right panel of Figure 2.2. Recall that the number of observations indicates the number of CUSIP pairs, which implies a paring of about 13,000 individual CUSIPs. Table A.1 in the Appendix provides the summary statistics for the final sample and shows that the average coupon rate is 31 basis points higher for taxable securities than for exempt securities. However, the coupon comparison panel of Figure 2.2 shows that this relationship is not consistent and for a portion of observations - taxable securities offer lower coupons than their tax-exempt twins. Of the 6,472 CUSIP pairs, 27% have call options attached to them, 23% are insured, 48% are rated, 44% are new issues, 25% are GO, and only 4% have a sinking fund feature. The average age of a matched-pair is about eight years.

Figure 2.3 demonstrates the distribution of the naive implied tax rate, which is obtained by comparing the offering yields of the matched pairs using Equation 2.1. The graph
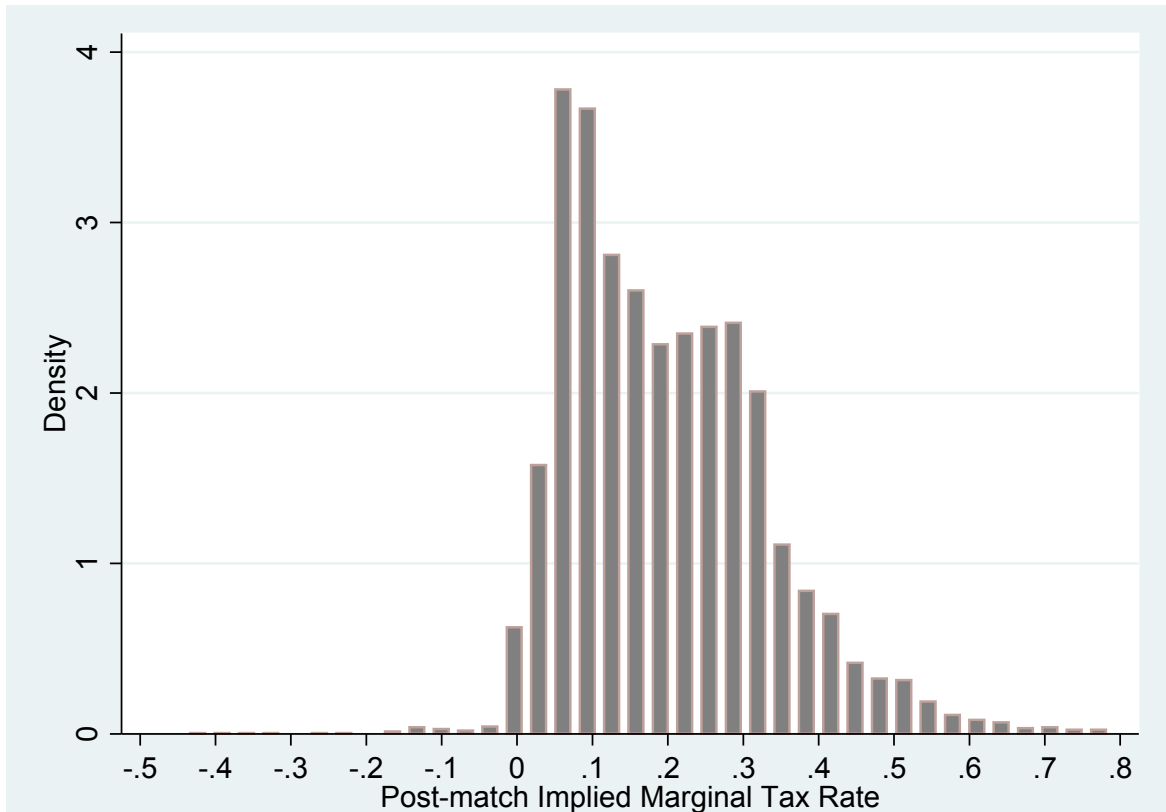
Figure 2.3: *Distribution of Implied Marginal Tax Rate, τ, Post-match*

shows that the implied tax rate ranges from values above the theoretical range $(35 - 39.6\%)$ extending into negative values, which imply a tax burden rather than a tax reduction benefit. Such heterogeneity in the naive rates warrants a more rigorous approach and supports the claim that a single point estimate for the implied marginal tax rates without accounting for issuer- and issuance-level variation may be driving the muni puzzle.

Further, Figure 2.4 shows the variation in the naive implied tax rate by issuer type (cities, counties, states, school districts, special districts, and towns/townships). Again, the naive implied tax rate here is simply the binary relationship between matched taxable and exempt offering yields based on Equation 2.1. The horizontal lines mark the 35% (solid blue), 30% (short-dash pink), and 20% (long-dash green) tax rates, which are the highest corporate income tax rate, lower bound of the effective individual income tax rate for a typical muni investor, and typical estimate of the implied tax rate found in the literature,
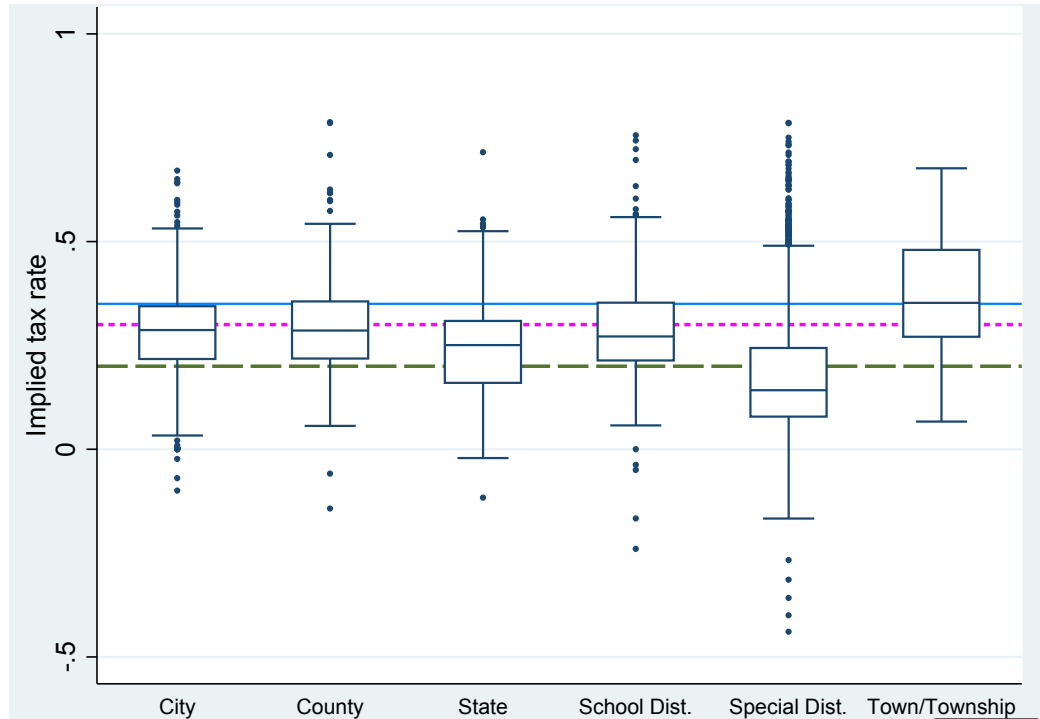
Figure 2.4: *Distribution of Implied Marginal Tax Rate, τ, Post-match, by Issuer Type*

Note: Solid Blue=35%, Short-Dash Pink = 30%, Long-Dash Green = 20%

respectively. According to the box plot, the median implied tax rate is around 30% for cities, counties, and school districts. However, implied tax rates are near 18% for special districts, and at about 25% for states. This suggests that different levels of government may be getting different levels of interest cost reduction benefits from the tax-exemption policy. There is quite a bit of variation in tax benefits offered by various types of local governments. School and special districts display the largest dispersion in the distribution of the naive τ, the implied tax rate obtained from comparing matched yields. This level of variation warrants a more rigorous empirical approach given that Figure 2.4 cannot account for fluctuations over time. Final sample distribution of issuer types is displayed in Table A.3 in the Appendix.

33

2.5.2 Empirical Results

First, Table 2.4 shows the generalized linear model (GLM) regression of the naive implied marginal tax rate, τ, the binary relationship between matched taxable and exempt offering yields obtained using Equation 2.1, on several important covariates, with standard errors clustered at the issuer level. The key coefficient of interest in this model is the coefficient on the intercept, which provides the population average for the implied tax rate, all else equal. Model (3) in Table 2.4 shows an implied marginal tax rate of 22% for the reference group, a new, non-callable, uninsured, unrated, 10-year, general obligation security-pair issued by a city in 2016, where the matched pair have no coupon, price, or issue size differences (all covariates are set to zero). This estimate is consistent with previous estimates in the literature. Positive coefficients on the covariates increase the spread between the taxable and tax-exempt yields, thereby, increasing the implied tax rate. Model (3) in Table 2.4 supports the claim that issuer type matters in estimating the implied marginal tax rates. As issuer- and issuance-level controls are added, implied marginal tax rate estimates increases. Issuer-type identifiers show that smaller municipalities such as towns-townships incur the lowest borrowing costs (largest positive and statistically significant coefficient) and special districts display the lowest implied tax rates.

Control variables not used in matching, coupon, price, and par difference, are designed so that the intercept identifies the implied marginal tax rates in the absence of any differences between taxable and tax-exempt securities. Recall that the reference group is a new, non-callable, uninsured, unrated, 10-year, general obligation security-pair issued by a city in 2016 where the matched pair have no coupon, price, or issue size differences (all covariates are set to zero). Coupon difference is constructed by subtracting taxable coupon rate from the tax-exempt security's coupon rate. As the coupon difference increases by one percentage point, the implied tax rate declines by 8 basis points. Price difference is constructed by subtracting taxable offering price from the tax-exempt security's offering price. As the price difference increases by one percentage point, the implied tax rate declines by

Table 2.4: GLM Results, Dependent Variable = τ

	(1)	(2)	(3)
Intercept	**0.15***	**0.18***	**0.22***
	(0.01)	(0.01)	(0.02)
Issuer Type Reference Group = City			
County			0.00
			(0.01)
State			-0.02
			(0.01)
School District			0.01
			(0.02)
Special District			-0.05***
			(0.01)
Town/Township			0.05***
			(0.02)
Market Spread (MMA)		-0.06***	-0.06***
		(0.01)	(0.01)
Callable		0.02**	0.02**
		(0.01)	(0.01)
Sinking Fund		0.04***	0.04***
		(0.01)	(0.01)
Credit Rating		-0.00***	-0.00***
		(0.00)	(0.00)
General Obligation		0.05***	0.01
		(0.01)	(0.01)
Insured		0.01	0.01
		(0.01)	(0.01)
New (vs. Refunding)		-0.00	-0.00
		(0.00)	(0.00)
Coupon Difference	-0.06***	-0.08***	-0.08***
	(0.01)	(0.01)	(0.01)
Price Difference	0.02***	0.02***	0.01***
	(0.00)	(0.00)	(0.00)
Size Difference	0.00**	0.00	0.00
	(0.00)	(0.00)	(0.00)
Maturity Effects	NO	YES	YES
Year Effects	NO	YES	YES
Observations	6,472	6,472	6,472
R^2	0.14	0.62	0.63
Issuances	1,138	1,138	1,138
Issuers	579	579	579

Notes: ***p< 0.01, **p< 0.05, *p< 0.1. Standard errors in parentheses.

one basis points.

Issue size difference variable is constructed by dividing the difference between tax-exempt and taxable par amounts by $100,000.[17] Previous literature has identified that larger bonds are associated with lower borrowing costs. However, results here indicate that the size of the issuance does not have a statistically significant effect on the yields (and therefore implied tax rates), all else equal. Market spread variable is constructed by taking the difference between the exempt offering yield and the corresponding part of the MMA yield curve (same day, same maturity length). The more the exempt security deviates from prevailing market yields, the lower the implied marginal tax rate. This implies that interest cost reductions for tax-exempt securities are the highest when they can match the market environment.

Table 2.4 supports the claim that issuer characteristics affects yields and therefore the implied tax rates. However, an ordinary GLM model ignores issuer- and issuance-level unobserved effects which may also vary over time. Therefore, to control for issuer- and issuance-level unobserved effects, as explained in Section 2.3.2 and Equation 2.3, Table 2.5 presents the RCM estimates. In contrast to Table 2.4, the dependent variable in Table 2.5 is the offering yield for the tax-exempt security. Model (1) accounts for only issuer-level unobserved effects and Model (2) accounts for both issuer- and issuance-level effects. Models (3) and (4) include additional covariates. The reference group is a new, non-callable, uninsured, unrated, 10-year,[18] general obligation security-pair issued by a city in 2016 where the matched pair have no coupon, price, or issue size differences (all covariates are set to zero). Results in the final Model (4) show that a one percentage point increase in the taxable offering yield results in a 67 basis points increase in the tax-exempt yield. This estimate implies a marginal tax rate of 33%.

A confidence interval of $[0.66, 0.68]$ on the key independent variable, THE taxable

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[17]Taking logs would drop all observations where the difference is zero given that logs are undefined for zero values.

[18]Results are robust to the inclusion of different maturity lengths as the base.

Table 2.5: RCM Results, DV = Exempt Yield

	(1)	(2)	(3)	(4)
Taxable Yield	0.843***	0.827***	0.708***	0.675***
	(0.003)	(0.004)	(0.005)	(0.006)
Issuer-level (std)		0.005	0.004	0.004
		(0.000)	(0.000)	(0.000)
Issuance-level (std)	0.009	0.005	0.002	0.002
	(0.000)	(0.001)	(0.000)	(0.000)
County				0.045**
				(0.022)
State				0.047**
				(0.022)
School District				0.081***
				(0.022)
Special District				0.281***
				(0.017)
Town/Township				-0.033
				(0.029)
Callable			0.032***	0.018**
			(0.009)	(0.009)
Sinking Fund			-0.066***	-0.063***
			(0.014)	(0.014)
Credit Rating			0.002***	0.001***
			(0.000)	(0.000)
General Obligation			-0.024**	0.182***
			(0.009)	(0.016)
Insured			0.002	0.004
			(0.014)	(0.014)
New (vs. Refunding)			0.027***	0.012 ***
			(0.003)	(0.003)
Market Spread (MMA)			0.275***	0.290 ***
			(0.011)	(0.010)
Coupon Difference	-0.034***	-0.033***	-0.023***	-0.022***
	(0.001)	(0.001)	(0.001)	(0.001)
Price Difference	0.152***	0.152***	0.111***	0.104***
	(0.005)	(0.005)	(0.004)	(0.004)
Issue Size Difference	-0.000***	-0.000***	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Maturity/Year Effects	NO	NO	YES	YES
Obs (Security Pairs)	6,475	6,475	6,475	6,475
Issuances	1,138	1,138	1,138	1,138
Issuers	579	579	579	579

Notes: ***$p< 0.01$, **$p< 0.05$, *$p< 0.1$. Standard errors in parentheses.

yield, indicates an implied marginal tax rate of 32% to 34% with an additional 0.2 basis point deviation by issuer and another 0.04 basis point deviation by issuance.[19] Positive coefficients shrink the spread between taxable and tax-exempt yields, decreasing the implied tax rates. Further, the results show that special districts are paying higher interest costs than the rest of the issuers on their exempt debt, while cities, towns, and townships are recouping close to full benefits of the exemption policy. This is consistent with the argument that investors may care about more than just a the immediate return on their investment and prefer one issuer over another.

