Tax Advantages and Imperfect Competition in Auctions for Municipal Bonds *

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Abstract

We study the interaction between tax advantages for municipal bonds and the market structure of auctions for these bonds. We show that this interaction can limit a bidder's ability to extract information rents and is a crucial determinant of state and local governments' borrowing costs. Reduced-form estimates show that increasing the tax advantage by 3 pp lowers mean borrowing costs by 9-10%. We estimate a structural auction model to measure markups and to illustrate and quantify how the interaction between tax policy and bidder strategic behavior determines the impact of tax advantages on municipal borrowing costs. We use the estimated model to evaluate the efficiency of Obama and Trump administration policies that limit the tax advantage for municipal bonds. Because reductions in the tax advantage inflate bidder markups and depress competition, the resulting increase in municipal borrowing costs more than offsets the tax savings to the government. Finally, we use the model to analyze a recent non-tax regulation that affects entry into municipal bond auctions.
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1 Introduction

State and local governments finance multi-year expenditures by issuing municipal bonds. In 2017, outstanding municipal debt totaled $3.7 trillion, and annual interest payments of $122 billion surpassed municipal expenditures in other categories such as unemployment insurance, policing, and workers' compensation.[1] To reduce the borrowing costs of state and local governments, municipal bond income is excluded from federal and, in most cases, state taxation. This tax advantage creates a tax *expenditure* for the federal and state governments, which is forecast to cost the federal government alone more than $500 billion over the coming decade, has been rising over time, and is mainly enjoyed by top-income individuals. Not surprisingly, the tax advantage of municipal bonds has been the subject of a controversial policy debate. However, in spite of the more than 120 proposals made since 1918 to eliminate or limit this tax advantage, including in every budget proposal released by the Obama administration from 2012-2016, this favorable treatment within the U.S. tax code has remained largely unchanged.[2]

We contribute to this debate by showing that the interaction of the tax advantages with the structure of the municipal bond issuance market plays a crucial role in determining the effect of these tax advantages on borrowing rates as well as the efficiency of this subsidy. To do so, we analyze a novel dataset on over 14,000 new issuances of municipal bonds sold at auction between 2008 and 2015.[3] In these auctions, underwriters bid for municipal debt and the winning bid determines the issuer's borrowing cost. We exploit within-state changes in taxes over time to show that tax advantages have large effects on the borrowing costs of state and local governments. We further find that auction participation decisions of potential underwriters are also appreciably sensitive to changes in tax advantages.

Our empirical findings motivate us to develop an auction model that clarifies the economic mechanisms in this market. The model allows us to understand the link between the level of competition in the auctions and the effect of the tax advantage on both the strategic decisions of underwriters and the borrowing rates faced by bond issuers. Given the role of imperfect competition in setting borrowing rates, a model with these features is essential to understanding the workings of this market and the effects of relevant government policies. The model quantifies equilibrium markups and yields the valuable insight that the impact of tax policy changes on these markups is a key driver of the overall effect on municipal borrowing costs.[4] We put the model to use by evaluating recent proposals by the Obama and Trump administrations that affect the tax advantage of municipal bonds and by examining the effects of a recently enacted Internal Revenue Service (IRS) regulation of bond auctions with few participants. By highlighting the interactions between taxes and imperfect competition, our results suggest the need for a fundamental reassessment of the mechanism through which tax subsidies reduce borrowing costs and provide new evidence that tax

[1]See SIFMA (2020) for reports and data on the state of the market for municipal bonds and U.S. Census Bureau (2020) for state and local government expenditures.

[2]See U.S. Treasury (2016) for a fiscal year 2017 forecast of the cost of tax expenditures. See Zweig (2011), Tax Policy Center (2015), and Greenberg (2016) for a summary of the debate surrounding tax advantages of municipal bonds.

[3]Auctions make up an important part of the municipal bond issuance market. Roughly half the municipal bonds issued in any year are sold to underwriters via auctions, in which underwriters submit bids in the form of the interest rate they are willing to charge an issuer, with the low bidder winning and the issuer paying the winner's bid (interest rate). The other half are mainly sold through negotiations. See Section 2 for details. We concentrate on the auction side of the municipal bond market as the well-defined nature of the auctions enables us to more cleanly analyze how market structure and tax policy interface with one another to determine the borrowing costs of state and local governments.

[4]The markup is the difference between the lowest acceptable interest rate and the bid.

subsidies may be more efficient at subsidizing local borrowing costs than previously thought.

We begin our analysis by providing reduced-form evidence that a 1 percentage-point (pp) increase in the personal income tax subsidy, or what we term the effective rate, leads to a decrease in borrowing costs of 6.5-7 basis points. Given the mean borrowing rate is 2.14%, a 3 pp increase in the effective rate would reduce borrowing costs by 9-10%. Our results imply a passthrough elasticity of the borrowing rate to the tax advantage of 1.7-1.9.[5] We also find that changes in the effective rate have sizable effects on the competitiveness of these auctions. Specifically, a 4 pp increase in the tax advantage adds 2 additional underwriters to the set of potential bidders who can potentially participate in the auction.[6]

The causal interpretation of these results relies on the identifying assumption that changes in the effective rate are not driven by other factors that may spuriously correlate with borrowing costs. This assumption is supported by several facts. First, interactions between federal and state tax policy yield additional cross-sectional variation in effective rates when federal taxes change. Second, the vast majority of the auctions are held by sub-state municipalities that have no influence over the effective rate. Finally, this result is robust to controlling for a number of potential confounders including determinants of borrowing rates and economic conditions of the municipal bond market. Our most demanding specification identifies this effect using repeated bond auctions by the same issuer (municipality) in time periods with different (federal and state) tax rates, which greatly limits concerns that our results are driven by omitted factors that may be correlated with both tax changes and borrowing costs.

To better understand the economic mechanisms behind this reduced-form result, we estimate an empirical auction model in the spirit of Li and Zheng (2009) that accounts for the effect of the tax advantage on the distribution of bidders' values for the bonds, as well as on their decision to participate in an auction.[7] Owing to the imperfectly competitive nature of the setting, auction participants in this model submit bids larger than the lowest interest rate they would be willing to accept for the bond. The model recovers the latent distribution of bidders' willingness to pay for bonds and quantifies the equilibrium markups enjoyed by bidders. Our model implies that the average markup is 17 basis points, or about 21% of borrowing costs, and that state issuers enjoy smaller markups than do cities, counties, or school districts.