Recall that securities were not matched on price, coupon rate, or par value.[20] Given the deterministic relationship among yields, time to maturity, par value, and price, as shown in Equation 2.2, the maturity amount is not included in the model. If the coupon rates on exempt securities are higher (higher coupon difference), this is reflected in lower exempt yields (negative coefficient on the coupon difference variable). If the price on exempt securities is higher (higher coupon difference), this is reflected in higher exempt yields (positive coefficient on the price difference variable). Issue size differences do not have a statistically significant effect on yields. Finally, the relationship between maturity lengths and yields are not linear. Yields increase (non-linearly) as time remaining until maturity increases. However, it is important to include maturity length effects rather than a continuous variable for time remaining until maturity.[21]

Remaining control variables have the expected signs. Market yields have the expected positive effect on tax-exempt offering yields. This is expected as interest costs tend to rise with the prevailing market rates. Securities with a call feature have higher yields to compensate the investor for the call risk. New issues have higher interest costs compared

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[19]Variation instead of deviation can be obtained by squaring the standard deviations of issuer and issuance effect.

[20]There are, in fact, 90 observations in the final sample with no coupon or price differences. In this small subsample, the offering yield on taxable and tax-exempt securities is identical, implying a zero implied tax rate. All of the securities in this small subsample are issued by special districts, however. The only plausible explanation for this is under-subscription for the exempt securities.

[21]Coefficients on maturity length indicators are not displayed due to space limitation but are available upon request.

to refunding issues. Credit rating has a positive effect on exempt offering yields, but this is mostly driven by the fact that 52% of the sample is unrated (credit rating coded as zero). Results are robust to the inclusion of binary rated/unrated variable. These results confirm that the level of heterogeneity in the municipal bond market should not be ignored.

2.5.3 Discussion

State and local governments may choose to issue tax-exempt and taxable securities simultaneously for regulatory reasons, to attract foreign and tax-exempt investors (e.g. IRA investments), or simply because of habit. To qualify for a tax-exempt status, issuers have to meet and comply with a multitude of IRS and SEC regulations and meet specific requirements. One caveat is that taxable and tax-exempt securities may attract different investors with fundamentally different income tax profiles, such as foreign investors and mutual funds, who want higher returns and have nothing to gain from the tax exemption of interest income. Without access to data on investors' portfolio composition, it is difficult to identify the exact tax benefits to each bond holder. Nonetheless, underwriters generally have an idea of the profile of the potential investors and bid on new issues or work with issuers to structure the debt accordingly. This study argues that assuming investors have access to a pair of taxable and tax-exempt securities identical in almost every other way at the time of issuance, the marginal investor reveals her tax preferences/burden if the debt clears the market.

The value of the exemption to investors is just as important to take into account as the subsidy to state and local governments. Bergstresser and Cohen (2015), using the Surveys of Consumer Finances, show that municipal debt holdings of households have changed significantly over time [14]. Despite the increase in the size of municipal debt, ownership has shifted to portfolios of more concentrated investors - Bergstresser and Cohen (2015) show that the share of households holding any municipal debt dropped from 4.6% in 1989 to 2.4% in 2013 but the share of total debt held by the top 0.5% of households rose from

24% in 1989 to 42% in 2013 and the top 1.2% held more than 97% of all munis [14]. This shift in the holdings of municipal bonds into portfolios of the wealthiest households implies that the benefit of the exemption is now more concentrated among the wealthiest Americans. This is consistent with my findings that implied marginal tax rates are near the top statutory rates. Bergstresser and Cohen (2015) also show that at least 30% of munis are held by households with marginal federal tax rates above 35% [14]. These household level estimates further support my findings of implied marginal tax rate of $32 - 34\%$.

Another relevant point to this study is the difference between marginal and effective tax rates. Due to the effects of various tax exemptions, deductions, and credits for a tax payer within the current tax system, average (effective) tax rates tend to be lower than marginal tax rates for the average taxpayer. An investor with a 25% effective tax rate may be less inclined to give up 35% of potential interest income. However, the typical muni holder is not an average taxpayer. Piketty et al. (2018) show that the all-inclusive effective tax rate[22] for the top 1% of Americans (whose average pre-tax income was 1.3 million in 2014) ranged from 31% to 39% between 2001 and 2014, the time period used in my analysis [15].[23] These effective tax rate estimates for the top 1% coupled with the finding that the muni holders are concentrated at the very top of the wealth distribution provide strong support for my results, that implied marginal tax rates are between $32 - 34\%$ for municipal debt.

2.6 CONCLUSION

In a decentralized government like the United States, responsibility to invest in public projects falls mostly on the shoulders of state and local governments. From a policy perspective, it is important to understand whether state and local governments are recouping the full benefits of the federal subsidy through tax-exemption of municipal bonds. This

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[22]Taxes on individual incomes, payroll, estates, corporate profits, properties, and sales.

[23]The implied average effective rate then would be 35%. See Piketty et al. (2018)'s Appendix Table G1 which is available on-line [15].

study estimates the tax benefits of municipal bonds and finds that the answer is affirmative for general purpose governments. The use of the entire bond universe data results in a paired taxable and tax-exempt subsample which provides the necessary precision to account for the difference in underlying idiosyncratic risk and investor preferences. Results of the Random Coefficients Model show that implied marginal tax rates are $32 - 34\%$, which is consistent with theory. The muni puzzle, the previous finding that interest rates on tax-exempt bonds are too high, disappear under more careful scrutiny. This implies that if the tax-exemption policy is eliminated or even capped, interest costs for general purpose governments will increase substantially.

CHAPTER 3

THE EFFECTS OF THE SECONDARY MUNICIPAL BOND MARKET ON FUTURE COST OF BORROWING FOR SUBNATIONAL GOVERNMENTS

ABSTRACT

The primary market for state and local government borrowing receives great attention yet researchers as well as subnational debt-issuing governments tend to ignore the secondary municipal bond market. However, if the primary market rewards issuers for the favorable performance of their outstanding debt in the secondary market, then state and local governments are neglecting an important piece of the puzzle - the potential to reduce future borrowing costs. This study combines large proprietary databases of primary and secondary market information to test whether the performance of existing debt in the secondary market affects future cost of borrowing for state and local governments. Results show that fluctuations in the secondary market prices and yields impact future borrowing costs. Further, the effect of the secondary market varies significantly by issuer. Findings imply that the secondary market contains an additional layer of real-time quality information not captured by other lagged metrics such as credit ratings.

3.1 INTRODUCTION

While underwriters, investors, and traders pay close attention to market activity in the secondary municipal[1] bond market in addition to the primary market, subnational governments tend to ignore the market performance of their outstanding debt. However, if the primary market rewards favorable performance in the secondary market, state and local governments are neglecting an important piece of information - the effect of the issuer's outstanding debt performance on future interest costs and the potential to reduce future borrowing costs. This effect may be particularly pronounced in the wake of the recent Great Recession of 2008-2009 as the faith in the lagged credit ratings by the "Big Three" (Moody's Investor Services, Standard & Poor's (S&P), and Fitch Ratings) as the measure of creditworthiness has wavered.

Underwriters, who act as financial intermediaries between the debt-issuing governments and investors, have an incentive (earn fees) to quickly clear the market and therefore, make pricing decisions accordingly. My informal interviews with Citigroup's Municipal Securities Division underwriters and traders suggest that the secondary market transactions play an important role in the structuring and/or sale of new debt.[2] Underwriters, at both competitive and negotiated sales desks, pay close attention to issuer's existing debt in addition to similar issuances by other governments. Thus, secondary market activity can be a valuable tool for estimating market demand, understanding investor perceptions, and therefore, borrowing costs for state and local governments.

The purpose of this study is to estimate the extent to which price and yield fluctuations of issuer's existing debt in the secondary muni market affect future borrowing costs in the primary muni market. Contributions of this study are as follows. A review of extant literature indicates this to be the first study to directly link the secondary market to

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[1]The initial sale of new debt by state and local governments takes place in the primary municipal bond market and any subsequent sales take place in the over-the-counter secondary market.

[2]Citigroup Global Markets Inc. ranks 1st for their market share in key municipal tax-exempt products. The author would like to thank Joseph Geraci, Deputy Head of the Municipal Securities Division at Citigroup, and W. Bartley Hildreth (the author's dissertation chair) for organizing this site visit.

future borrowing costs for state and local governments. The research design utilizes large proprietary databases of issuance (primary market), trade (secondary market), and market (public finance industry) information. Finally, the analysis focuses on multiple layers of government and estimates the effects of the secondary market on interest costs for different jurisdiction types.

Results show that better performance of the issuer's outstanding debt in the secondary market reduces borrowing costs for state and local governments. This implies that the secondary market contains an additional layer of real-time credit quality information not captured by other lagged metrics such as credit ratings. These findings have several policy implications for debt-issuing subnational governments. Given that price and yield fluctuations of existing debt are significant real-time predictors of future borrowing costs, state and local governments may be able to save on borrowing costs by timing their debt issuance based on the market performance of their existing debt. Further, such knowledge may provide issuers with leverage when negotiating with or requesting bids from underwriters or underwriting syndicates. Reducing borrowing costs, in turn, is of significant value as it can free up resources for other public goods and services.

3.2 BACKGROUND AND LITERATURE

3.2.1 Borrowing Costs and Creditworthiness

Credit ratings were generally perceived as the primary measure of quality/ riskiness until the 2008-2009 financial crisis (the "Great Recession"). Bond ratings assigned by major rating agencies[3] came under serious scrutiny in the wake of the Great Recession. First, the Big Three were blamed for exacerbating the global financial crisis by assigning overly optimistic credit ratings. Second, the "issuer pays" model, where the debt issuer pays the fees and the investors can access the rating free of charge, is argued to introduce a conflict of interest and is likely to alter the incentives of parties involved in the transaction. In par-

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[3]Moody's Investor Services, Standard & Poor's (S&P), and Fitch Ratings also knowns as the "Big Three."

ticular, one of the major concerns is that the rating agencies are likely to assign higher letter grades to earn or keep the issuer's business. Third, credit ratings are perceived as lagging indicators. By the time a credit rating or rating change is announced, the information is already saturated into the market. It is plausible that these factors, which are likely to reduce the influence of credit ratings on investor perception of creditworthiness, encourage market participants, including underwriters, to turn to other, more reliable and more real-time metrics to measure credit quality. Perception of credit quality, in turn, is likely to affect future borrowing costs in the primary muni market for state and local governments.

Further, municipal bond credit ratings by Moody's and Fitch Ratings were re-calibrated to the Global Rating Scales in 2010. This recalibration was intended to alleviate the stricter rating standards for municipal bonds compared to corporate bonds. Kriz and Xiao (2017) show that this recalibration increased borrowing costs (the spread between the yields and the risk-free comparison group) for high quality municipal bonds by 15 basis points, implying that a high credit rating no longer had the same indication of quality [16].

3.2.2 Financial Intermediaries

Bond-level determinants of borrowing costs are well studied. Early studies primarily focused on bond characteristics and prevailing market rates as explanatory factors for the variation in borrowing costs. These explanatory factors include market interest rates (e.g. the Bond Buyer 20 Index), credit ratings provided by the Big Three, security types (e.g. general obligation vs. revenue bonds), issue size, time remaining until maturity, presence of bond insurance and other credit enhancements, various complex features such as call options, sinking fund provisions, bank qualification, tax exemption status, etc. Park et al. (2016) provide a nice summary of these control variables and the expected relationship between each factor and borrowing costs [17]. In addition to these covariates, Guzman and Moldogaziev (2012) find that the purpose of bond issuance also has an impact on borrowing costs [18].

More recent research has extended the list of factors driving borrowing costs as studies have shifted focus to more refined stakeholder characteristics, especially those of financial intermediaries. Sophisticated market participants, such as underwriters and large institutional investors, are more likely to keep the pulse of market activities than local governments or non-institutional investors. Consider the private sector - Corwin and Schultz (2005) explain that the information production for Initial Public Offerings (IPOs) by underwriters involves analyzing both comparable traded companies as well as current market demand for new issues [19]. Similar strategies are employed by municipal bond underwriters/ underwriting syndicates.

The underwriting process deserves some attention here. Typically, underwriting commercial banks purchase the entire bond issuance from the issuer at a discount[4] and sell these securities to the investors at the initial offering price. The difference between the offer price paid by the investors and the price paid by the underwriter, also known as the gross spread, compensates the underwriting group/syndicate for their services. Several studies have focused on whether the method of sale (competitive vs. negotiated) makes a significant difference in borrowing costs and have found mixed results. In a competitive sale, the issuer requests bids from underwriters and accepts the best bid whereas in a negotiated sale, the issuer works with a single underwriter or underwriting syndicate to structure and price the debt. Most studies show that with sufficient level of competition, competitive sales yield better interest rates for municipal borrowers [17], [20]. On the other hand, a group of scholars argue that the negotiated bond sales establish a close relationship between underwriters and issuers and result in a more optimal outcome and lower borrowing costs through a more exhaustive market search by the underwriter [21], [22]. In contrast, Peng and Brucato (2003) argue that method of sale does not matter once you control for selection bias, as issuers self-select into the most optimal method of sale [23].

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[4]This constitutes the underwriting fee, which is generally around half a percent.

3.2.3 Measures of Borrowing Costs

By design, each municipal bond series is comprised of multiple maturities with different maturity dates, par values, offering prices, and offering yields, with the exception of term bonds. Term bonds are a single security. An issuer may issue multiple bonds/series and term bonds simultaneously. Therefore, offering yield for each maturity provides a proxy for borrowing costs at the maturity level rather than at the series level and is more granular. On the other hand, the primary measure of borrowing cost used in the public finance literature is the True Interest Cost (TIC). The TIC discounts all future principal and interest payments such that the present value of all cash flows equals the bond proceeds that the government receives. Such internal rate of return measure is generally considered best practice and has become the industry standard. TIC is only available at the bond/series level and not at the maturity level. Both TIC and offering yield have been used to measure borrowing costs incurred by debt-issuing municipal governments. For example, Schwert (2017) uses the offering yield as a measure of cost of borrowing whereas Moldogaziev and Luby (2016) only use the TIC [24], [25].

TIC, however, is not without its shortcomings as a measure of borrowing costs. Simonsen and Robbins (2002) argue that the TIC generally understates the real cost of borrowing given that there is quite a bit of variation in terms of which costs are included in the interest rate calculations across state and local governments [26]. Rating fees, bond counsel fees, bond insurance, and advisory fees are generally not included in TIC calculations [26]. Nonetheless, the TIC is still one of the best measures of borrowing cost available since it incorporates underwriting fees. For munis, the underwriting costs range from half a percent to a full percent of the par value depending on the size of the issuance. Weitzman and Kyler (2016) state that underwriters were making $4.64 per $1,000 of face value in 2015 compared to $7.77 per $1,000 in 1996 [27]. These fees are generally lower for larger bond issues.

3.3 RESEARCH DESIGN AND THEORY

How financial intermediaries, especially underwriters, gather and process information is at the core of municipal bond pricing. Underwriters face some level of uncertainty from the time they acquire the bonds from the debt-issuing government until all inventory is cleared and sold to investors. Consequently, these underwriters face pressure to estimate the demand as accurately as possible. If demand is overestimated, underwriters face the risk of not clearing the market and inventorying the securities they failed to sell to potential investors. Given the declining reputation of credit rating agencies, underwriters may seek other avenues such as the secondary muni market for additional and more-real time information.