The model helps us understand the relationship between bidder markups and the tax advantage. In imperfectly competitive auctions, one way that changes in taxes can have large impacts on borrowing costs is through their effect on equilibrium markups. An increase in the tax advantage leads bidders to decrease their bid and further lowers the equilibrium borrowing rate as other participants respond to this incentive by lowering their bids. We show that these forces affect equilibrium markups and are one reason that we find greater-than-unity passthrough elasticities on borrowing costs.[8] As foreshadowed by the reduced-form results, our approach also highlights the importance of accounting for the participation margin. The

[5] A 3 pp increase in the effective tax rate is less than a 1 standard deviation increase, and is equivalent to moving from the 50th percentile to the 75th percentile as shown in Table A.1. The ratio between yields on a taxable and tax-exempt asset is $(1-\tau)$, where τ is the effective rate. For this reason, we calculate elasticities with respect to the net-of-tax rate. Given an average τ of 40.87%, a 3 pp increase—which leads to a 9% decline in borrowing costs—implies an increase in the tax advantage of 5%. This calculation yields a passthrough elasticity at the mean of $1.8(\approx \frac{9\%}{5\%})$. Appendix C.10 provides additional details, including tax and net-of-tax elasticities for each state.

[6] In Section 3.2, we show that this result is robust to using different definitions of potential bidders.

[7] In Section 3.4, we demonstrate that there is no supply-side response to the change in the tax advantage. Based on this evidence, our model focuses on the strategic behavior of underwriters in a given auction.

[8] In addition to exploring these effects through the lens of our model, we also provide non-parametric evidence that this mechanism is at play in the data.

model shows how additional competitive pressure from the extra participants reduces bidder markups and increases the magnitude of the passthrough elasticities.

Finally, we use the model estimates to evaluate the effects of a range of policies directly or indirectly affecting the tax advantage of municipal bonds. The first set of policies includes a number of potential reforms that affect the effective tax rate, including (i) increasing or decreasing the size of the federal exemption, (ii) eliminating the state exemption altogether, and (iii) limiting the federal state and local tax (SALT) deduction in concordance with the Tax Cuts and Jobs Act of 2017 (TCJA17). We find that capping the excludability of municipal bond interest income at 37%, as proposed by the Trump administration, would increase the average borrowing rate by 5% and markups by 15% and that states with fewer bidders and lower state taxes would be more affected by this policy. Removing the excludability of municipal bond interest income from state taxation would increase borrowing costs by 23% and markups by 70%. Limiting the SALT deduction would *increase* the tax advantage of municipal bonds at the federal level, and we predict that this tax change would lead state and local government borrowing costs to fall by over 6%. Combined with personal income tax cuts in the TCJA17, which would otherwise increase borrowing costs, we predict that the net effect of the recent Trump tax cuts will be a decrease in borrowing costs of 1.7%. These simulations show that state and federal tax policies can have significant impacts on the borrowing costs of state and local governments. We then assess the effectiveness of the federal subsidy, and find that the increased borrowing costs from reducing tax advantages are 3.2 times as large as the reduction in the cost of the tax expenditure. The effects of tax advantages on auction competitiveness and equilibrium markups are key to this cost-effectiveness calculation, as removing these impacts lowers this relative cost number to 1.21. This suggests that, while this tax advantage is mostly enjoyed by top-income individuals, its effect on the market structure of municipal bond offerings makes it a cost-effective way to lower the borrowing rates used to finance public goods.

The second policy we study is a 2017 IRS regulation that determines the maximum tax-exempt yield in auctions with fewer than three participants (Internal Revenue Service, 2016). We model this policy as a reduction in the tax shield offered by bonds sold at such low-participation auctions. To understand the impact of this policy, it is crucial to characterize participation decisions and bidding strategies of potential bidders. Because the number of participants is unknown when underwriters place bids, the rule leads bidders that value bonds at a high interest rate—and that are more likely to win in low-participation auctions—to further inflate their bids. We find that this IRS rule creates a meaningful distortion in bidding strategies, significantly inflating the markups of underwriters with large latent valuations for the bonds. In most auctions, this distortion is mitigated by overall high levels of participation since underwriters with distorted markups rarely win the auctions. Nonetheless, for auctions where the rule is likely to bind, the regulation can lead to a significant increase in municipal borrowing costs, showcasing how this seemingly well-intentioned policy can distort bidding behavior and increase borrowing costs.

This paper contributes to several literatures. First, we contribute to the growing literature studying market power in important and policy-relevant financial markets (e.g., Hortaçsu et al., 2018; Kang and Puller, 2008). This work demonstrates that large financial markets are characterized by imperfect competition and informational asymmetries and that even in markets for highly liquid assets, such as U.S. treasury bills, auction winners may enjoy positive markups. Like previous studies, we too use methods from the empirical auction literature to study market power in a key financial market. Our paper is set apart from this literature not only by its focus on municipal bonds (e.g., Tang, 2011) but additionally, and perhaps more importantly, by its concentration on the interaction between tax policy and market structure, including bidders' endogenous participation decisions.[9] Recent work has shown the importance of allowing for endogenous participation in auctions (e.g., Li and Zheng, 2009) for a variety of mechanism design and policy-related questions in both theoretical and empirical settings.[10] This paper contributes further evidence to this literature by showing that endogenous participation influences the effect of taxes on municipal borrowing costs.

Second, we contribute to the literature on municipal bonds, which is important for three reasons. First, interest payments on municipal bonds are a significant component of state and local governments' budgets. Second, the borrowing rate for specific projects (such as schools, airports, museums) directly determines the scale of public good provision. The rationale for the tax advantage of municipal bonds is that local governments may not internalize the value of public goods for the residents of nearby locations. By lowering borrowing costs, the tax advantage may partially solve this problem.[11] While most of this literature focuses on arbitrage of existing issues of municipal bonds, our paper focuses on the primary market and particularly on the impact of municipal bonds' tax advantage on local government borrowing costs.[12] Third, from the point of view of federal and state governments, the tax advantages of municipal bond interest represent a large tax expenditure; the federal government alone is forecast to face more than $500 billion in forgone revenue over the next 10 years. Critics of the tax-excludability of interest from municipal bonds argue that it allows top-income earners to lower their effective tax rates. Indeed, the push to cap the excludability was part of a broader campaign during the Obama administration to close "loopholes" for top earners that allowed them to avoid paying higher marginal taxes (Walsh, 2012). It is thus a first-order concern to understand whether this expenditure serves a public purpose and whether it is efficient in reducing borrowing costs, with the current conventional wisdom holding that it is not.[13]

[9] Tang (2011) and Shneyerov (2006) study municipal bond auctions for the purposes of non-parametrically analyzing the revenue implications of alternative mechanism designs. Brancaccio et al. (2017) examines municipal bond trading on secondary markets and quantifies experimentation by traders in this relatively opaque market. None of these papers study the tax incentives associated with such bonds.

[10] See, for example, Sogo et al. (2016) or Roberts and Sweeting (2013).

[11] See Saez (2004) for a broader rationale for tax expenditures. Gordon (1983) provides a model of fiscal federalism where subsidies for public goods ameliorate the under-provision of public goods. Adelino et al. (2017) show that exogenous changes in borrowing rates lead to additional spending by local governments. Cellini et al. (2010) show that investments in school facilities through bond measures in California raise home prices by more than the cost of the bond, suggesting an under-provision of bond-financed public goods.

[12] A prominent strand of literature compares tax-exempt municipal bonds to bonds with different tax treatments (e.g., Poterba, 1986; Feenberg and Poterba, 1991; Green, 1993; Schultz, 2012; Ang et al., 2010b; Cestau et al., 2013; Liu and Denison, 2014; Kueng, 2014). While previous papers address important interactions between tax advantages and the behavior of financial markets, they do not directly measure the passthrough of tax advantages to the borrowing costs of state and local governments, with the exception of Kidwell et al. (1984), which examines how preferential tax treatment of within-state bond income lowers in-state bond yields. Relative to existing methods, our approach obviates the need to select a comparable taxable security, allows us to decompose borrowing costs into values and markups, and, by focusing on the primary instead of secondary market, directly ties the statutory tax rate to municipal outcomes. Nonetheless, the existence of markups in our analysis is consistent with results in Green et al. (2007) showing that broker-dealers benefit from the losses of uninformed investors in secondary markets.

[13] Liu and Denison (2014) discuss potential rents that might be obtained by high-income individuals from the municipal bond exemption. Some highlights of this literature include Poterba (1989, 1986) as well as more recent papers that compare expenditures between tax-exempt bonds and Build America Bonds (Cestau et al., 2013; Ang et al., 2010a). We focus directly on the efficacy of the tax exemption instead of on other mechanisms that may also lower municipal borrowing costs. Our paper is also related to papers that study the implications of removing the tax subsidy for municipal debt for individual portfolio

Finally, we contribute to the literature focused on the importance of competition for auction outcomes. Despite the conventional wisdom in the literature that the level of competition is more important than many parameters of auction design for maximizing sellers' revenues, or in this case minimizing borrowing costs, there are few real-world examples of policies designed to promote more competition in auctions.[14,15] In contrast, our paper analyzes a real-world policy that subsidizes the value of the auctioned good, which affects the set of all potential bidders as well as their entry and bidding decisions. In our study of the role that imperfect competition plays in dictating passthrough, our paper complements other work investigating related questions in different settings like electricity or import markets.[16] Subsidizing good valuations may be justified in other markets from a social welfare perspective and may be particularly important for the efficient provision of public goods.

The rest of the paper is organized as follows. We describe the institutional context and our data in Section 2. Section 3 describes reduced-form relationships between tax advantages, borrowing costs, and imperfect competition in auctions for municipal bonds. In Section 4, we develop an auction model for municipal debt with tax advantages. Section 5 describes the estimation procedure and results of this model. Section 6 explores the mechanisms through which taxes influence municipal borrowing costs. We simulate the effects of changing effective tax rates in Section 7.1 and of policies that interact with auction participation in Section 7.2. Section 8 concludes.

2 Institutional Details on Municipal Bond Auctions, Tax Advantages, and Data

In the U.S., municipal bonds are issued by state and local governments to fund various public projects including the construction of schools, highway repairs, and capital improvements to water and sewage facilities. These bonds are usually bought by underwriters, who subsequently resell them on the secondary market to final consumers. The primary issuance market is comparable in size with the world's largest equity markets, with total outstanding debt currently surpassing \$3.7 trillion and about \$425 billion worth of bonds having been issued in 2019 alone (SIFMA, 2020). The secondary market for municipal bonds is characterized by low liquidity; often, purchasers in this market do not trade the bonds again.

substitution (Feenberg and Poterba, 1991; Poterba and Verdugo, 2011) and for changes in municipal spending (Gordon and Slemrod, 1983; Galper et al., 2014).

[14] See, for example, the influential arguments in Klemperer (2002) or Bulow and Klemperer (1996). It is worth noting that avoiding bidder collusion could be just as important, if not more so. As we are not aware of any claims regarding collusion in these municipal bond auctions, our focus is more on the role that tax policy plays in determining the number of potential and actual bidders, as well as their submitted markups.

[15] Key exceptions are bidder subsidies and training programs, some of which have been studied in the existing literature. Some examples include Bhattacharya (2017), De Silva et al. (2017), Athey et al. (2013), and Krasnokutskaya and Seim (2011). However, these subsidies are generally targeted at small or minority-owned bidders and thus may be driven more by a desire to spread resources across a wider variety of firms than by hopes of increasing revenues or decreasing procurement costs. Moreover, these subsidies usually take the form of prioritizing a particular class of bidders' bids to treat them favorably relative to a non-subsidized bidder as opposed to directly subsidizing the value of the auctioned good.

[16] Fabra and Reguant (2014) analyze how emission costs pass through to electricity prices, and Goldberg and Hellerstein (2008) study how changes in exchange rates pass through to import prices.

2.1 Issuance of Municipal Debt through Auctions

There are three ways in which municipal bonds are issued: through negotiations, competitive auctions, or private placements. Approximately 50% of bond issuances are sold via auction. When holding an auction, the issuer first designs the bonds and puts up a notice of sale, and then participants place bids.[17] In practice, municipalities often sell a series of bonds in a single batch, and potential underwriters compete for the whole series at the same time by placing true interest cost bids. These interest costs correspond to the interest rate that they are willing to charge the municipality. The auctions are run as first-price sealed-bid auctions, with the lowest bidder winning and being paid its bid. When bidders submit their bids, they do not observe the number of other bidders or competing bids.[18]

2.2 Tax Advantages of Municipal Debt

Interest income from most municipal debt is exempt from both federal corporate tax and federal personal income tax, as well as from many state-level taxes. The Revenue Act of 1913, which established a federal income tax in the U.S., explicitly stated that interest paid on state and local government debt could not be taxed by the federal government. This exemption was largely unchanged until the Tax Reform Act of 1986 limited the use of municipal debt to fund non-municipal projects—so-called private activity bonds.[19]

The focus of this paper is on personal income taxes, which we refer to as $\tau_{s,t}$ for each state-year, but we include controls for corporate tax rates in the empirical analysis.[20] The effective tax advantage in state s at time t depends on interactions between state and federal taxes and is given by:

$$\tau_{s,t} = \tau_t^{Federal}(1 - \tau_{s,t}^{State}) + \tau_{s,t}^{State} \times \mathbb{1}[Tax\ \ Exempt]_{s,t}^{State}. \tag{1}$$

First, income from municipal bonds is exempt from personal income taxes at the federal level, $\tau_t^{Federal}$, which shows up as the first term in Equation (1). The federal personal income tax allows for the deduction of state income taxes paid in the last year, as reflected by the factor $(1 - \tau_{s,t}^{State})$ in the equation above, so the marginal federal income tax rate can be higher in states that do not have a personal income tax. Second, most states that collect a personal income tax, $\tau_{s,t}^{State}$, exempt interest earned from municipal bonds sold within their borders and tax earnings from out-of-state municipal bonds. Of the 43 states that levy a personal income tax, only five tax interest from municipal bonds sold by municipalities within the state. However, none of the states with a personal income tax exempt interest from municipal bonds sourced from

[17]When the issuer designs the bonds, it chooses, among other things, par amounts, coupon rates, maturity dates, and refunding opportunities. Refunding is when a bond is issued to make payments on an existing issue.