Further, competitive and negotiated bond sales provide underwriters with different time lines. For negotiated sales, which is the most common sale type, underwriters have 2-3 months from the time they are selected until the final sale to evaluate the issuer, conduct market evaluation, estimate the demand, and solicit to potential investors [23]. This provides ample time to evaluate the true credit quality of the issuer and price securities accordingly. With competitive bid sales, the second most common offering type, the timeline is much tighter. Issuers publish a notice of sale with a request for bids and the underwriter who submits the lowest interest cost (highest purchase price) bid is selected. Underwriters have at most a few weeks to prepare and submit a bid. This implies that for competitive issues, underwriters do not have the same luxury of time as with negotiated sales to determine issuer's true credit quality. Thus, they may place even more weight on the secondary market information to estimate market demand and investor perception of issuer's true creditworthiness.

The underwriter's timeline difference for negotiated versus competitive bids has several potential implications. Negotiated sales may allow for better timing of issuance since underwriters have more time and flexibility to evaluate market demand. If the underwriters

rely more heavily on the secondary market signals under the competitive bid time constraint, the effect of the secondary market on interest might be stronger for competitive sales than for negotiated sales. On the other hand, since the underwriters in a negotiated sale have more time to incorporate all relevant information into the pricing decision, they may rely more heavily on the secondary market information. Additionally, the time constraint may induce the competitive bid underwriters to make larger mistakes in estimating the secondary market signals which would manifest itself in smaller effect of the secondary market price and yield fluctuations.

A review of extant literature reveals a lack of studies considering the effect of the secondary municipal bond market on future borrowing costs for state and local governments. If the secondary market contains information that could potentially reduce interest costs for issuers, the relationship between the secondary market and the primary market is worth consideration. This study argues that the mechanism through which the secondary muni market affects primary market performance is through the underwriting process. Underwriters have to provide additional certification of the issuer's quality and I test whether they do so by evaluating the secondary market signals of the issuer's creditworthiness. One strategy for estimating market demand is to look at the secondary market performance of the issuer's outstanding debt. If the underwriters use the secondary market performance to estimate market demand, then it is plausible that recent transaction prices and yields may have an effect on borrowing costs. This relationship may also be stronger and/or more volatile for negotiated bids than for negotiated sales. Recall that there is a relative time crunch for competitive sales between the time the issuer requests bids and an underwriter submits a bid compared to negotiated offerings. This time crunch may reduce the effect of the secondary market signals for competitive bids, as the underwriters do not have as much time to analyze all available information as they do in negotiated sales.

3.3.1 Theoretical Framework

In this paper, both the True Interest Cost (TIC) and the offering yields are used as the dependent variables to measure borrowing costs. The theoretical framework employed in this study falls along the lines of the traditional asset pricing theory. The theory dictates that, in financial markets, demand for safer assets is reflected in higher prices. Consequently, investors demand higher rewards (yields) for taking on higher risk and thus, issuers receive lower prices for their bonds:

- Higher risk $\rightarrow$ higher yields $\rightarrow$ lower prices.

Therefore, all else equal, increasing prices and/ or decreasing yields of the issuer's existing debt in the secondary market can be interpreted as a signal of higher demand and lower risk. The following hypotheses are tested to tease out whether the data support these claims:

H1: Increasing yields in the secondary market increase borrowing costs in the future periods.

H1 Corollary: Decreasing prices in the secondary market increase borrowing costs in the future periods.

H2: The secondary market effect is stronger for negotiated sales than for competitive sales, since the underwriters have more time to incorporate all information into pricing decision.

Hypotheses H1 and H1 Corollary are essentially testing the same thing. If yields are going up, prices should decline, all else equal. Conversely, if yields are decreasing, prices should increase signaling higher demand and therefore increase the probability of reduced borrowing costs. Rejection of H2, on the other hand, would imply that competitive sale underwriters rely more heavily on secondary market information, given they do not have the luxury of getting to know the issuer as closely as the negotiated sale underwriters. The

next section outlines the key measures and how these hypotheses are translated into an empirical model.

3.3.2   Key Covariates

To examine the effect of the secondary market performance on borrowing costs, measures of average monthly trade price and trade yield performance in the previous period are computed. For models with the offering yield as the dependent variable, key factors are defined as follows:

$$\text{Trade Yield}_{ikt} = \frac{\sum_{s=1}^{S} \left(y_{ikts} - oy_{ik} \right)}{S} \tag{3.1}$$

$$\text{Trade Price}_{ikt} = \frac{\sum_{s=1}^{S} \left(p_{ikts} - op_{ik} \right)}{S} \tag{3.2}$$

where i identifies the security, j is the issuer, t is the calendar month, y indicates the trade yield, oy indicates the offering yield, p is trade price, op is offering price, and S is the number of trades in the calendar month for debt issued by the **same issuer** with the **same time remaining** until maturity. These measures track the transaction-level deviations from the offering yield. Time remaining until maturity is important for investors with different investment horizons. Further, time to maturity directly affects yields by definition and is therefore indirectly controlled for by matching on time remaining until maturity.

For models with TIC as the dependent variable, the secondary market yield and price performance have to be aggregated from the security level to the bond level - the TIC is only available at the bond/ series level. To aggregate the market performance to bond level, previous period yield and price measures in Equation 3.1 and Equation 3.2 are weighted by the new security's maturity amount as a share of the bond's total par value, so that:

$$\text{Weight}_{ij} = \frac{m_{ij}}{P_j} \tag{3.3}$$

where i identifies a specific maturity within series j, m is the maturity amount and P is

the total par value of the new bond issued in the primary market. Such weighting by size ensures that an appropriate weight is given to securities of different sizes when measuring the effect of secondary market price and yield fluctuations. Essentially, this weighting mechanism constructs a comparison group for the new issue from the issuer's outstanding securities with similar maturity horizons.[5]

3.3.3 Model

For models where the offering yield is the dependent variable, a Random Coefficients Model (RCM) is estimated to analyze the effect of the secondary market on future cost of borrowing. The RCM has several advantages. First, it accounts for dependency across observations. There are multiple sources of correlation - securities are clustered within bonds which are clustered within issuances and issuances are in turn clustered within issuers. Different issuers may have different idiosyncratic risks that change over time, potentially more frequently than their credit ratings. Similarly, there may be issuance-level unobserved effects which may induce security-level dependency. In this case, the estimates from simple regressions that do not account for such nesting will be biased and unreliable. Finally, the RCM does not require that the panel data be balanced.

The RCM is a more appropriate empirical strategy to identify, model, and leverage unobserved but important heterogeneity among various municipal securities. Random coefficients/ slopes allow each covariate of interest to vary at multiple levels. The three levels/ dimensions in this study are defined as securities within issuances within issuers. The logic for this type of nesting, as explained in the previous paragraph, is driven by issuer- and issuance-level unobserved heterogeneity and dependency. The three-level random coeffi-

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[5]A less conservative methodology for estimating the effect of the secondary market on future cost of borrowing would be to expand the price and yield factors to all similar maturities trading in the market by all issuers rather than the matching by issuer's own debt. This strategy significantly increases the sample size since there are more comparable securities in the market by all issuers than one specific issuer but also introduces concerns about inference due to underlying risk differences across different issuers.

cients model can be expressed as:

$$oy_{ijkt} = \alpha + (\beta_1 + \theta_j + \lambda_k)\textbf{Trade Yield}_{ijk,t-1} \tag{3.4}$$

$$+ \beta_2\textbf{Trade Price}_{ijk,t-1} + \beta_3 X_{ijkt} + \epsilon_{ijkt} \tag{3.5}$$

where oy_{ijkt} is the offering yield for i^{th} security within j^{th} issuance within k^{th} issuer at time t.[6]

The key covariates are defined in Section 3.3. The *Trade Yield*$_{ijk,t-1}$ variable measures the average trade yield deviations from the offering yields for the issuer's other outstanding securities in the previous period. *Trade Price*$_{ijk,t-1}$ measures the average trade price deviations from the offering prices for the issuer's other outstanding securities in the previous period. Note that, theoretically, trade yields and trade prices should be negatively correlated. As prices increase, yields should decline given the bond price formula in Equation 2.2. However, the relationship is not deterministic and can vary by trade size. Therefore, both price and yield movements are accounted for in the model.

The βs capture the fixed effects. These are the mean effects of each covariate in the population. θ and λ capture the random parts of the coefficient that display cluster-level unobserved effects. The θ captures the variation by issuance and λ captures variation by issuer. Conditional on the covariates, each random effect is equal to zero in expectation. Consequently, we analyze the variance of each random effect by evaluating their point estimates and standard errors. Thus, there are three coefficients on the *Trade Yield*$_{ijk,t-1}$ variable. The first one, β_1, measures the mean population effect of the key variable, the second one, θ_j measures the variation by issuance, and the third one, λ_k, measures the

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[6]Similarly, we can analyze the effect of average trade price deviations of similar maturities on offering prices:

$$op_{ijkt} = \alpha + (\beta_1 + \theta_j + \lambda_k)\textbf{Trade Price}_{ijk,t-1} + \beta_2\textbf{Trade Yield}_{ijk,t-1} + \beta_3 X_{ijkt} + \epsilon_{ijkt} \tag{3.6}$$

where op_{ijkt} is the offering price and the rest of the variables are same as before.

variation by issuer.[7] The vector X_{ijkt} includes issue-, issuer-, and market-level controls as described in Table 3.1.

For models where TIC is the dependent variable, the following panel fixed-effects model is estimated:

$$\text{TIC}_{it} = \alpha + \beta_1 \textbf{Trade Yield}_{i,t-1} + \beta_2 \textbf{ Trade Price}_{i,t-1} + \beta_k X_{kt} + \alpha_i + \epsilon_{it} \qquad (3.7)$$

where α is the intercept, α_i is the issuer-level unobserved effects, and ϵ_{it} represents the error term. The dependent variable is the True Interest Cost (TIC) at the bond level, which measures the borrowing cost the issuer incurs in the primary market in period t. See Section 3.3 for the definition of the key independent variables at the series level.

3.4   DATA

This study uses large databases of primary and secondary municipal market information currently not available to the public. The data for this study come from the Municipal Securities Laboratory at the Andrew Young School of Policy Studies at Georgia State University. The primary market data includes all initial issuance-level information. The secondary market data includes information on all transactions following the issuance. Analysis is conducted at the security level for models where the offering yield is the dependent variable and at the bond level where TIC is the dependent variable. Recall that the offering yield is available at the maturity level, whereas the TIC is available only at the bond level. Primary and secondary market data are matched by issuer name and CUSIP identifiers.[8] Municipal bonds, with the exception of term bonds, are issued in multiple increments (maturities) at different prices with different amounts, maturity dates, coupon rates, and CUSIP

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[7]Note that it does not make much sense to add issuance level random effects if there is no variation at the security level.

[8]CUSIPs are unique security identifiers issued by the Committees on Uniform Securities Identification Procedures (CUSIP) Bureau.

numbers.[9] CUSIP-level analysis, therefore, is more granular than bond-level analysis.

3.4.1 Primary Market Data

The primary market data is obtained from IPREO, Inc and Mergent Inc. These are proprietary data sets not available to the public. The IPREO database contains the true interest cost (TIC) variable. The data also includes other issuance level information such as issuer name, issuer state, issuance and maturity dates, coupon codes, total debt outstanding, population size, etc. The data used in this study covers issuances in years 2005 through 2016. Due to the nature of the market, the TIC variable is available only for competitive issues in the IPREO data set.

Mergent's Municipal Bond Securities Database (MBSD) provides a rich set of covariates at the maturity and bond levels. This database contains the CUSIP numbers and issuance information, including issuance and maturity dates, debt type, coupon type, capital purpose, use of proceeds, credit rating and other enhancements, default information, original sale type, etc. The Mergent data includes a variety of information on more than 3.5 million securities. Issuer types are manually identified by issuer names as the data does not contain such classification. Variable descriptions and covariate constructions are described in Table 3.1.

3.4.2 Secondary Market Data

Daily historical transaction data is obtained directly from the Municipal Securities Rulemaking Board (MSRB). MSRB is a regulatory organization under the Securities and Exchange Commission (SEC) which writes rules for broker-dealers and banks. Each observation of the MSRB data contains the CUSIP numbers, transaction date and time, trade price and yield, trade amount, and whether the trade was a sale to a customer (investor), purchase from a customer, or an inter-dealer trade. The data also has an indicator for

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[9]For example, a municipality may issue a $1 million bond comprised of 10 CUSIPs, with the first maturity in the amount of $100,000 maturing in one year, $100,000 maturing in two years, and so forth.

Table 3.1: Variable Descriptions and Data Source

Variable Name	Description and Measurement	Source
	Dependent variables	
Offering Yield	Yield offered to the initial investor	Mergent
True Interest cost (TIC)	Series level internal rate of return	IPREO
	Independent variables	
Trade Yield	See Section 3.3	MSRB
Trade Price	See Section 3.3	MSRB
Issuer Type	Indicators for city, county, state, school district, special district, and town/ township	Mergent[10]
Credit Rating Score	Average credit rating based on Moody's, S&P, Fitch, converted to a $0 - 21$ scale with unrated $= 0$ and $21 =$ best possible credit rating	Mergent
Coupon Rate	Coupon paid to the investor	Mergent
Call Option	Indicator for call feature	Mergent
Bank Qualified	Indicator for bank qualification[11]	Mergent
Sinking Fund	Indicator for sink fund	Mergent
Insured	Indicator for presence of insurance	Mergent
ln(Issue Size)	Natural logarithm of the total offering size	Mergent
New (vs. Refunding)	Indicator for new issuance vs. refunding	Mergent
Market Yield (MMA)	The MMA yield curve	MMA
Market Yield (BBI20)	The Bond Buyer 20 Index	The Bond Buyer
Time to Maturity	Years remaining until maturity	Mergent

whether the transaction was the initial sale. Initial sales are dropped from the secondary

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[10]Coded manually based on Google searches of the issuer's name.

[11]Like other investors, commercial banks purchase munis to benefit from tax-exempt features of public debt. Until the Tax Reform Act of 1986 (TRA86), banks were the major holders of municipal bonds [28]. The passage of TRA86, now under section 265(b) of the Internal Revenue Code of 1986, altered the banks' demand for municipal securities by essentially eliminating tax benefits for banks (with a few exceptions). The bank-qualified designation allows banks to deduct a portion of the interest expense for the purchase and holding of municipal obligations. Under TRA86, bonds can be classified as bank-qualified ("qualified tax-exempt obligation") if the debt is (1) issued by a qualified small government issuing no more than $10 million of tax-exempt securities, (2) issued for public purposes, and (3) and designated as qualified tax-exempt obligation. Consequently, issues sold after August 6, 1986 have two designations: bank-qualified and non-bank-qualified securities. Banks are willing to accept lower returns on bank-qualified issues due to the tax benefits. Bank-qualified issues reduce interest costs for small issuers and provide attractive tax benefits for commercial banks.

market data. The data used in this study covers trades in years 2005 through 2015.

3.4.3   Market Conditions Data

The third dataset is obtained from the Municipal Market Analytics (MMA).[12] The MMA's benchmark is used as a proxy for prevailing market yields and represents dealer opinion on daily muni yields. The MMA data more is granular than other market indexes as it is constructed separately for each maturity. The MMA yield is created by surveying 38 institutions. The MMA's median consensus yield scale is constructed for a triple A, tax exempt, callable, 5% coupon GO bond for each of the $1, 2, 3...., 30$ year maturities. The MMA benchmark is constructed daily and separately for each maturity. Thus, each bond issuance is matched to a corresponding part of the MMA curve based on the issuance date and time left until maturity.

The Bond Buyer 20 Index is used as a proxy for the overall market conditions for the models with bond/series as the unit observation. Since the unit of analysis is a series rather than a maturity, the maturity-level market proxy (MMA) is not needed for the TIC analysis. The BBI20 index is obtained from the The Bond Buyer website and is available to the public.

3.4.4   Exclusion Criteria

Using the primary market data, the sample is restricted to competitive and negotiated issues due to the nature of the research question and data availability - offering types that are classified as limited, private placement, remarketing, or missing are removed. Debt types other than bonds, such as notes, derivatives, etc. are excluded. Issues with variable coupon rates are removed.[13] Analysis is restricted to new and refunded securities - observations are

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[12]The author would like to thank Municipal Market Analytics, Inc. (MMA), an independent research firm, and especially Tripp Kaiser, for allowing me to use the MMA yield curve in this research.

[13]More specifically, these are adjustable, deferred, floating auction, floating, floating at floor, inverse floater, index-linked, stripped, stripped convertible, stripped principal, stepped, or variable rate coupons. Analyzing variable rate issues and the impact of rate changes on borrowing costs are beyond the scope of this paper.

excluded if capital purpose is listed as remarketing/convertible, cross-over refunding, sale canceled, restructured debt, or municipal forward. The sample is further restricted to tax-exempt (federal and state) general obligation debt. General Obligation (GO) security types included in this study are limited GOs, unlimited GOs, and double-barreled obligations. Revenue bonds are excluded due to the fact that information on the revenue source/ risk is not available and will likely have an impact on borrowing costs. Below investment-grade securities and securities with less than one year until maturity are removed as well. Finally, debt issued by territories and their subsidiary governments are discarded as a precaution. In the secondary market data, trades are limited to customer purchases only to avoid concerns due to dealer-level interactions. Trades are limited to secondary trades only and initial sales are removed.

3.5 FINDINGS

3.5.1 Maturity-level Results

Table 3.2 and Table 3.3 show the results of the RCM model for competitive and negotiated sales, respectively. Descriptive statistics for these variables are provided in the Appendix in Table B.1 and Table B.2. The model is estimated separately for competitive and negotiated samples to avoid the method of sale selection bias. Results indicate that the secondary market trade yield fluctuations have a positive effect on future borrowing costs. A one percentage point increase in trade yields of comparable outstanding securities increases future borrowing costs by 1.7 basis point for competitive sales and by 3.4 basis points for negotiated sales. The effect of the secondary market price and yield fluctuations are larger for negotiated sales than competitive sales and the difference in the coefficients is statistically significant ($p = 0.0007$). This is consistent with the fact that in negotiated sales underwriters have more time to incorporate all available information into bond prices, including the secondary market signals. This supports the claim that, in negotiated sales, underwriters are able to better incorporate market signals into pricing decisions as they

59

Table 3.2: RCM, **Negotiated Sales**, DV = Offering Yield

Trade Yield$_{t-1}$	**0.036*****		**0.034*****
	(0.003)		(0.004)
Trade Price$_{t-1}$		-0.007***	-0.001**
		(0.001)	(0.000)
Issuer Variation	0.079	0.020	0.079
	(0.004)	(0.001)	(0.004)
Issuance Variation	0.148	0.032	0.147
	(0.003)	(0.001)	(0.003)
County	-0.058***	-0.064***	-0.058***
	(0.007)	(0.007)	(0.007)
State	-0.113***	-0.128***	-0.113***
	(0.007)	(0.007)	(0.007)
School District	-0.005	-0.002	-0.005
	(0.005)	(0.005)	(0.005)
Special District	0.063***	0.027***	0.063***
	(0.007)	(0.007)	(0.007)
Town/Township	-0.086***	-0.064***	-0.085***
	(0.010)	(0.010)	(0.010)
Credit Rating	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Coupon rate	-0.084***	-0.079***	-0.084***
	(0.001)	(0.001)	(0.001)
Call Option	-0.116***	-0.121***	-0.116***
	(0.007)	(0.007)	(0.007)
Bank Qualified	-0.076***	-0.052***	-0.076***
	(0.005)	(0.005)	(0.005)
Sinking Fund	-0.039***	-0.034***	-0.039***
	(0.009)	(0.010)	(0.009)
Insured	0.078***	0.105***	0.078***
	(0.004)	(0.004)	(0.004)
Ln(Issue Size)	-0.000	0.004 ***	-0.000
	(0.002)	(0.002)	(0.002)
New (vs. Refunding)	0.072***	0.060***	0.072***
	(0.004)	(0.004)	(0.004)
Market Yield (MMA)	0.973***	1.004***	0.973***
	(0.004)	(0.004)	(0.004)
Constant	YES	YES	YES
Maturity/Year effects	YES	YES	YES
Issuers	3,837	3,837	3,837
Issuances	8,033	8,033	8,033
Observations	43,304	43,304	43,304

*Notes: ***p< 0.01, **p< 0.05, *p< 0.1. Standard errors in parentheses.*

Table 3.3: RCM, **Competitive Sales**, DV = Offering Yield

Trade Yield$_{t-1}$	**0.019*****		**0.017*****
	(0.003)		(0.003)
Trade Price$_{t-1}$		-0.004***	-0.001**
		(0.001)	(0.000)
Issuer Variation	0.113	0.028	0.114
	(0.004)	(0.001)	(0.004)
Issuance Variation	0.118	0.034	0.118
	(0.002)	(0.001)	(0.002)
County	-0.019***	-0.034***	-0.019***
	(0.004)	(0.003)	(0.004)
State	0.046***	0.026***	0.046***
	(0.005)	(0.004)	(0.005)
School District	0.045***	0.030***	0.045***
	(0.003)	(0.003)	(0.003)
Special District	0.204***	0.146***	0.204***
	(0.006)	(0.005)	(0.006)
Town/Township	-0.037***	-0.032***	-0.037***
	(0.005)	(0.005)	(0.005)
Credit Rating	0.000*	0.001***	0.000*
	(0.000)	(0.000)	(0.000)
Coupon rate	-0.016***	-0.018***	-0.016***
	(0.001)	(0.001)	(0.001)
Call Option	-0.020***	-0.018***	-0.020***
	(0.005)	(0.005)	(0.005)
Bank Qualified	-0.099***	-0.073***	-0.099***
	(0.004)	(0.003)	(0.004)
Sinking Fund	-0.055***	-0.070***	-0.055***
	(0.007)	(0.008)	(0.007)
Insured	0.105***	0.128***	0.105***
	(0.003)	(0.003)	(0.003)
Ln(Issue Size)	-0.019***	-0.022***	-0.020***
	(0.001)	(0.001)	(0.001)
New (vs. Refunding)	-0.001	-0.000	-0.001
	(0.002)	(0.002)	(0.002)
Market Yield (MMA)	0.894***	0.925***	0.895***
	(0.003)	(0.003)	(0.003)
Constant	YES	YES	YES
Maturity/Year effects	YES	YES	YES
Issuers	4,310	4,310	4,310
Issuances	12,010	12,010	12,010
Observations	61,828	61,828	61,828

Notes: ***p< 0.01, **p< 0.05, *p< 0.1. Standard errors in parentheses.

have more time to evaluate the issuer's creditworthiness and investor demand.

The random part of the model shows that there are large issuer- and issuance-level variations in the effect of the secondary market yields on future borrowing costs. Issuance-level variation is much larger than variation by issuer. The standard deviation of the issuance-level effect is about 15 basis points, implying that the trade yield effect can vary by 2.2 basis points $(0.147^2 = 0.022)$ depending on the specific issuance. Similarly, the standard deviation of the issuer-level effect is about 8 basis points, implying that the trade yield effect can vary by about 1 basis points $(0.079^2 = 0.006)$ depending on the issuer. In terms of the effect on the borrowing costs, trade price and yield fluctuations have the expected negative relationship. Although very small, increasing market prices have a negative effect on borrowing costs as hypothesized. The effect of the secondary market price fluctuations shrinks once the yield fluctuations are accounted for.

Another interesting set of results are revealed by issuer-type indicators. For negotiated sales, states incur the lowest interest costs and special districts fare worse than any other level of government. Borrowing costs for towns, townships, and counties in negotiated sales are slightly higher than that of states but still lower than borrowing costs of cities (the reference group). The yields are statistically the same for cities and school districts. Special districts are the worst performers. States perform much more favorably in negotiated sales than in competitive sales. For competitive sales, offering yields are the lowest for smaller municipalities such as towns, townships, and counties. Borrowing costs are comparable for states and school districts in competitive sales as they pay slightly higher offering yields than cities. Special districts are paying highest borrowing costs compared to all other governments both in negotiated and competitive sales. Investor preference and heightened demand for more locally decentralized general purpose government debt may partially explain why smaller municipalities such as towns or townships generally perform better in terms of interest costs than special districts.

Control variables provide additional insights. An interesting result is that credit rat-

ings do not have a statistically significant effect, which supports the argument for more real-time credit quality metrics. This is plausible given the declining faith in rating agencies following the Great Recession of 2008-2009. These findings provide further support for one of the main claims of this study that investors and the market base decisions on more real-time metrics of creditworthiness. Previous studies have argued that larger issues benefit from economies of scale and incur lower borrowing costs given that large issues tend to be issued by larger governments with lower idiosyncratic risks. However, offering size seems to be beneficial only in competitive sales based on my results. New issues pay higher borrowing costs in negotiated sales, whereas capital purpose does not have a statistically significant effect in competitive sales. The remaining covariates have the expected signs across both models. Maturity-matched market yields have the expected positive and almost an one-to-one relationship with yields, which is consistent with the fact that borrowing costs correspond to prevailing market yields. As a robustness check, the effect of secondary market performance on issue prices is given in the Appendix in Table B.7.

3.5.2 Series-level Results

Table 3.4 shows the panel fixed effects results with True Interest Cost (TIC) as the dependent variable for competitive issues only. Similar to the RCM models with the offering yield as the dependent variable, the positive relationship between the secondary market performance and next-period borrowing costs are confirmed. Recall that TIC is only available for competitive issues in the IPREO data.[14] Higher trade yields in the previous period are associated with higher borrowing costs in the next period. As the weighted trade yield performance on existing debt of the issuer with similar maturity structure increases by one percentage point, the issuer's borrowing cost (TIC) in the next month increases by 1.4

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[14]Note that panel fixed effects model, by design, does not allow multiple TICs per unit of time (days). Therefore, issuers which issued multiple bonds at once were dropped from the analysis. TIC level analysis, although costly in terms of sample size, is important because it incorporates additional interest cost parameters (e.g. underwriting fees, etc.) that offering yields analysis ignores. This model restriction results in some sample size reduction - 865 observations are lost. Therefore, as a robustness check, RCM model is also run on this full sample and the results remain the same.

Table 3.4: Panel Fixed Effects, Competitive Sales, DV = TIC

	(1)	(2)	(3)	(4)
Trade Yield$_{i,t-1}$		**1.20***		**1.36****
		(0.13)		(0.15)
Trade Price$_{i,t-1}$			**-0.06****	**0.06****
			(0.03)	(0.03)
ln(Total Debt)	0.16***	0.15***	0.16***	0.15***
	(0.03)	(0.03)	(0.03)	(0.03)
ln(Population)	0.20***	0.19***	0.20***	0.19***
	(0.01)	(0.01)	(0.01)	(0.01)
ln(Issue Size)	-0.04	-0.05	-0.05	-0.05
	(0.04)	(0.03)	(0.04)	(0.03)
Market yield (BBI20)	0.66***	0.60***	0.65***	0.60***
	(0.03)	(0.03)	(0.03)	(0.03)
Constant	-5.75***	-4.74***	-5.58***	-4.77***
	(0.70)	(0.68)	(0.70)	(0.68)
Bonds	6,863	6,863	6,863	6,863
R^2	0.70	0.73	0.71	0.73
Issuers	2,732	2,732	2,732	2,732

*Notes: ***p< 0.01, **p< 0.05, *p< 0.1. Standard errors in parentheses, clustered at the issuer level.*

percentage points, all else equal. The magnitude of the relationship should be interpreted with caution as the yield fluctuations measure is weighted. The sign of the relationship here is more important. These estimates are consistent with the hypothesis that the primary municipal bond market rewards, whether directly or indirectly, the secondary market performance. Results are robust to the definition of periods and inclusion of additional periods.

The effect of trade prices on borrowing costs is small and only statistically significant at the 5% level. The small and insignificant relationship should not be surprising as trade yields calculations incorporate prices by definition (See Equation 2.2). In Model (3), the relationship between the secondary market and next-period borrowing costs, although small, is negative as hypothesized. However, this negative relationship is reversed once the secondary market yield is added in to the specification in Model (4). The magnitude is

still vary small given the wide range of secondary market trade price fluctuations shown in Table B.8.

Control variables provide additional insights. Given that the TIC is measured at the series level, the model only includes issuance- and issuer-level controls.[15] Issuer-level controls included in Models (2)-(4) are measures for issuer's total outstanding debt and population size. These variables are provided in the IPREO database for competitively-sold issues. Debt burden has the expected positive sign. As the issuer's total debt increases (borrowing and repayment capacity decreases), borrowing costs increase. Issuer size, proxied by the issuer's population size, has a positive effect on borrowing costs. This may at first be surprising given that larger subnational governments are generally more experienced in the market compared to smaller issuers and are able to negotiate better rates with underwriters. Local governments with larger population are usually big cities or counties with more debt-issuing capacity, stronger economy but also lower debt capacity compared to some of the smaller issuers. Further, there may be higher risk of these securities not clearing the market if the investors are concerned about the debt capacity of larger issuers. This reduced demand for debt issued by larger issuers may result in under-subscription and push underwriters to increase interest offered to investors.

Previous studies have demonstrated that larger issues tend to incur lower borrowing costs due to the economies of scale. The relationship is negative but statistically insignificant in my results. This is consistent with the theory that investors care about the issuer's creditworthiness rather than the issue size. Finally, prevailing market yields (daily BBI20 Index) have the expected positive effect. As market interest rates increase, borrowing costs tend to rise.

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[15]As a robustness check, the Appendix includes another specification with weighted maturity-level controls in Table B.10. Results remain the same.

3.6 CONCLUSION

This study shows that the secondary municipal bond market contains an additional layer of credit quality information not captured by other lagged metrics such as credit ratings. A favorable secondary market performance of the issuer's existing debt has a negative effect on future cost of borrowing for state and local governments. Better performance in the secondary market is associated with better borrowing cost outcomes in the primary market in the future period. Underwriters gauge market perception of the issuers debt and true credit quality and the secondary market price and yield fluctuations provide a significant signal in addition to credit ratings and issue/ issuer characteristics.