[18]In negotiated sales, the issuer finds a willing underwriter and together they discuss the conditions of the sale and design of the bonds. Private placements involve selling bonds directly to final consumers. In Appendix C.6, we show that the mechanism used to sell bonds is not affected by changes in tax advantages. We also show that we obtain similar estimates of the effects of tax advantages on borrowing costs in states with the strongest restrictions on the use of negotiated sales.

[19]See Fortune (1991) for more information on specifics about the history of private activity bonds and the history of municipal bonds more generally. Today, municipalities can still sell private activity bonds, but the returns to bond owners can be taxable in certain circumstances. Private activity bonds are generally sold as revenue bonds, which are paid back using income associated with the project that the bond finances but without the backing of the full faith and credit of the municipality.

[20]Almost all of the tax subsidies for municipal bonds stem from the exclusion of municipal bond interest from personal income taxation. Most municipal bonds, particularly the relatively large issues of greater than $5 million in principal that we focus on in this paper, are subject to corporate taxation. So-called bank-qualified bonds can have preferential corporate tax treatment when owned by commercial banks in addition to interest exempt from personal income taxation, but such issues are restricted to issuers who issue no more than $10 million in bonds outside of 2009-10. Given such restrictions, bank-qualified bonds only constitute 14.9% of the total debt issued in our sample.

other states. The tax benefit given to municipal bonds by states is the second term, in which state tax rates are multiplied by an indicator for whether municipal bond income is considered tax-exempt by the state.[21]

Equation 1 contains two major sources of variation that we use to identify how tax rates affect borrowing costs for municipal debt. First, the effective tax rate depends on state tax rates and on whether states exclude interest income from taxation. From 2008 to 2015, many states increased their top marginal rates by introducing a new tax bracket with higher marginal rates for top incomes.[22] In addition, several states cut the top state income tax between 2011 and 2013. Second, when federal rates change, as with the sunsetting of the Bush tax cuts in 2012, states with relatively higher tax rates will have marginally smaller changes in overall effective tax rates than states with no or low income taxes. This large variation in federal rates arose at the end of 2012, when the federal top marginal rate increased from 35% to 39.6%. Overall, this time period presents significant variation in both state and federal tax rates. This allows our identification to be driven by within-state changes in the effective rate, avoiding cross-sectional comparisons of states with different tax rates. Our analysis exploits changes in both state and federal taxes as sources of variation, and we also show that our main result is robust to relying only on tax changes at the state level. Finally, it is worth noting that most of the issuers in our data are sub-state municipalities that cannot directly influence state or federal tax rates.

As noted in the introduction, the favorable tax treatment of municipal bonds has been a controversial policy issue for several years. Indeed, in the past few years there has been continued interest in changing the tax status of these bonds. For example, the Simpson-Bowles Commission on Fiscal Responsibility and Reform of 2010 sought, but failed, to eliminate the tax exemption on all interest from new municipal bonds. Afterwards, in each of its last four years, the Obama administration proposed, but did not achieve, a reduction in the tax advantage that these bonds receive. However, state treasurers warn that eliminating or capping the exemption would "hurt taxpayers in every state, because municipalities will have to either curtail infrastructure projects or raise taxes on sales, property or income" (Ackerman, 2016). The TCJA17 included policy changes that may increase the tax advantage of municipal bonds (by limiting the SALT deduction)[23] as well as measures that would decrease the tax advantage (by cutting top personal income tax rates). We discuss proposed reforms in more detail in Appendix G, and we simulate the effects of some of these proposals in Section 7.1.

[21] Some states allow exemptions for federal income taxes. Currently, eight states allow federal taxes to be deducted from state taxable income, but three of those have a cap on the deduction. This formula abstracts away from the possibility of state deduction of federal taxes for simplicity. Our empirical analysis incorporates the effects of these policies.

[22] Specifically, California, Connecticut, Hawaii, New York, New Jersey, North Carolina, Maryland, Oregon, and Wisconsin increased the top personal tax rate between 2008 and 2009. Some of these new top marginal rates represent economically large rate increases such as an additional 3% surtax on income over \$150,000 in North Carolina and a 2.75% marginal rate increase on income over \$200,000 in Hawaii.

[23] Limiting SALT deductions raises tax rates by limiting the ability of high-income individuals to deduct state and local taxes paid from federal taxable income on the margin. If such individuals are able to deduct all state taxes paid from federal income, they are only taxed on the remainder, or one minus the state tax rate, which lowers the effective rate. SALT is shown in the first term of Equation 1, where federal personal income tax rates are multiplied by the remainder after state taxes paid are taken out. Eliminating SALT gets rid of the $(1 - \tau_{s,t}^{State})$ term, which is weakly less than 1, so effective tax rates increase.

2.3 Data

Data on bond auctions come from two sources. The first source is *The Bond Buyer*, the leading news resource of the industry, which posts notices of upcoming sales as well as results of past sales. We obtain data on all competitive bond sales as well as all bids submitted in each auction from this source. We supplement these data with information from the SDC Platinum database, which includes detailed bond characteristics such as refund status, funding source, and rating.

Our analysis focuses on issuances of general obligation bonds, which are not associated with a particular revenue source, that were issued between February 2008 and December 2015. Complete details of the sample construction are given in Appendix B.[24] Our final sample includes 14,631 auctions for tax-exempt bonds. For each auction that takes place in the sample, we observe the winning bid and up to the next 15 lowest bids, as well as the name of each bidder. The bids vary greatly across auctions, with a mean winning bid of 213.9 basis points and a standard deviation of 135.5 basis points. However, the variation in bids within auctions with more than one bidder is much smaller than the variation between auctions, as the mean standard deviation of bids within an auction is only 24.8 basis points. The observed number of bidders falls in the range of 1 to 16, and 50% of auctions in the sample have between 4 and 7 bidders.

The data contain bonds from all fifty states. While more than half of the bond issuances come from five states (Massachusetts, Minnesota, New Jersey, New York, and Texas), the dollar value of the bonds is more spread out, with half of the value coming from eight states (California, Florida, Maryland, Massachusetts, New Jersey, New York, Texas, and Washington). There is also considerable variation in the average winning bid by state with some no-income-tax states, like Texas, Washington, and Nevada, featuring higher borrowing costs.