For a $40 million issue, three basis points reduction in borrowing costs means $12,000 reduction in interest costs per year. For a frequent issuer that periodically issues large long-term bonds, this reduction translates into significant savings over the life of each bond. The effect of the secondary market on the primary market, therefore, should not be ignored.These findings have several policy implications for debt-issuing subnational governments. Given that price and yield fluctuations of existing debt are significant real-time predictors of future borrowing costs, state and local governments may be able to save on borrowing costs by timing their debt issuance based on the market performance of their existing debt. Further, such knowledge may provide issuers with leverage when negotiating with or requesting bids from underwriters or underwriting syndicates. Reducing borrowing costs, in turn, is of significant value as it can free up resources for other public goods and services.

CHAPTER 4

DISPERSION IN TRADING ACTIVITY IN THE SECONDARY MUNICIPAL BOND MARKET: PORTFOLIO ABSORPTION, PREEMPTIVE ACTION, OR SPECULATIVE TRADING?

ABSTRACT

The municipal bond market is full of peculiarities. One such puzzling fact is that some securities trade thousands of times in the secondary market while most do not trade at all. Studies have shown that these differences in trading frequency cannot simply be attributed to transaction costs - actively traded bonds are not necessarily less expensive to trade. Understanding what accounts for such distinct patterns of trading activity can inform investors and issuers about market demand and potentially improve government debt issuance outcomes and household portfolio allocation decisions. This chapter examines the dispersion of trading activity of municipal securities in the secondary market using large databases of security- and transaction-level information. Results show that safer and high quality securities tend to be taken off the market quickly and likely absorbed into the portfolios of buy-and-hold type investors. Further, the call complexity hypothesis reveals distinct trading patterns for different trade types (interdealer trades vs. retail customer trades) as the call date approaches. Finally, there is some evidence of speculative trading in the secondary market which further contributes to the wide dispersion in trading activity among various securities.

Keywords: municipal securities, municipal bonds, secondary market, trading activity, trading frequency, bank-qualified bonds, speculative trading, portfolio absorption, bond complexity, call option.

JEL Codes: G12, G14, H5, H70, H71.

4.1 INTRODUCTION

The municipal bond market is full of peculiarities. One such puzzling fact is that most municipal bonds do not trade at all, while a small subset of munis display surprisingly high levels of trading activity in the secondary muni market.[1] This dispersion in the number of trades cannot be attributed to transaction costs. Harris and Piwowar (2006) show that actively traded bonds are not necessarily less costly to trade than infrequently traded bonds, implying that differences in trading activity cannot be attributed to trading costs [29]. The public finance literature does not provide any substantial explanation for why some municipal securities trade thousands of times in the secondary market while other do not trade at all.

Understanding what drives these large variations in trading activity can benefit investors as well as debt-issuing state and local governments. Issuers may be able to achieve lower borrowing costs in the future if they understand how the market values their securities (market perception), what clears the market, and what drives the demand. On the other hand, investors can make better inferences about the liquidity of their investments. In financial markets, investors place higher value on assets that are liquid and lack of trading activity may signal liquidity issues. Consequently, issuers may benefit from knowing what features make their debt more attractive to potential retail and institutional investors.

This paper examines the dispersion of trading activity for municipal securities in the secondary market using large databases of issuance and transaction information. Different hypotheses are tested to identify potential drivers of trading frequency by focusing on the effect of varying security features on the secondary market trading activity. First, I test the portfolio absorption hypothesis, that seasoned and attractive maturities display lower trading activity, potentially due to the fact that they are quickly absorbed into the portfolios of inactive retail and institutional investors. I also test the call complexity hypothesis,

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[1]In this paper, terms "trade/trading frequency" and "trading activity" are used interchangeably and refer to a number of trades in a given period (year).

that a callable security is traded more (preemptively "dumped") closer to its call date or alternatively traded less merely due to the analytical burden of valuing its complex call feature. Finally, I test the speculative trading hypothesis to explore whether securities with high price and yield volatilities are traded more than their less volatile counterparts.

My results support the portfolio absorption and speculative trading hypotheses. Further, the call complexity hypothesis reveals distinct trading patterns for different trade types as the call date approaches. These findings are important for several reasons. First, Chapter 3 shows that the secondary market has a significant effect on future borrowing costs for state and local governments. Thus, it is important to understand and explore all available information the muni market provides, which can then be translated into more policy-relevant metrics such as borrowing costs. Second, if the secondary market contains information about investor perceptions and demand for specific securities, issuers and underwriters may want to restructure future bond issuances to supply munis that the market demands the most. Tapping into a larger investor pool, in turn, is likely to reduce interest costs for subnational governments. Finally, if there are activities in the secondary market that particularly harm retail investors or introduce unsubstantiated speculative trading, then the regulators, such as the Municipal Securities Rulemaking Board (MSRB), may want to be aware of such activity.

4.2 RESEARCH DESIGN AND LITERATURE

This study proposes and tests three hypotheses to understand the drivers of trading activity in the secondary market for municipal securities:

- *Portfolio Absorption Hypothesis*: Seasoned and attractive securities trade less frequently.

- *Complexity Hypothesis*: Callable securities trade more frequently closer to the call date.

- *Speculative Trading Hypothesis*: Securities with more volatile secondary market performance trade more frequently.

The following sections discuss the logic behind each of the claims and relevant evidence from corporate and municipal bond literature.

4.2.1   Portfolio Absorption

Lower Trading for Seasoned Securities

Part of the reason why most munis do not trade much in the secondary market could be that they are simply not available for trading. The idea behind the portfolio absorption hypothesis is that if investors buy and hold securities until maturity, then this will reduce the overall trading activity in the secondary market since there are less munis available to trade. Observing reduced trading activity over time, therefore, would be consistent with such buy-and-hold behavior. Observing a negative relationship between the age of the bond and its secondary market trading frequency would support the portfolio absorption hypothesis. Corporate bond studies have found that trading frequency generally declines as bonds age and find their way into portfolios of household investors and mutual funds [30]. Given the perceived safety of the munis and the dominance of high net-worth retail investors with long investment horizons in the market, the portfolio absorption hypothesis seems rather plausible.

Investors are more likely to buy and hold a security to maturity if they believe the security is safe and does not pose significant default risk. Ronen and Zhou (2013) find that once corporate bonds are absorbed into portfolios, their liquidity declines rapidly, especially if they are rated as investment-grade [31]. Bond research shows that newly issued securities have much lower liquidity premiums than older bonds and trade much more frequently than similar but "seasoned" bonds [32]. Securities are generally considered seasoned within the first or second year of issuance [30]. However, Ronen and Zhou (2013) show that infrequent trades are not necessarily a sign of illiquidity or market inefficiency for corporate

bonds - investors might simply be waiting for specific information and act on that information in large trades in the future [31].

Lower Trading Activity for Bank-qualified Securities

Like other investors, most commercial banks purchase munis to benefit from the tax-exemption interest income. Until the Tax Reform Act of 1986 (TRA86), banks were the major holders of municipal bonds [28]. The passage of TRA86, now under section 265(b) of the Internal Revenue Code of 1986, altered the banks' demand for municipal securities by essentially eliminating tax benefits for banks (with a few exceptions). The bank-qualified designation allows banks to deduct a portion of the interest expense for the purchase and holding of municipal obligations. Under TRA86, bonds can be classified as bank-qualified ("qualified tax-exempt obligation") if the debt is 1) issued by a qualified small government issuing no more than $10 million of tax-exempt securities, 2) issued for public purposes, and 3) and designated as qualified tax-exempt obligation.

Consequently, issues sold after August 6, 1986 have two designations: bank qualified and non-bank qualified securities. The interest cost savings give commercial banks an incentive to absorb bank-qualified issues into their portfolios. Consequently, banks are willing to accept lower returns on bank-qualified municipal bonds compared to other taxable securities such as corporate bonds. As such, bank-qualified issues reduce interest costs for small issuers and provide attractive tax benefits for commercial banks simultaneously. A significantly lower trading activity for bank-qualified maturities could be a signal of market demand for debt issued by smaller governments and potentially enable these issuers to better negotiate and/or structure their interest costs.

Both municipal and corporate bond markets are dominated by large institutional investors, such as commercial banks and property and casualty insurance companies [28]. Harris and Piwowar (2006) argue that large institutional traders have a better sense of the valuation of municipal bonds than uninformed retail investors [29]. Municipal bond trades

are generally categorized as large institutional-size trades and smaller retail-size trades, although the threshold between the two categories is somewhat arbitrary. The cutoff point between institutional and retail trades ranges from $25,000$ to $100,000$ in most studies. The report issued by Municipal Securities Rulemaking Board (MSRB) shows that $25,000$ is the median trade size in the municipal market [33]. Since it is not necessarily correct to distinguish institutional and retail size trades simply based on trade size and we do not have access to additional identifying information, this research focuses on whether a trade is reported as a customer sale/purchase or an interdealer trade by the MSRB.[2] The institutional and retail distinction of the secondary market transactions if left for future research.

4.2.2   Call Complexity - Preemptive Action?

The municipal bond markets have a rich product diversity in terms of the types of debt issued and various features attached to them. This creates a significant heterogeneity in the secondary market. Security complexities, such as call features, may reduce the likelihood of a trade due to the cost of information dissemination. Harris and Piwowar (2006) characterize bond complexity by the following six features to explore their effect on transaction costs: call feature,[3] sinking fund provision,[4] special redemption/extraordinary call features, nonstandard interest payment frequency,[5] nonstandard interest accrual basis bonds and financial guarantees such as insurance, letter of credit, etc. [29]. Other studies have explored the effect of credit ratings, insurance, and debt types on market yields, but the effects of the approaching call date on trading activity have not been explored.

Securities with complex features, such as extraordinary call options, can be difficult

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[2] The MSRB reports secondary transactions as customer trades (purchases from customers or sales to customers) or interdealer trades. Customers in this context are non-institutional investors. Therefore, retail-size trades and interdealer trades are not mutually exclusive. A dealer may be involved in both a retail-size trade and an institutional-size trade. Similarly, a customer sale (sale to a customer) or customer purchase (purchase from a customer) may be of institutional size but that is less likely.

[3] The call feature allows the issuer to call (pay back) the bonds before the maturity date.

[4] Sinking fund provision in many bond indentures stipulates that the borrower retire a certain proportion of the debt annually.

[5] Standard interest payment frequency is semiannual.

to evaluate, especially for unsophisticated retail investors. A call option gives the issuer the ability to call the debt and reissue at a lower rate if the market conditions change. Therefore, the call feature protects the issuer from undesirable changes in interest rates. It is plausible that buy-and-hold investors will be less inclined to hold on to these securities if they expect the issuer will exercise the call option. This implies that callable securities can potentially have different trading patterns and trading frequencies, especially closer to the call date compared to non-callable securities. The other complexity features described in this section are fixed at the issuance and do not vary over time and therefore not used in this longitudinal analysis.

4.2.3 Speculative Trading

Traditional finance literature defines speculation as trading high risk securities with the motive of taking advantage of market fluctuations. Speculative trading is more prevalent in financial markets if price movements are highly volatile and relatively frequent.[6] Price volatilities are lower for bonds with higher yields[7] and yield volatility is generally considered to be an indicator of risk arising from movements in interest rates. High volatility of bond yields, therefore, implies less predictability in the yields.[8] A simple and straightforward measure of historical or realized volatility is the standard deviation of yield changes from the previous, most recent trade. This is an ex-post measure of volatility.

The stock market displays enough trading activity to analyze the change in yields/prices from the previous trades and easily estimate the volatility of prices/yields on a daily/weekly basis. Unfortunately, such equity market strategy for estimating volatilities is not feasible for municipal securities since a significant portion of munis do not trade at all. Further, even if there is a previous trade, it may be a different type of a trade (e.g. customer purchase verses interdealer trade) which makes analyzing the change less systematic. Therefore,

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[6]Factors that affect a bond's price volatility are coupon rate, time to maturity, and trading yield.

[7]The price of a bond is an inverse function of the required bond yield.

[8]A yield volatility near zero would indicate that overall yields are clustered around the average and are relatively stable.

price and yield volatility effects have to be evaluated separately for different types of trades (customer sales vs. customer purchases vs. interdealer trades).

Downing and Zhang (2004) argue that price range, scaled by the inverse of average prices, is a better proxy for price volatility than changes from the previous day's closing price since it captures more of the variation and is less noisy [34]. However, the authors do not distinguish between trade types when estimating volatilities. This is important in a market where inefficiencies may arise depending on whether the trade is a customer trade and an interdealer transaction. Downing and Zhang (2004) estimate the effect of trading frequency on price volatility, but the direction of the relationship is not justified [34]. If there is speculative trading in the market, it may be that price and yield volatilities affect trading frequency rather than vice versa. I discuss and analyze this further in Section 4.4.2 and Section 4.5. Since most munis are considered safe, with high credit ratings and bond insurance, speculative trading on a small subset of the outstanding issues with above average price and yield fluctuations may partially explain low trading activity for the majority of outstanding securities.

4.3 DATA

This study uses large issuance (primary municipal bond market), transaction (secondary municipal bond market), and market (bond market indexes) data sets, currently not available to the public. The data come from the Municipal Securities Laboratory at the Andrew Young School of Policy Studies at Georgia State University. The analysis is conducted at the CUSIP level (maturity level), rather than the issuance level. CUSIPs are unique security identifiers issued by the Committees on Uniform Securities Identification Procedures (CUSIP) Bureau. Municipal bonds, with the exception of term bonds, are issued in multiple increments at different prices with different amounts, maturity dates, discounts/premiums, and CUSIP numbers.[9] CUSIP-level analysis, therefore, is more granular than issuance- or

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[9]For example, a municipality may issue a $1 million bond comprised of 10 CUSIPs, with the first maturity in the amount of $100,000 maturing in one year, $100,000 maturing in two years, and so forth.

bond-level analysis.

Daily historical transaction data for the secondary market from 2005 through 2015 is obtained from the MSRB. Each observation of the MSRB data contains the CUSIP number, the transaction date and time, trade price, coupon rate, yield to maturity, trade amount, and whether the trade was sale to a customer (investor) by a dealer, purchase from a customer by a dealer, or an interdealer trade. The data on issuance information is obtained from the Mergent's Municipal Bond Securities Database (MBSD). This database contains the CUSIP numbers and a variety of security- and issuance-level information such as issue and maturity dates, debt type, coupon type, type of capital purpose and use of proceeds, credit rating and other enhancements, default information, call dates, etc.

4.3.1 Exclusion Criteria

First, I analyze only bonds. Bonds have different risk and reward properties than derivatives and other securities. Second, issues with variable coupon rates are removed. More specifically, these are adjustable, deferred, floating auction, floating, floating at floor, inverse floater, index-linked, stripped, stripped convertible, stripped principal, stepped, or variable rate coupons. Analyzing variable rate issues and the impact of rate changes on trading activity are beyond the scope of this paper. Third, the sample is restricted to the 50 states and their subsidiary governments. All securities issued by American Samo, Canal Zone, Guam, Northern Mariana Islands, Puerto Rico, Virgin Islands, District of Columbia, the United States government agencies, as well as any issues with missing state information are removed. Fourth, securities that are taxable federally and/or at the state level are excluded from the sample to guarantee that the results are not driven by complex tax features.

Fifth, the sample is restricted to issues with new or refunding capital purpose.[10] I exclude securities that have a lifespan of one year or less to avoid the confounding effects of demand for short-term securities. I also exclude securities with make-whole features, of

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[10]I exclude observations with capital purpose listed as remarketing/convertible, cross-over refunding, sale canceled, restructured debt, or municipal forward. These observations are a very small subset of the data set.

which there are only a handful in the sample. Only general obligation bonds are analyzed in the final sample.[11] I only keep investment-grade securities and drop unrated or below-investment grade maturities. As a robustness check, results are also presented for unrated securities in the Appendix in Table C.3. The original issue premium bonds are the most prevalent securities, so I drop all other coupon types. Finally, I drop uninsured bonds and securities with sinking fund provisions.

4.4 METHODOLOGY

4.4.1 Circumventing Truncated Data Issue

The few studies that analyze trading activity have examined only securities that have traded at least once, ignoring other outstanding securities which did not trade.[12] Given that most securities trade very infrequently, such strategy discards too much information. Analyzing only traded securities biases the results when predicting trading frequency for all outstanding securities. In this study, primary market data is transformed to security-years for all years that a security was active to construct a sample of all outstanding securities in a given year. For example, instead of one observation for a security with CUSIP (See Section 4.3 for CUSIP definition) identifier 356231KH7, which was outstanding for four years between 2005 and 2008 and only traded 45 times in 2006, four security-year observations are created to account for trading activity in year 2006 and lack of trading activity in the remaining years. Table 4.1 provides a visual example of this. Identifying all outstanding issues in this way allows to circumvent truncated transaction data issue and allows us to analyze all outstanding securities rather than the ones that traded.

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[11]Security types listed as revenue, fuel/vehicle tax, lease/rent, other, public improvement, sales/excise tax, special assessment, tax allocation, US government, sales agreement, loan agreement, tobacco agreement, tuition agreement, special tax, mortgage loans, education loans, certificate of participation are removed.

[12]See Dougal et al. (2016) [35] for municipal bonds and see Alexander et al. (2000) [30] for corporate bonds.

Table 4.1: Data Transformation

Original Data			Transformed Data				
CUSIP	Issue Yr	Maturity Yr	CUSIP	Issue Yr	Maturity Yr	Trade Yr	# of Trades
656451ZT2	1995	1998	656451ZT2	1995	1998	1995	0
356231KH7	2005	2008	656451ZT2	1995	1998	1996	10
			656451ZT2	1995	1998	1997	0
			656451ZT2	1995	1998	1998	0
			356231KH7	2005	2008	2005	0
			356231KH7	2005	2008	2006	45
			356231KH7	2005	2008	2007	0
			356231KH7	2005	2008	2008	0

4.4.2   Measurements

Table 4.2 provides an overview of variables used in the analysis. The measures of trade frequency (by trade type) used as the dependent variables in this study are listed in the first part of the table. The next subsection elaborates on measures that were constructed for this study, namely the price and yield volatility variables.

Price and yield volatility

Section 4.2.3 describes the logic behind using volatility measures as a signal of speculative trading. In this study, price/yield volatilities of each CUSIP are first measured as the standard deviation of prices/yields of the previous ten trades for that CUSIP. This threshold is chosen because the default number of past trades shown on MSRB's Electronic Municipal Market Access (EMMA) website by CUSIP is ten adn there is no theoretical reason to choose another threshold. Further, it is plausible that market participants give more weight to recent yield and price changes than all historical performance. Therefore, a shorter time horizon is more likely to capture market reactions to price and yield fluctuations. Such backward-looking (rolling) measure of volatility captures the trade performance information that would have been available to the investor at the time of the trade. After creating

Table 4.2: Variable Descriptions and Data Sources

Variable Name	Description and Measurement	Source
All trades	Number of trades per year	MSRB
Customer purchases	Number of customer purchases per year	MSRB
Customer sales	Number of customer sales per year	MSRB
Interdealer trades	Number of interdealer trades per year	MSRB
Age	Average annual number of years since issuance	MBSD
Bank Qualified	Identifier for bank-qualification[13]	MBSD
Time to Maturity	Average annual number of years left until maturity	MBSD
Time to Call	Average annual number of years left to call	MBSD
Price Volatility	Std of the previous 10 trade prices. See Section 4.4.2	MSRB
Yield Volatility	Std of the previous 10 trade yields. See Section 4.4.2	MSRB
Unemployment rate	Annual state unemployment rate, seasonally adjusted	BLS

BLS = Bureau of Labor Statistics
MBSD = Mergent's Municipal Bond Securities Database
MMA = Municipal Market Analytics
MSRB = Municipal Securities Rulemaking Board Historical Trade Data

past yield/price volatility for each trade, the volatility measures are averaged to annual level for each CUSIP so that the unit of observation is CUSIP-years.

I assume zero volatility in the absence of any previous trades. Without this assumption, the final sample will have only securities that had a trade. This would defeat the goal of this study to analyze all outstanding securities. Again, the purpose of this study is to understand secondary market trading activity for all securities, not just the ones that traded.

4.4.3 Model

Given that most municipal securities do not trade at all, while others trade frequently, a model that takes lower bound censoring into account is methodologically necessary. When

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[13]Binary variable equal to 1 if the security is bank-qualified.

the dependent variable has a significant pile-up at zero, Tobit-type models that take the dependent variable's skewed distribution into account can better address the selection bias.[14] This study uses the random-effects Tobit design to model the trade frequency:

$$\text{Trade Frequency}_{it} = \max(\alpha_i + X_{it}'\beta + \epsilon_{it}, 0) \tag{4.1}$$

$$\epsilon_{it}|x_i, \alpha_i \sim \text{Normal}(0, \sigma_\epsilon^2) \tag{4.2}$$

where α_i is the unobserved effect and X is a vector of explanatory variables including an intercept. Note that the assumption of random-effects rather than fixed-effects is constraining. There is likely a correlation between observables and the unobserved effect, α_i. However, fixed-effects Tobit (or probit) is computationally unfeasible and random-effects Tobit is the next best alternative. One advantage of a panel model is that it controls for characteristics that do not vary over time and thereby eliminates the need to include maturity and issue-specific variables in the regression and increases the degrees of freedom.

4.5 FINDINGS

First, the sample is separated into callable and non-callable bonds. Callable securities are likely to have different trading patterns, especially closer to the call date. Further, yield to call is likely to be different from yield to maturity. The sample is separated into callable and non-callable subsets rather than just adding a call option indicator in the models because of the fundamental underlying differences in callable and non-callable securities. For callable securities, the analysis is based on the time period until call rather than time remaining until maturity. Summary statistics for non-callable and callable subsamples is given in the Appendix in Table C.1 and Table C.2, respectively.

Table 4.3 and Table 4.4 show the breakdown of the dependent variables for callable

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[14]Zero-inflated negative binomial model (ZINB) is used as a robustness check and is available upon request. Results remain essentially the same. ZINB does not account for the panel nature of the data. However, the model assumes that two different data generating processes account for zero and non-zero outcomes.

and non-callable samples. As expected, there is a significant pile-up at zero in trading frequency for all trade types. Summary statistics for the variables used in the analysis are in the Appendix in Table C.1 and Table C.2. Results in Table 4.5 and Table 4.6 are shown for all trades, interdealer trades, purchases from customers, and sales to customers separately. Conducting the analysis by trade type allows a more granular look at the behavior of market participants, in this case broker-dealers and retail and institutional investors.

Results for **non-callable** securities are given in Table 4.5. Overall, as securities age, trading activity increases. About every two years, there is a new trade. The negative coefficient on the interaction of the age variable and the bank-qualification identifier indicates that trading activity declines with age for bank-qualified securities compared to non-bank-qualified securities. This is consistent with the fact that commercial banks have an incentive to buy and hold bank-qualified securities until maturity, thereby reducing the number of such securities available for trade. Consistent with portfolio absorption hypothesis, there is a positive relationship between time remaining until maturity and trading frequency. As time remaining until maturity declines, trading activity declines or said differently, there is less trading activity toward the end of the life of the security. This is consistent with the previous finding that newer securities with longer maturity horizons tend to trade more frequently. These results provide support for the portfolio absorption hypothesis.

Results in Table 4.5 show that recent trade price and trade yield fluctuations have a significant effect on trade frequencies. A one percentage point increase in the yield volatility measure implies about one more trades for that security overall. If higher volatility is driven by lack of trading activity, then we would be more likely to find a negative rather than a positive relationship. In this scenario, increased trading would likely lead to convergence to the mean and reduce volatility. However, we find a positive relationship between the volatility and trading activity, further supporting the hypothesized direction of the relationship. The effect of price fluctuations is also significant. A one percentage point increase in the recent trade price volatility implies about 4 more trades. Regional economic conditions,

Table 4.3: Trading Frequency: **Non-callable** Securities

	Frequency	Percent
All Trades		
0	83,661	65.53
1-10	29,444	23.06
10+	14,557	11.4
Interdealer Trades		
0	93,816	73.49
1-10	28,941	22.67
10+	4,905	3.84
Customer Purchases		
0	89,845	70.38
1-10	36,275	28.41
10+	1,542	1.21
Customer Sales		
0	84,315	66.05
1-10	39,214	30.72
10+	4,133	3.24

Table 4.4: Trading Frequency: **Callable** Securities

	Frequency	Percent
All Trades		
0	229,742	67.06
1-10	67,819	19.8
10+	45,012	13.14
Interdealer Trades		
0	257,924	75.29
1-10	69,862	20.39
10+	14,787	4.32
Customer Purchases		
0	239,626	69.95
1-10	97,061	28.33
10+	5,886	1.72
Customer Sales		
0	231,364	67.54
1-10	93,542	27.31
10+	17,667	5.16

Table 4.5: **Non-Callable** Securities: Random-Effects Tobit, DV= # of Trades per Year per CUSIP

	All Trades	Interdealer	Purchases from Customers	Sales to Customers
Age	0.44***	0.17***	0.18***	0.14***
	(0.01)	(0.01)	(0.00)	(0.01)
Time to Maturity	0.36***	0.20***	0.06***	0.18***
	(0.01)	(0.01)	(0.00)	(0.01)
Age * Bank-qualified	-0.39***	-0.16***	-0.15***	-0.10***
	(0.01)	(0.01)	(0.00)	(0.01)
Yield Volatility	1.03***	2.68***	0.59***	-0.15
	(0.15)	(0.15)	(0.01)	(0.11)
Price Volatility	3.63***	1.78***	0.43***	1.08***
	(0.06)	(0.03)	(0.01)	(0.03)
Unemployment Rate	0.31***	0.17***	0.06***	0.11***
	(0.02)	(0.01)	(0.00)	(0.01)
Year Fixed Effects	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Obs (CUSIP-years)	127,662	127,662	127,662	127,662
# of securities	26,529	26,529	26,529	26,529

Notes: ***p< 0.01, **p< 0.05, *p< 0.1.

proxied by the state unemployment rates, have a small positive effect on trading activity. This may be due to the fact that traders care more about issuer's financial conditions and yield and price characteristics than their current economic environment. Finally, the trend (year fixed effects) for the trading activity (not shown due to space constraints) indicates that trade frequencies declined during the recent Great Recession and have been increasing since.

Analyzing trade frequencies by various trade types reveals interesting patterns. The effect of the price and yield volatility measures are larger for interdealer trades than other trade types. Given that dealers are one of the most sophisticated market participants who are able to effectively weigh all of the market characteristics, this is not completely surprising. A dealer may be better able to take advantage of price and yield fluctuations through new

Table 4.6: **Callable** Securities: Random-Effects Tobit, DV=
# of Trades per Year per CUSIP

	All Trades	Interdealer	Purchases from Customers	Sales to Customers
Age	0.27***	0.06***	0.20***	0.03
	(0.03)	(0.02)	(0.01)	(0.02)
Time to Call	0.26***	0.22***	-0.01	0.22***
	(0.04)	(0.02)	(0.00)	(0.02)
Time to Call * Bank-qualified	-0.69***	-0.31***	-0.04***	-0.47***
	(0.01)	(0.01)	(0.00)	(0.01)
Yield Volatility	-0.36***	0.64***	0.07*	0.13
	(0.12)	(0.08)	(0.01)	(0.09)
Price Volatility	0.45***	1.27***	0.17***	0.13***
	(0.06)	(0.02)	(0.01)	(0.03)
Unemployment Rate	0.52***	0.28***	0.11***	0.27***
	(0.02)	(0.01)	(0.00)	(0.01)
Year Fixed Effects	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Obs (CUSIP-years)	187,241	187,241	187,241	187,241
N of securities	34,699	34,699	34,699	34,699

Notes: ***p< 0.01, **p< 0.05, *p< 0.1.

trades than a retail investor.

Table 4.6 provides the same results as in Table 4.5 but for **callable** maturities. Aging has a small positive effect on trading activity. Again, for non-bank-qualified securities, trading frequency declines with age. A five-year change in age implies three more trades for non-bank-qualified securities but only two more trades for bank-qualified securities. Interestingly, as the call date approaches, trading activity decreases (as time to call increases, trading increases). The number of purchases from customers has an insignificant but negative relationship with time remaining until call. Furthermore, sales to customers and interdealer trades respond equally to the approaching call time. This may be a sign that dealers are transferring the call risk to retail investors and other customers.

Price volatility measure has the expected positive effect on trading activity. The effect

of the price volatility is larger for interdealer trades than customer transactions. Again, given that dealers are one of the most sophisticated market participants who are able to effectively weigh all of the market characteristics, this is not completely surprising. Dealers may be better able to take advantage of price and yield fluctuations through new trades. The effect of the yield volatility is not consistent across different trade types. Yield volatility has a positive effect on interdealer trades, again most likely due to dealer sophistication. However, yield volatility and trading have a significant positive relationship only for interdealer trades. Exploring why this is the case is left for future research. The state unemployment rate has a significant and positive effect on trading activity. These results provide some evidence for portfolio absorption, speculative trading, and call complexity hypotheses. The negative effect of bank qualification on trading activity is consistent across all trades both for callable and non-callable security samples.

4.6 CONCLUSION

This study uses large databases of municipal market issuance and transaction data not availably to the public to explore the drivers of the secondary market trading activity by testing three hypotheses. Findings indicate that as bank-qualified munis age, trading activity declines, since banks have an incentive to buy and hold these securities. The call complexity hypothesis reveals interesting findings as trading activity declines closer to call date. However, interdealer sales and sales to customers increase closer to call date while purchases from customers remain stable. This may be a signal that dealers transfer the call risk to customers by selling off their inventories as the call date approaches. Finally, as past price and yield volatilities increase, trade frequencies tend to increase which may be an indication that traders are trying to take advantage of price and yield fluctuations and any potential arbitrage opportunities.

Policy implications of these findings are multi-faceted. Quick absorption of desirable munis into inactive investor portfolios implies that there may be more demand for

investment-grade munis than what the market currently supplies. This is especially relevant for governments who are able to issue smaller, bank-qualified issues. Issuers may be able to negotiate better borrowing costs if they are aware of market demand and investor preferences. Further, regulators should be aware of market trading behavior and investigate further whether traders are transferring the call risk to retail investors.

CHAPTER 5

CONCLUSION AND POLICY IMPLICATIONS

5.1 CONCLUSION

In a decentralized government like the United States, the responsibility to make capital investments in public projects falls mostly on the shoulders of state and local governments. From a policy perspective, it is important to understand whether state and local governments are getting the full benefits of the federal subsidy through tax-exemption of municipal bonds. Following a brief introduction to the municipal bond market in Chapter 1, Chapter 2 estimates the tax benefits of municipal bonds. The use of the entire bond universe data results in a paired taxable and tax-exempt subsample which provides the necessary precision to account for differences in the underlying idiosyncratic risk and investor preferences. Results of the Random Coefficients Model (RCM) show that implied marginal tax rates are $32 - 34\%$ for general purpose governments, which is consistent with theory. The muni puzzle, the previous finding that interest rates on tax-exempt bonds are too high, disappears under more careful scrutiny. This implies that if the tax-exemption policy is eliminated or even capped, interest costs for municipal governments will increase substantially.