The data contain substantial detail regarding the auction participants, including the names of the firms that submit bids in an auction. In addition to the number of actual bidders, which we denote as n, we construct a measure of the set of bidders who potentially could have bid but did not.[25] We define the number of potential bidders in a given auction as the number of actual bidders in the auction plus the number of other, unique bidders who bid in similar auctions held during the same month and in the same state. Specifically, for each auction j in a given state-month combination G, the number of potential bidders

[24]Note that we focus exclusively on federally tax-exempt bonds, which are not subject to the alternative minimum tax (AMT). In particular, we exclude private activity bonds, which may be subject to the AMT. Our sample does not include municipal debt issued as auction rate securities, as these types of bonds were not issued during our sample period. We exclude small issuances, as these bonds are overwhelmingly very short term and are commonly issued for the purpose of refunding as opposed to supporting public improvement projects, and focus on bonds larger than $5 million, which make up over 90% of all the debt issued through competitive placements. As we discuss below, our results are robust to size-weighted specifications that include all bonds issued through competitive placement. Table A.1 provides summary statistics and Figure A.1 plots the geographic distribution of key variables.

[25]In the literature, there is typically no direct measure of the number of potential bidders, and such measures are constructed in a variety of ways. In procurement contexts, the set of potential bidders is often set to be those firms holding plans for the job for which the procurement is being conducted (e.g., Krasnokutskaya and Seim, 2011; Li and Zheng, 2009; Bhattacharya et al., 2014). In other contexts, the set of potential bidders is defined as firms bidding in "similar" auctions, which is the spirit of how we define potential bidders. For example, in Roberts and Sweeting (2016) and Athey et al. (2011), the set of potential bidders in a timber auction is those bidders who bid in the auction plus those bidders who bid in nearby auctions within a relatively short amount of time.

N_j is defined as follows:

$$N_j = n_j + \frac{\sum_{i \in G} \sum_{a \in i} \mathbb{1}(a \text{ not in } j) K\left(\frac{S_i - S_j}{h_S}\right) K\left(\frac{M_i - M_j}{h_M}\right)}{\sum_{i \in G} K\left(\frac{S_i - S_j}{h_S}\right) K\left(\frac{M_i - M_j}{h_M}\right)},$$

where i iterates over auctions in G and a iterates over agents in auction i. The second summand represents the probability that agent a, who did not participate in j, was a potential bidder in j, based on how much auctions in which a participated differ from j. The function $K\left(\frac{X_i - X_j}{h_X}\right)$ measures similarity between auctions i and j based on their observable characteristics. Note that, since the right-hand side of this equation conditions on state and month of the issuance, our definition effectively controls for all state-month level observables. In practice, we use a triweight kernel for $K(\cdot)$, observables we control for include size S and maturity M of the bonds, and we round up to the nearest integer.[26] While this measure of potential bidders is in line with the current literature, we also explore an alternative definition in Appendix C.3 that includes all bidders in auctions held in the same state and month as observed bidders.[27]

The primary tax policy of interest in this study is the top marginal personal income tax rate. To measure state and federal personal income tax rates, we use data from the NBER TAXSIM on maximum personal state income tax rates (Feenberg and Coutts, 1993).[28] We construct the effective tax advantage for municipal bonds in Equation 1 by combining the marginal state and federal rates from TAXSIM with state-level determinants of the personal income tax base from State Tax Handbooks (CCH, 2015). We use indicators for the state exemption of income from municipal bonds sold in a given state, the exemption of income from municipal bonds sold in other states, and the deductibility of federal taxes from state income taxation.

The average rate in our period of analysis is 40.1%, and the difference between the 5th and the 95th percentiles of the distribution is 12 pp. For 2008, for example, τ ranges from 32.99% in Wisconsin, where municipal bond income is not exempt from state taxes, to 42.45% in California, where municipal bond income is exempt and where state taxes are relatively high. Our period of study contains a significant number of policy changes that drive within-state variation in the tax advantage. Between 2008 and 2015, most states experienced an increase in the effective rate and this increase varied between 3.7 pp and 7 pp. Our analysis leverages this variation to identify the effects of the tax advantage on auctions for municipal bonds.

We also gather information about other state characteristics and policies that could influence the yield on municipal debt. The National Association of State Budget Officers (2015) provides an annual report

[26]Throughout the paper, we follow others in the auction literature, e.g., Li et al. (2000), by using the triweight kernel $K(u/h) = 35/32(1-[u/h]^2)^3 \mathbb{1}(|u/h| \leq 1)$, where h is the bandwidth. For a given variable X, we set the bandwidth $h_X = std(X)$, where $std(X)$ is set to the maximum of standard deviations of X across all state-month groups in our data. We obtain similar measures of potential bidders N when using alternative kernels (e.g., Epanechnikov), and we show that our results are robust to an alternative definition of potential bidders that does not rely on the use of kernels in Appendix C.3.

[27]Arguably, our definition of potential bidders represents an advance over similar methods. For example, in Roberts and Sweeting (2016) and Athey et al. (2011), who look at timber auctions, the similarity of the timber tracts sold is only indirectly controlled for by geographic proximity of recent sales.

[28]The exact number computed by the NBER is the simulated marginal tax rate, reported under the title "wages," on an additional \$1,000 of income on top of a base income of \$1,500,000 for a married couple filing jointly with several other deductions. These simulated tax rates closely approximate the tax rates for top earners, who represent the bulk of individuals investing in tax-exempt municipal bonds. We also calculate marginal tax rates at the 90th percentile of household income using TAXSIM and use them in a robustness check.

detailing state-level fiscal policies including balanced budget amendments and taxation and expenditure limitations. We use political party strength data from Caesar and Saldin (2006) as well as data on state sales tax rates, corporate tax rates and rules, and property tax rates gathered by Suárez Serrato and Zidar (2016). We collect data on overall financial market outcomes including the average short-term yield on high-quality, variable rate municipal debt from SIFMA (2020) and 1-year London Inter Bank Offering Rate (LIBOR) swap rates from Board of Governors of the Federal Reserve System (2018) to control for daily market conditions and perceptions of interest rate risk.

3 Reduced-Form Effects of Tax Rates on Borrowing Costs and Imperfect Competition

This section leverages the state-by-year variation in the tax advantages for municipal bonds to estimate the causal effects of tax rates on borrowing costs and imperfect competition. Section 3.1 presents our main estimates of the effects of taxes on borrowing costs. Section 3.2 discusses how taxes influence auction competitiveness and how this affects borrowing costs for state and local governments. We explore the robustness of these results in Section 3.3, where we use a variety of methods to argue that our estimated effects are not driven by spurious factors and can therefore be interpreted as causal. Finally, Section 3.4 shows that tax advantages do not affect the supply of bonds or important bond characteristics.

3.1 The Effect of Tax Advantages on Borrowing Costs

We start by estimating regressions of the form:

$$b_{1ist} = \beta\tau_{st} + \alpha_s + \eta_t + X_{ist}\Gamma + \varepsilon_{ist}, \tag{2}$$

where the borrowing cost of the municipality is determined by the lowest bid in the auction, b_{1i}. Our baseline specification includes state and year fixed effects, and X_{ist} includes measures of bond quality (including the refund status and credit rating) as well as fixed effects for the maturity of the bond. The coefficient β measures the degree to which higher tax advantages of municipal bonds are passed through to lower borrowing costs for municipalities. Recall from Section 2.3 that the effective rate is determined by both state and federal policies. The identifying variation for Equation 2 is then driven both by state changes in personal tax rates and by the interaction of federal changes in personal income tax rates with state-level policies.

Column (1) in the first panel of Table 1 reports the results of this regression and shows that increasing the effective rate by 1 pp leads to a decrease in the borrowing cost of 6.5 basis points. We reject the hypothesis of a null effect with a p-value of 0.010. The exogeneity assumption behind Equation 2 is that the effective rate is independent of other factors that may also affect the borrowing costs of municipalities. Columns (2)-(5) explore the plausibility of this assumption by controlling for potential confounders. Column (2) controls for measures of political climate in the state to assuage the concern that state tax changes are the result of changes in political conditions that may have broader implications for borrowing costs. We use data from Caesar and Saldin (2006) and include the fraction of state-level votes for the Republican candidate in the most recent presidential, gubernatorial, and Senate elections. Columns (3) and (4) control for personal tax base policies, corporate tax rate and base policies, property tax rates, and state sales tax

Table 1: Reduced-Form Effects of the Effective Rate on the Winning Bid and Number of Potential Bidders

	(1)	(2)	(3)	(4)	(5)
Unconditional Effect of Effective Rate on Bid					
Effective Rate	-6.531	-6.994	-6.819	-6.813	-6.806
	(2.527)	(2.349)	(2.273)	(2.248)	(2.244)
	0.010	0.003	0.003	0.003	0.003
Effect of Effective Rate on *N*					
Effective Rate	0.584	0.574	0.558	0.557	0.546
	(0.124)	(0.128)	(0.138)	(0.138)	(0.140)
	0.000	0.000	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid					
Effective Rate	-4.489	-5.034	-5.069	-5.066	-5.189
	(2.517)	(2.362)	(2.312)	(2.282)	(2.281)
	0.075	0.034	0.029	0.027	0.023
Observations	14,631	14,631	14,631	14,631	14,631
Median Bid	221.2	221.2	221.2	221.2	221.2
Median Effective Rate	40.79	40.79	40.79	40.79	40.79
Elasticity (Median)	1.748	1.872	1.825	1.824	1.822
	(0.677)	(0.629)	(0.609)	(0.602)	(0.601)
	0.010	0.003	0.003	0.002	0.002
Year Fixed Effects	Y	Y	Y	Y	Y
State Fixed Effects	Y	Y	Y	Y	Y
Maturity, Quality, and Refund Controls	Y	Y	Y	Y	Y
Political Party Controls		Y	Y	Y	Y
Personal, Business, and Prop. Tax Controls			Y	Y	Y
Sales Tax Controls				Y	Y
Size of Bond Package Controls					Y

Notes: This table reports regression estimates of the effect of effective marginal tax rates, in percentage points, on the winning bids, in basis points, in municipal bond auctions between 2008 and 2015. See Section 3 for further details and Appendix A for a discussion of the data. Additional robustness checks are discussed in Appendix C, while more specifications building from this table are presented in Table 2, with other measurement approaches shown in Table A.10. The first panel showcases estimates of the effect of effective marginal tax rates on the winning bid without controls for the effect of competition. The second panel shows the effect that effective tax rates have on the number of potential bidders. Results with flexible controls for competition through the number of bidders and the number of potential bidders are shown in the third panel. All specifications include fixed effects for the state and year as well as controls for maturity, credit rating, and refund status. Political party controls include the proportion of votes cast for the Republican candidate in the most recent Senate, gubernatorial, and presidential elections in the state. Personal, business, and property tax controls include indicators for alternative minimum taxes, exemption of in-state and out-of-state federally tax-exempt debt, deductibility of federal income taxes, corporate tax rates, property tax rates, and sales apportionment rules. Sales tax controls include state sales tax rates. The natural logarithm of size of the bond package in millions of USD is included in Column (5). Standard errors clustered at the state-year level are shown in parentheses, and p-values for each estimate are displayed below the standard errors.

rates to allay the concern that changes in the effective rate are correlated with other tax policies that may be the true drivers of borrowing costs.[29] Column (5) controls for the size of the bond package and shows that the inclusion of this control has a negligible effect on the estimated coefficient. Our estimate of β is remarkably stable, with a range of 6.5-7.0 basis points.

To gauge the magnitude of these coefficients, consider that at the mean borrowing rate of 2.14%, a 3 pp increase in the effective rate would imply reductions in borrowing costs of between 9.2% and 9.8%.[30] Since state and municipal governments spent $122 billion on interest payments in 2017, these estimates would imply cost reductions of $11.2-12.0 billion (U.S. Census Bureau, 2020). An additional way to appreciate the magnitude of this effect is through the passthrough elasticities of the net-of-tax rate (i.e., $1 - \tau$) on borrowing costs.[31] Given a median effective tax of 40.8% and a median winning bid of 221 basis points, Table 1 reports median passthrough elasticities between 1.7 and 1.9. The estimated elasticities in Columns (2)-(5) reject the hypothesis of a passthrough elasticity below unity at the 10% level.

3.2 The Effect of Tax Advantages on Auction Participation

We now explore the interaction between tax policy and participation in auctions. First, we estimate a specification analogous to that in Equation 2 but where the dependent variable is the number of potential bidders. The second panel in Table 1 presents the results from this estimation and shows that a higher effective rate is associated with a larger number of potential bidders. Intuitively, as the value of the bonds increases with the tax advantage, more bidders are likely to participate in a given auction. The estimates imply that a 4 pp increase in the effective rate leads to an increase of close to 2 potential bidders. This is a large effect, as it would move an auction from the median to the 75th percentile of the distribution of potential bidders. These estimates are also stable across specifications, and Table A.11 shows that we find a similar increase when using an alternative definition of potential bidders (see Appendix C.3 for additional details).