Chapter 3 shows that there is a significant relationship between primary and secondary municipal bond markets. This chapter shows that the secondary municipal bond market contains an additional layer of credit quality information not captured by other lagged metrics such as credit ratings by "The Big Three." A favorable secondary market performance of the issuer's existing debt decreases future cost of borrowing for state and local governments. Results imply that the secondary market price and yield fluctuations may provide a supplemental avenue for gaging the market demand and investor perception of the issuer's creditworthiness in addition to credit ratings. For an issue of $40 million, three basis points reduction in borrowing costs means a $12,000 reduction in interest costs per year. For a frequent issuer which periodically issues long-term bonds, this reduction translates into large savings over the life of each bond. The effect of the secondary market on the primary

market, therefore, should not be ignored.

Chapter 4 uses large databases of municipal market issuance and transaction data not availably to the public to explore the drivers of the secondary market trading activity by testing three hypotheses. Findings indicate that as bank-qualified munis age, trading activity declines, since banks have an incentive to buy and hold these securities. The call complexity hypothesis reveals interesting findings as trading activity declines closer to call date. However, interdealer sales and sales to customers increase closer to call date while purchases from customers remain stable. This may be a signal that dealers transfer the call risk to customers by selling off their inventories as the call date approaches. Finally, as past price and yield volatilities increase, trade frequencies tend to increase which may be an indication that traders are trying to take advantage of price and yield fluctuations and any potential arbitrage opportunities. Policy implications of these findings are multi-faceted. Quick absorption of desirable munis into inactive investor portfolios implies that there may be more demand for investment-grade munis than what the market currently supplies. This is especially relevant for governments who are able to issue smaller, bank-qualified issues. Issuers may be able to negotiate better borrowing costs if they are aware of market demand and investor preferences. Further, regulators should be aware of market trading behavior and investigate further whether traders are transferring the call risk to retail investors.

Appendices

APPENDIX A
CHAPTER 2 APPENDICES

A.1 Matched Sample Descriptives

Table A.1 provides summary statistics for the final matched sample based on the matching criteria described in Section 2.3.1. The average offering yield for taxable municipal securities is 59 basis points higher than the average yield on exempt securities. If we were to apply Equation 2.1 to these mean statistics, this would imply an average implied marginal tax rate of 18% which is much lower than the tax bracket for a typical muni investor. However, a better descriptive statistic is the implied marginal tax rate based on the matched pairs, τ, from Equation 2.1. The matched pairs imply a marginal tax benefit of 20%, on average. However, the range for τ is quite wide and includes negative values! Further, the larger portion of the final matched sample is comprised of special districts. The negative values imply that for these pairs, the offering yields on tax-exempt securities are higher than their taxable counterparts. At its worst, the tax benefit should be zero if coupon rates are the same.

Table A.1: Matched Sample Summary Statistics

	N	Mean	Std	Min	Max
Offering Yield (Exempt)	6,472	2.72	1.31	0.10	8.75
Offering Yield (Tax)	6,472	3.31	1.46	0.15	10.00
τ	6,472	0.20	0.13	-0.44	0.79
Market Yield	6,472	2.40	1.27	0.14	5.33
Coupon (Exempt)	6,472	3.63	1.25	0.00	8.75
Coupon (Tax)	6,472	3.94	1.36	0.00	10.00
Offering Price (Exempt)	6,472	104.31	8.36	6.61	131.72
Offering Price (Tax)	6,472	102.85	7.09	4.51	127.31
Issue Size (Exempt, millions)	6,472	67.00	129.00	0.00	1,190.00
Issue Size (Tax, millions)	6,472	62.20	109.00	0.06	826.00
Maturity Size (Exempt, millions)	6,466	3.16	8.10	0.01	181.00
Maturity Size (Tax, millions)	6,469	3.57	11.70	0.01	300.00
Credit Rating	6,472	8.94	9.45	0.00	21.00
General Obligation Bond	6,472	0.25	0.43	0.00	1.00
Call Option	6,472	0.27	0.44	0.00	1.00
Bank Qualified	6,472	0.00	0.00	0.00	0.00
Insured	6,472	0.23	0.42	0.00	1.00
Sinking fund	6,472	0.04	0.20	0.00	1.00
Time to Maturity	6,472	7.79	5.92	1.00	40.00
Rated	6,472	0.48	0.50	0.00	1.00
New (vs. Refunding)	6,472	0.44	0.50	0.00	1.00

Table A.2: Matched Sample Tabulations

	Frequency	Percent	Cumulative
Premium Bond	3,318	51.27	51.27
Par Bond	2,394	36.99	88.26
Discount Bond	739	11.42	99.68
Zero Coupon Bond	21	0.32	100.00
Negotiated	2,954	45.64	45.64
Competitive	2,428	37.52	83.16
NA	1,090	16.84	100.00
Semiannual	6,391	98.75	98.75
At Maturity	81	1.25	100.00
Total	6,472		

Table A.3: Matched Sample Distribution of Issuer Types

	Frequency	Percent	Cumulative
Special Districts	4,908	75.83	75.83
Cities	701	10.83	86.67
States	331	5.11	91.78
School Districts	224	3.46	95.24
Counties	206	3.18	98.42
Towns/Townships	102	1.58	100.00
Total	6,472	100	

Table A.4: Matched Sample Distribution of Use of Proceeds

	Frequency	Percent	Cumulative
General Purpose	1,618	25.00	25.00
Airports	1,205	18.62	43.62
Single Family Housing	971	15.00	58.62
Multi-Family Housing	651	10.06	68.68
Other Housing	376	5.81	74.49
Water and Sewer	211	3.26	77.75
Primary/Secondary Education	209	3.23	80.98
Higher Education	200	3.09	84.07
Seaports	195	3.01	87.08
Public Power	138	2.13	89.22
Redevelopment	130	2.01	91.22
Single/Multi-Family Housing	129	1.99	93.22
Economic Development	78	1.21	94.42
Solid Waste	58	0.90	95.32
Other Transportation	52	0.80	96.12
Hospital	36	0.56	96.68
Government/ Public Buildings	29	0.45	97.13
Veterans	23	0.36	97.48
Parking Facilities	21	0.32	97.81
Airlines	18	0.28	98.08
Pollution Control	18	0.28	98.36
Other Utilities	16	0.25	98.61
Industrial Development	13	0.20	98.81
Multiple Public Utilities	12	0.19	99.00
Fire Station/Equipment	12	0.19	99.18
Other[1]	53	0.83	100.00
Total	6,472	100	100

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[1]The following categories are condensed into other category due to space limitations: Toll roads, Other Healthcare, Other Recreation, Student Loans, Nursing Homes, Parks/Zoos/Beaches, Retirement centers, Stadiums/Sports Complex, Convention Centers, Gas, Library/Museums, Mass Transit, Other Education.

A.2 Full Unmatched Sample Statistics and Checks

One concern with employing such a strict matching technique as the one used in Chapter 2 may be that the final matched sample is not representative of the full muni universe. Table A.5 provides the summary statistics for the full sample, of which only 5% are taxable. I arrive at this full sample after applying the exclusions used in Section 2.4.2. Table A.6 provides the same statistics for the full taxable sample, and Table A.7 provides the same statistics for the full exempt sample. Table A.8 shows the RCM results for the full sample with all yields (taxable and tax-exempt) as the dependent variable and the taxable dummy as the key covariate.

First, the problem with full sample analysis compared to a matching technique used in this study is that identifying the proper sample weights is not easy. About 95% of the sample is comprised of tax-exempt securities. There are tens of thousands of different issuers and significant heterogeneity in the security characteristics which a taxable dummy cannot completely account for. Second, this setup does not allow us to test the relative yield relationship expressed in Equation ch1eq1 easily. Further, simply including dummy variables in Table A.8 may not fully address the effect of security characteristics on relative yields. Finally, the matched sample has no bank-qualified securities whereas 41% of the unmatched exempt sample is comprised of bank-qualified securities. However, this is mostly driven by the fact that taxable munis are generally not bank-qualified, only 0.3% of the unmatched taxable sample bank-qualified.

Table A.5: Unmatched Sample Summary Statistics

	N	Mean	Std	Min	Max
Offering Yield	1,481,961	3.27	1.23	0.03	14.72
Taxable	1,481,961	0.05	0.21	0.00	1.00
Market Yield	1,481,961	2.95	1.23	0.29	5.99
Coupon Rate	1,481,961	3.86	1.09	0.00	15.00
Offering Price	1,481,961	103.28	5.70	1.25	202.70
Issue size (millions)	1,481,961	47.20	150.38	0.01	12,850.00
Maturity size (millions)	1,472,342	2.51	16.88	0.00	12,850.00
Credit Rating	1,481,961	10.17	9.35	0.00	21.00
General Obligation	1,481,961	0.57	0.49	0.00	1.00
Call Option	1,481,961	0.48	0.50	0.00	1.00
Bank Qualified	1,481,961	0.39	0.49	0.00	1.00
Insured	1,481,961	0.39	0.49	0.00	1.00
Sinking Fund	1,481,961	0.10	0.29	0.00	1.00
Time to maturity	1,481,961	10.22	6.17	2.00	45.00
Rated	1,481,961	0.55	0.50	0.00	1.00
New (vs. Refunding)	1,481,961	0.51	0.50	0.00	1.00

Table A.6: Unmatched Taxable Sample Summary Statistics

	N	Mean	Std	Min	Max
Offering Yield	70,064	3.91	1.47	0.29	14.72
Market Yield	70,064	2.86	1.30	0.29	5.99
Coupon Rate	70,064	4.10	1.42	0.00	14.00
Offering Price	70,064	100.97	3.16	13.72	151.82
Issue size (millions)	70,064	41.56	82.88	0.01	2,260.38
Maturity size (millions)	69,613	3.68	14.08	0.01	1,000.00
Credit Rating	70,064	9.63	9.39	0.00	21.00
General Obligation	70,064	0.29	0.45	0.00	1.00
Call Option	70,064	0.35	0.48	0.00	1.00
Bank Qualified	70,064	0.00	0.06	0.00	1.00
Insured	70,064	0.31	0.46	0.00	1.00
Sinking Fund	70,064	0.18	0.39	0.00	1.00
Time to maturity	70,064	9.84	7.50	2.00	45.00
Rated	70,064	0.52	0.50	0.00	1.00
New (vs. Refunding)	70,064	0.55	0.50	0.00	1.00

Table A.7: Unmatched Exempt Sample Summary Statistics

	N	Mean	Std	Min	Max
Offering Yield	1,411,897	3.24	1.21	0.03	14.00
Market Yield	1,411,897	2.96	1.22	0.29	5.99
Coupon Rate	1,411,897	3.85	1.07	0.00	15.00
Offering Price	1,411,897	103.39	5.77	1.25	202.70
Issue size (millions)	1,411,897	47.48	152.95	0.01	12,850.00
Maturity size (millions)	1,402,729	2.46	17.00	0.00	12,850.00
Credit Rating	1,411,897	10.20	9.35	0.00	21.00
General Obligation	1,411,897	0.59	0.49	0.00	1.00
Call Option	1,411,897	0.48	0.50	0.00	1.00
Bank Qualified	1,411,897	0.41	0.49	0.00	1.00
Insured	1,411,897	0.39	0.49	0.00	1.00
Sinking Fund	1,411,897	0.09	0.29	0.00	1.00
Time to maturity	1,411,897	10.24	6.10	2.00	45.00
Rated	1,411,897	0.55	0.50	0.00	1.00
New (vs. Refunding)	1,411,897	0.51	0.50	0.00	1.00

Table A.8: Unmatched Sample RCM, DV = Yield

Taxable	**1.007 *****	**1.003 *****	**0.155 *****	**0.160 *****
	(0.013)	(0.013)	(0.004)	(0.004)
Issuance-level (std)	**0.661**	**0.516**	**0.013**	**0.014**
	(0.017)	(0.017)	(0.001)	(0.001)
Issuer-level (std)		**0.198**	**0.043**	**0.042**
		0.006	0.001	(0.001)
Offering Price	-0.000 ***	-0.000	-0.002 ***	-0.003 ***
	(0.000)	(0.000)	(0.000)	(0.000)
Coupon Rate	0.310 ***	0.303 ***	0.173 ***	0.176 ***
	(0.001)	(0.001)	(0.000)	(0.000)
Issue Size	0.032 ***	0.032 ***	0.065 ***	0.069 ***
	(0.000)	(0.000)	(0.000)	(0.000)
County				0.014 ***
				(0.001)
State				-0.160 ***
				(0.002)
School District				0.011 ***
				(0.001)
Special District				0.023 ***
				(0.001)
Town/Township				0.040 ***
				(0.001)
Call Option			0.133 ***	0.131 ***
			0.001	(0.001)
Sinking Fund			0.054 ***	0.055 ***
			0.001	(0.001)
Credit Rating			-0.004 ***	-0.004 ***
			0.000	(0.000)
General Obligation			0.021 ***	0.037 ***
			0.001	(0.001)
Insured			0.012 ***	0.004 ***
			0.001	(0.001)
New (vs. Refunding)			0.078 ***	0.080 ***
			0.001	(0.001)
Market Spread (MMA)			0.866 ***	0.859 ***
			0.001	(0.001)
Bank Qualified			0.200 ***	0.197 ***
			0.001	(0.001)
Maturity/Year Effects	YES	YES	YES	YES
Obs (CUSIPs)	1,481,961	1,481,961	1,481,961	1,481,961
Issuances	106,169	106,169	106,169	106,169
Issuers	32,595	32,595	32,595	32,595

APPENDIX B
CHAPTER 3 APPENDICES

B.1 Maturity-level Descriptives and Checks

Table B.1 and Table B.2 show the summary statistics for the competitive and negotiated samples for the variables used in the maturity level analysis. The sample is separated into competitive and negotiated sales to avoid the selection bias concerns regarding the method of sale. Average offering yields are higher but less variable for the negotiated sample than for the competitive sample. However, offering prices are lower and more variable for the negotiated sample than the competitive sample. This may be partially due to the fact that average credit ratings are higher for competitive issues than for negotiated issues. Negotiated issuances also tend to be much larger. The two samples look relatively similar in remaining categories. Table B.6 and Table B.5 show the most frequent issuers for each subsample. New York City is the most frequent issuer for both sale types.

Table B.7 shows the effect of secondary market price fluctuations on the future offering prices. Market prices have a positive effect on offering prices and this effect varies largely by issuers and bond issuances. A one percentage point fluctuation in trade prices of comparable outstanding securities increase future prices by 9 basis point for competitive sales and by 11 basis points for negotiated sales. However, the difference is not statistically significant ($p = 0.18$).

Table B.1: Negotiated Sample Statistics, N= $43,304$

Variable	Mean	Std	Min	Max
Offering Yield	3.07	1.26	0.08	8.00
Offering Price	103.55	13.02	5.34	176.67
Trade Yield Spread$_{t-1}$	-0.89	1.49	-93.38	58.72
Trade Price Spread$_{t-1}$	2.96	8.57	-47.94	85.62
Credit Rating	10.95	9.45	0.00	21.00
Call option	0.37	0.48	0.00	1.00
Bank Qualification	0.18	0.39	0.00	1.00
Maturity Par (in million)	4.96	17.00	0.00	1,200.00
Offering Par (in million)	124.00	307.00	0.04	6,540.00
Market yield (MMA)	2.90	1.21	0.25	5.99
Time to Maturity	9.21	5.74	1.00	39.00
Sale year	2009	3.25	2005	2015
Rated	0.58	0.49	0.00	1.00
Coupon Rate	3.85	1.28	0.00	12.00
Insured	0.35	0.48	0.00	1.00

Table B.2: Competitive Sample Statistics, N= $61,828$

Variable	Mean	Std	Min	Max
Offering Yield	2.54	1.25	0.05	7.89
Offering Price	105.67	8.43	6.68	149.52
Trade Yield Spread$_{t-1}$	-0.97	1.36	-58.37	56.66
Trade Price Spread$_{t-1}$	2.00	6.79	-33.65	87.06
Credit Rating	11.51	9.63	0.00	21.00
Call option	0.36	0.48	0.00	1.00
Bank Qualification	0.23	0.42	0.00	1.00
Maturity Par (in million)	4.29	9.31	0.00	304.00
Offering Par (in million)	84.50	155.00	0.07	1,260.00
Market yield (MMA)	2.52	1.24	0.25	5.71
Time to Maturity	8.41	5.46	1.00	37.00
Sale year	2010	3.18	2005	2015
Rated	0.58	0.49	0.00	1.00
Coupon Rate	3.72	1.14	0.00	9.00
Insured	0.21	0.40	0.00	1.00

Table B.3: Negotiated Sample Distribution of Issuer Types

School Districts	18,511	42.75	42.75
Cities	9,293	21.46	64.21
States	6,068	14.01	78.21
Counties	4,075	9.41	87.63
Special Districts	3,916	9.04	96.67
Towns/Townships	1,441	3.33	100.00
Total	43,304		

Table B.4: Competitive Sample Distribution of Issuer Types

School Districts	17,411	28.16	28.16
Cities	16,044	25.95	54.11
Counties	11,643	18.83	72.94
States	9,069	14.67	87.61
Towns/Townships	4,207	6.80	94.41
Special Districts	3,454	5.59	100.00
Total	61,828		

Table B.5: Negotiated Sample Frequent Issuers

Issuer Name	Frequency	Percent	Cum
NEW YORK N Y	1,548	3.3	3.3
OREGON ST	1,062	2.26	5.56
CALIFORNIA ST	1,049	2.24	7.8
TEXAS ST	821	1.75	9.55
LOS ANGELES CALIF UNI SCH DIST	587	1.25	10.8
CHICAGO ILL	553	1.18	11.98
CONNECTICUT ST	395	0.84	12.82
OHIO ST	390	0.83	13.66
HONOLULU HAWAII CITY & CNTY	378	0.81	14.46
COLUMBUS OHIO	324	0.69	15.15
ALASKA MUN BD BK ALASKA MUN BD BK AUTH	293	0.62	15.78
ILLINOIS ST	291	0.62	16.4
HAWAII ST	250	0.53	16.93
ANCHORAGE ALASKA	246	0.52	17.46
MASSACHUSETTS ST	236	0.5	17.96

Table B.6: Competitive Sample Frequent Issuers

Issuer Name	Frequency	Percent	Cum
NEW YORK N Y	1,644	2.34	2.34
NEVADA ST	745	1.06	3.4
WASHINGTON ST	724	1.03	4.43
MINNESOTA ST	697	0.99	5.42
SOUTH CAROLINA ST	673	0.96	6.38
CONNECTICUT ST	637	0.91	7.28
CALIFORNIA ST	590	0.84	8.12
ANNE ARUNDEL CNTY MD	471	0.67	8.79
PENNSYLVANIA ST	462	0.66	9.45
SAN FRANCISCO CALIF CITY & CNTY	460	0.65	10.11
FLORIDA ST BRD ED PUB ED	445	0.63	10.74
GEORGIA ST	424	0.6	11.34
SUFFOLK CNTY N Y	414	0.59	11.93
KING CNTY WASH	379	0.54	12.47
MASSACHUSETTS ST	373	0.53	13

Table B.7: Random Coefficients Model, DV = Offering Price

	Negotiated Sale	Competitive Sale
Trade Price$_{t-1}$	**0.112 *****	**0.095 *****
	(0.010)	(0.008)
Trade Yield$_{t-1}$	0.023	0.082 ***
	(0.022)	(0.015)
Issuer variation	0.199	0.199
	(0.014)	(0.014)
Issuance Variation	0.366	0.366
	(0.010)	(0.010)
County	0.665 ***	0.227 ***
	(0.111)	(0.053)
State	0.977 ***	-0.007
	(0.109)	(0.064)
School District	0.048	-0.170 ***
	(0.078)	(0.048)
Special District	-0.211 *	-0.690 ***
	(0.111)	(0.080)
Town/Township	0.638 ***	0.000
	(0.161)	(0.074)
Credit Rating	0.013 ***	0.028 ***
	(0.004)	(0.003)
Coupon rate	8.186 ***	5.814 ***
	(0.024)	(0.018)
Call Option	4.407 ***	-0.591 ***
	(0.123)	(0.077)
Bank Qualified	1.242 ***	0.990 ***
	(0.088)	(0.052)
Sinking Fund	3.725 ***	1.064 ***
	(0.162)	(0.121)
Insured	-0.934 ***	-1.122 ***
	(0.069)	(0.048)
Ln(Offering Par)	0.095 ***	0.169 ***
	(0.025)	(0.015)
New (vs. Refunding)	-0.946 ***	-0.276 ***
	(0.060)	(0.036)
Market Yield (MMA)	-4.522 ***	-3.568 ***
	(0.069)	(0.044)
Maturity & Year Effects	YES	YES
Observations	43,304	61,828
Issuers	3,837	4,310
Issuances	8,033	12,010

Notes: ***p< 0.01, **p< 0.05, *p< 0.1. Standard errors in parentheses.

B.2 Series-level Descriptives and Checks

Table B.10 replicates Table 3.4 but with additional maturity level controls. Results remain the same on the previously included variables. Maturity levels are weighted as discussed in the research design section. These covariates have the expected signs. Investors require interest compensation for the call risk, therefore, callable securities are associated with higher borrowing costs. Bank-qualified securities are more attractive to commercial banks who are willing to accept lower returns. Therefore, bank-qualified issues are associated with lower borrowing costs. Higher credit ratings tend to reduce borrowing costs, however, this relationship is not statistically significant. Higher prevailing muni market rates result in higher borrowing costs, TIC. These results are robust to exclusion of recession years, 2008 and 2009 (not shown here, available upon request).

Table B.8: Competitive IPREO Sample Summary

Variable	N	Mean	Std	Min	Max
True Interest Cost (TIC)	6,863	3.18	1.02	0.30	7.44
Trade Yield$_{t-1}$	6,863	-0.06	0.16	-3.43	2.80
Trade Price$_{t-1}$	6,863	0.09	0.85	-14.06	31.74
Market yield (BBI20)	6,863	4.29	0.43	3.36	5.50
ln(Offering Par)	6,863	16.10	1.10	13.24	20.33
ln(Total Debt)	6,863	18.08	1.19	12.25	22.38
ln(Population)	6,863	10.85	1.42	4.30	20.06

Table B.9: IPREO Sample Distribution of Issuer Types

School Districts	2,614	38,09	38.09
Cities	1,897	27.64	65.73
Counties	1,067	15.55	81.28
Towns/Townships	927	13.51	94.79
Special Districts	358	5.22	100.00
Total	6,863	100	

Table B.10: Panel Fixed Effects, Competitive Sales, DV = TIC

	(1)	(2)	(3)	(4)
$TradeYield_{i,t-1}$		1.05***		1.23***
		(0.10)		(0.13)
$TradePrice_{i,t-1}$			-0.02	0.08***
			(0.02)	(0.03)
Weighted Credit rating	-0.01	-0.01	-0.01	-0.02
	(0.02)	(0.02)	(0.02)	(0.02)
Weighted Time to Maturity	-0.18***	-0.09*	-0.17***	-0.10**
	(0.05)	(0.05)	(0.05)	(0.05)
Weighted Insurance	0.25	0.06	0.23	0.11
	(0.29)	(0.27)	(0.29)	(0.26)
Weighted Sinking Fund	2.66***	1.84**	2.58***	2.07***
	(0.81)	(0.79)	(0.80)	(0.76)
Weighted Capital Purpose	0.62**	0.54**	0.61**	0.57**
	(0.30)	(0.27)	(0.30)	(0.27)
Weighted Call Option	4.65***	3.40***	4.55***	3.64***
	(0.97)	(1.00)	(0.98)	(0.95)
Weighted Bank qualification	-2.50***	-2.18***	-2.49***	-2.18***
	(0.35)	(0.32)	(0.35)	(0.34)
ln(Total Debt)	0.11***	0.10***	0.11***	0.11***
	(0.02)	(0.02)	(0.02)	(0.02)
ln(Issue Par)	0.19***	0.17***	0.19***	0.17***
	(0.02)	(0.01)	(0.02)	(0.01)
ln(Population)	-0.02	-0.03	-0.03	-0.02
	(0.04)	(0.04)	(0.04)	(0.04)
Market yield (BBI20)	0.65***	0.59***	0.64***	0.60***
	(0.03)	(0.03)	(0.03)	(0.03)
Constant	1.14***	1.02***	1.14***	1.02***
	(0.04)	(0.04)	(0.04)	(0.04)
Bonds/Series	7,619	7,619	7,619	7,619
R^2	0.74	0.76	0.74	0.76
Issuers	2,787	2,787	2,787	2,787

*Notes: ***p< 0.01, **p< 0.05, *p< 0.1. Standard errors in parentheses, clustered at the issuer level.*

APPENDIX C
CHAPTER 4 APPENDICES

C.1 Descriptives

Table C.1 provides descriptive statistics for the random sample of investment-grade, non-callable, tax-exempt, unlimited general obligation bond CUSIPs. Recall that the unit of observation is CUSIP-years. The breakdown by trade type shows that there are a lot more sales to customers and interdealer trades than purchases from the customers. This makes sense given that most muni holders are buy-and-hold-type investors. The average muni age in the sample is a little over three years and the average time remaining until maturity is 6.6 years. Almost half the outstanding securities are bank-qualified and 41% are insured. Rating of 12 corresponds to the lowest investment-grade rating and the rating of 21 corresponds the highest investment-grade rating. The credit rating scale constructed for this study is the average of all available credit ratings provided by the three major rating agencies, Moody's, Standard & Poors, and Fitch Rating.

Table C.1: Summary Statistics: **Non-callable** Securities

Variable	N	Mean	Std	Min	Max
# of All Trades	127,662	3.81	12.11	0.00	1392
# of Interdealer trades	127,662	1.50	5.04	0.00	392
# of Purchases	127,662	0.84	2.62	0.00	134
# of Sales	127,662	1.48	5.36	0.00	906
Age	127,662	3.21	2.78	0.00	22
Bank Qualified	127,662	0.53	0.50	0.00	1
Time to Maturity	127,662	5.19	2.98	0.00	26
Yield Volatility (All)	127,662	0.04	0.13	0.00	25
Yield Volatility (Dealer)	127,662	0.01	0.06	0.00	13
Yield Volatility (Purchase)	127,662	0.06	0.15	0.00	6
Yield Volatility (Sale)	127,662	0.05	0.13	0.00	5
Price Volatility (All)	127,662	0.16	0.33	0.00	10
Price Volatility (Dealer)	127,662	0.14	0.38	0.00	14
Price Volatility (Purchases)	127,662	0.26	0.64	0.00	12
Price Volatility (Sale)	127,662	0.23	0.50	0.00	9
Unemployment rate	127,478	7.05	2.01	2.60	14
Credit Rating	127,662	18.46	1.39	12.00	21
Coupon Rate	127,662	4.05	1.04	1.00	12

An interesting pattern emerges from the yield and price volatility measures. Dealer trades display the lowest yield and price volatilities on average. This is not surprising given that the dealers are more sophisticated and knowledgeable of the market than the retail investors. Purchases from customers display the highest volatility which may be partially due to the market illiquidity. In periods of high demand, investors and dealers may overpay for the securities to balance their portfolios, for example.

Table C.2: Summary Statistics: **Callable** Securities

Variable	N	Mean	Std	Min	Max
# of All Trades	342,573	4.83	21.25	0.00	3506
# of Interdealer trades	342,573	1.67	7.42	0.00	933
# of Purchases	342,573	1.02	3.87	0.00	533
# of Sales	342,573	2.15	11.36	0.00	2071
Age	342,573	4.96	3.35	0.00	23
Bank Qualified	342,573	0.32	0.46	0.00	1
Time to Maturity	112,831	10.40	4.29	0.04	35
Time to Call (All)	342,573	8.25	4.57	0.00	36
Time to Call (Dealer)	84,313	5.08	2.87	0.00	15
Time to Call (Purchase)	102,441	4.72	2.75	0.00	14
Time to Call (Sale)	110,752	5.06	2.90	0.00	15
Yield Volatility (All)	342,573	0.05	0.16	0.00	23
Yield Volatility (Dealer)	342,573	0.01	0.13	0.00	38
Yield Volatility (Purchase)	342,573	0.07	0.18	0.00	18
Yield Volatility (Sale)	342,573	0.06	0.17	0.00	15
Price Volatility (All)	342,573	0.17	0.35	0.00	18
Price Volatility (Dealer)	342,573	0.14	0.38	0.00	18
Price Volatility (Purchase)	342,573	0.28	0.66	0.00	25
Price Volatility (Sale)	342,573	0.22	0.47	0.00	27
Unemployment rate	341,845	7.06	2.14	2.60	14
Credit Rating	342,573	18.47	1.36	12.00	21
Coupon Rate	342,573	4.62	0.57	1.50	9

Table C.3: **Non-Callable, Unrated** Securities: Random-Effects Tobit, DV= # of Trades per Year per CUSIP

	All Trades	Interdealer	Purchases from Customers	Sales to Customers
Age	0.27 ***	0.09 ***	0.12 ***	0.08 ***
	(0.01)	(0.00)	(0.00)	(0.00)
Time to Maturity	0.36 ***	0.15 ***	0.06 ***	0.19 ***
	(0.01)	(0.00)	(0.00)	(0.00)
Age * Bank-qualified	-0.20 ***	-0.06 ***	-0.09 ***	-0.04 ***
	(0.00)	(0.00)	(0.00)	(0.00)
Yield Volatility	1.93 ***	0.17 ***	0.35 ***	1.04 ***
	(0.04)	(0.04)	(0.01)	(0.04)
Price Volatility	3.96 ***	2.24 ***	0.76 ***	1.15 ***
	(0.03)	(0.01)	(0.00)	(0.01)
Unemployment Rate	0.12 ***	0.06 ***	0.03 ***	0.03 ***
	(0.01)	(0.00)	(0.00)	(0.00)
Year Fixed Effects	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Obs (CUSIP-years)	540,309	540,309	540,309	540,309
# of securities	109,354	109,354	109,354	109,354

***p< 0.01, **p< 0.05, *p< 0.1

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