If the increase in competitive bidding also lowers the winning bid, then the total impact of τ on b_1 includes the effects of τ on N.[32] To test one possible way in which taxes affect the outcomes in these auctions, we estimate additional specifications that directly control for N. Specifically, one possibility is that τ only impacts b_1 through N. If this were the case, then τ would have no impact on b_1 after we control for N. The third panel of Table 1 presents estimates of Equation 2 where we now partial out this mechanism

[29] Business and property tax policies include the state corporate tax rate, business tax apportionment rules, and a measure of the average property tax rate in the state from Suárez Serrato and Zidar (2016). From State Tax Handbooks (CCH, 2015), we use digitized variables including whether a state has an alternative minimum tax, whether a state allows for deductibility of federal taxes, and whether own- or other-state municipal bond income is excluded from taxation. We considered controlling for other institutional variables such as budget balance amendments and debt limits as in Poterba and Rueben (2002). However, no states changed these policies in our sample period, so these variables would be absorbed by the state fixed effects.

[30] Accounting for interactions between state and federal tax rates in our sample, a state income tax increase of 5.45 pp would increase the effective rate by 3 pp, on average.

[31] Our focus on this elasticity can be motivated by previous work that compares returns on municipal bonds to treasuries. Assuming an equilibrium between after-tax returns on taxable and tax-exempt assets implies a net-of-tax rate elasticity of one. Appendix C.10 discusses this result further, relates our focus on the net-of-tax rate elasticity to other areas of public finance, where it is common to focus on this elasticity, and shows that we obtain similar results when we analyze tax elasticities.

[32] Figure A.3 reports the coefficients on the fixed effects for the number of bidders relative to the median winning bid in the sample, along with the distribution of this variable. This graph shows that moving from a single bidder to 8 bidders lowers the winning bid by 30%, on average, but that further increases in the number of bidders do not affect the winning bid. Since a significant number of bond auctions have less than 8 bidders, there is substantial scope for lowering municipal borrowing costs by increasing competition in auctions.

by adding fixed effects for the number of potential and actual bidders. Conditioning on auction competition leads to smaller effects of the tax advantage on borrowing costs, confirming that one of the mechanisms through which higher taxes lead to lower borrowing costs is through an indirect competitiveness effect. However, the inclusion of controls for potential and actual auction participation fails to explain the whole effect of changing taxes. Comparing the results from the first and third panels of Table 2, we find that between 23% and 31% of the coefficient in the first panel is due to auction competitiveness.[33] By showing that τ still impacts b_1 conditional on N, this empirical result motivates our model, where τ directly impacts bond valuations and the individual decision of each bidder to participate in a given auction. In addition, to capture the observed effect of τ on N, our model and counterfactuals also allow the set of potential bidders to expand with the tax benefit.

3.3 Robustness and Identification of Causal Effects

This section provides evidence that the reduced-form effects from Sections 3.1 and 3.2 are driven by state tax changes that are plausibly exogenous from other drivers of municipal borrowing costs. We first discuss how an omitted variable might affect our results. We show that potential confounders, such as budget or rating shocks, would bias our estimates in the direction of finding a null effect. We then show in Section 3.3.1 that our estimates are robust to controlling for a battery of potential confounders and to differently constructed samples.

We begin by considering how an omitted variable could influence the estimates from Equation 2. While the variation in effective rates comes from the interaction of federal and state tax policy, most of the variation in the effective rates during our period stems from state tax changes. The exogeneity assumption is then that state tax rate adjustments are uncorrelated with unobserved factors that may also influence borrowing costs. For example, shocks to local economic conditions, municipal budgets, or the creditworthiness of the locality could influence borrowing costs. If one of these factors, labeled Z_{st}, is also correlated with state tax rates, omitting this factor from the analysis would result in the following bias:

$$\text{Bias} = \frac{Cov(\tilde{Z}_{st}, \tilde{\tau}_{st})}{Var(\tilde{\tau}_{st})} \frac{Cov(\tilde{Z}_{st}, \tilde{b}_{1ist}|\tilde{\tau}_{st})}{Var(\tilde{Z}_{st}|\tilde{\tau}_{st})},$$

where the tildes note that the variables have been residualized by all other controls in the regression. Since investors would demand a higher interest rate following a negative economic, budget, or rating shock, we would expect $Cov(\tilde{Z}_{st}, \tilde{b}_{1ist}|\tilde{\tau}_{st}) > 0$ if Z_{st} is one of these events.

For the omission of Z_{st} to bias our estimates in any direction, states would need to respond to these shocks by changing tax rates, i.e., $Cov(\tilde{Z}_{st}, \tilde{\tau}_{st}) \neq 0$. This is an unlikely source of bias since most of the bonds in our dataset are issued by school districts, cities, and counties, which do not set state tax rates, and it is unlikely that states would adjust state taxes in response to a shock to a local government.

Moreover, the existing literature on how states respond to fiscal pressure shows that states generally increase taxes when facing state budget shortfalls, so that, if anything, $Cov(\tilde{Z}_{st}, \tilde{\tau}_{st}) > 0$. For instance, Poterba (1994) describes how many states have policies in place that forbid extended periods of deficit spending, which can force states with unexpected negative fiscal shocks to raise taxes, in which case the

[33] We compute standard errors for this quantity by jointly bootstrapping the estimates in the first and third panels and find that, even in our most demanding specification in Column (5), we can reject the null of no difference with a p-value of 0.084.

bias would be positive.[34] This discussion shows that the most likely potential confounders would bias our estimates toward 0 and against finding a negative effect of taxes on borrowing rates.

3.3.1 Controlling for Potential Confounders

Following the discussion in the previous section, we now show that our reduced-form results are robust to controlling for a battery of potential confounders and to various sample constructions. Table 2 shows that our estimates are robust to controlling for local economic conditions, state spending and intergovernmental transfers and to including bidder and issuer fixed effects. Columns (2) and (3) use the identity of the winning bidder and the issuing municipality to test whether unobserved factors at the issuer or buyer levels may confound the role of effective tax rates. Columns (4)-(7) include additional state economic and spending controls: unemployment rate, state GDP, government spending, and intergovernmental transfers. Column (8) includes every control used in the robustness table. In this specification, β is identified by repeated bond auctions by the same issuer (municipality) with the same bidder (underwriter) in time periods with different (federal and state) tax rates. This strongly limits concerns that our results are driven by omitted factors that may be correlated with both tax changes and borrowing costs.

The estimated effects of tax rates on the winning bid after we control for the bidder, issuer, and economic characteristics range between -6.1 and -7.2, with the lowest and highest estimates both coming from specifications with issuer fixed effects. These results are remarkably robust across these specifications, which suggests that the exogeneity assumption likely holds. We formalize this evidence of coefficient stability by using the methods proposed by Altonji et al. (2005) and Oster (2017). Appendix C.8 discusses the results in Table A.18, which suggest that it is extremely unlikely that our main effects are driven by selection on unobservables. The effect on the number of potential bidders is also stable, with effects between 0.54 and 0.64 with the additional controls.

In Online Appendix C.1, we continue exploring the robustness of the results with respect to measurement and sample construction decisions. Table A.9 replicates the baseline results from Table 1 with different assumptions regarding standard errors, with monthly (and even daily) fixed effects, with the sample restricted to exclude bonds sold during 2008-09, and with an additional 20,237 bonds with less than \$5 million in par value. Similarly, Table A.10 includes additional controls for municipal market trends and financial provisions and shows that the baseline results are similarly robust to redefining the effective tax rate for households in the 90^{th} income percentile in each state, dropping states and state agencies that may have control over their effective tax rate, excluding all states that do not exempt interest on their own bonds from income taxes, and restricting the variation from federal tax rates. All of these robustness checks show similar estimates that are all statistically significant at the 5% level, which further suggests that the baseline estimates are not influenced by spurious factors or by sample measurement decisions.[35]

[34] Similarly, states are likely to increase tax rates to raise revenue to pay for higher interest rates following a negative credit-rating shock. We discuss negative shocks for illustration purposes, but a positive shock would also result in a positive bias since both correlations would be negative in that case.

[35] Appendix C performs a wide variety of analyses to demonstrate the robustness of our reduced-form results. We use an event study approach to show that the timing of tax changes coincides with changes in borrowing costs and that future taxes, as a placebo, do not predict changes in borrowing costs. We provide further evidence against the reverse causality hypothesis by showing that state tax rates are unaffected by previous, current, and future state interest payments. We also show that most of the variation is driven by sub-state agencies that cannot affect the tax advantage for their bonds. Column (5) of Table A.10 reproduces our preferred reduced-form estimates but excludes all entities that have the ability to change tax rates (states

Table 2: Reduced-Form Effects of the Effective Rate on the Winning Bid and Number of Potential Bidders: Extended Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Unconditional Effect of Effective Rate on Bid								
Effective Rate	-6.531	-6.686	-6.169	-6.572	-6.709	-6.708	-6.531	-7.159
	(2.527)	(2.361)	(2.440)	(2.484)	(2.560)	(2.577)	(2.574)	(2.249)
	0.010	0.005	0.012	0.009	0.009	0.010	0.012	0.002
Effect of Effective Rate on *N*								
Effective Rate	0.584	0.560	0.648	0.583	0.576	0.587	0.569	0.546
	(0.124)	(0.113)	(0.162)	(0.124)	(0.109)	(0.123)	(0.114)	(0.129)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid								
Effective Rate	-4.489	-4.777	-4.370	-4.516	-4.645	-4.626	-4.540	-5.873
	(2.517)	(2.351)	(2.423)	(2.477)	(2.463)	(2.568)	(2.551)	(2.314)
	0.075	0.043	0.072	0.069	0.060	0.072	0.076	0.012
Observations	14,631	14,631	14,631	14,631	14,631	14,631	14,631	14,631
Median Bid	221.2	221.2	221.2	221.2	221.2	221.2	221.2	221.2
Median Effective Tax	40.79	40.79	40.79	40.79	40.79	40.79	40.79	40.79
Elasticity (Median)	1.748	1.790	1.651	1.759	1.796	1.796	1.748	1.916
	(0.677)	(0.632)	(0.653)	(0.665)	(0.685)	(0.690)	(0.689)	(0.602)
	0.010	0.005	0.011	0.008	0.009	0.009	0.011	0.001
Base Controls	Y	Y	Y	Y	Y	Y	Y	Y
Bidder Fixed Effects		Y						Y
Issuer Fixed Effects			Y					Y
Unemployment Rate				Y				Y
Gross Domestic Product (log)					Y			Y
State Government Spending (log)						Y		Y
State Intergov Spending (log)							Y	Y
Political Party Controls								Y
Personal, Business, and Prop Tax								Y
Sales Tax Controls								Y
Size of Bond Package Controls								Y

Notes: This table presents more estimates corresponding to Table 1 with regressions showing the effect of effective marginal tax rates, in percentage points, on the winning bids, in basis points. The base controls include state, year, maturity, quality, and refund status fixed effects in addition to the effective rate, as in Column (1) in Table 1. See Section 3.3.1 and Appendix C for details and Appendix A for variable definitions. Standard errors clustered at the state-year level are shown in parentheses, and p-values for each estimate are displayed below the standard errors.

3.4 Lack of Supply-Side Response

Our results so far show that increasing the effective rate reduces borrowing costs for municipalities and increases the number of potential bidders in municipal bond auctions. To properly model how taxes impact participation and bidding in municipal bond auctions, we have to consider whether municipalities adjust their supply of bonds to changes in the effective tax rate. We investigate this possibility along a number of dimensions. Table A.12 shows that the effective rate does not affect the total number of bonds that are issued. Additionally, Tables A.13–A.15 show that the effective rate does not impact the mechanism used to sell a given bond. Finally, Table A.16 shows that the effective rate does not impact the size of bond issues or other bond characteristics including the maturity, callability, rating, or bank-qualified status. See Appendices C.5–C.6 for additional discussion. Overall, we find that municipalities do not respond to changes in the effective rate by supplying more, larger, or differently structured bonds.[36] Based on these facts, our model in the next section focuses on how tax advantages impact the participation and bidding strategies of potential underwriters.

The reduced-form results presented in this section have some immediate implications. First, the results on borrowing costs suggest that the tax advantage plays a major role in determining municipalities' borrowing costs and that removing the exclusion of municipal bond income from taxation may significantly affect this market. Second, understanding how tax advantages interact with entry into auctions is crucial to a full understanding of the passthrough of tax advantages into borrowing costs. Nonetheless, reduced-form analyses are unable to address important issues in this market, including how markups impact municipal borrowing costs, how changes in tax rates interact with imperfect competition in these auctions, and how regulations that depend on the degree of auction competition impact auction outcomes.

4 Model of Participation and Bidding in Municipal Bond Auctions

In this section, we present a model of participation and bidding in municipal bond auctions. Motivated by the reduced-form results in the previous section, the model is designed to capture how taxes affect the valuations of bonds, how agents adjust their participation decisions, and how the resulting competitive pressure affects the ability of bidders to extract information rents by shading their bids relative to their valuations. Capturing these margins is important for measuring equilibrium markups in each auction (Section 5), understanding how the effects of taxes on winning bids depend on changes in markups (Section 6), and analyzing counterfactual changes to tax policy (Sections 7.1 and 7.2). Our modeling approach most

and state agencies) from the sample. The resulting estimates are nearly identical to those from the regression including entities that have control over their own tax rates. This result shows that our main estimate is not driven by reverse causality, that is, by states changing their tax rates to influence their borrowing costs.

[36] These results are consistent with findings from the literature. For instance, Adelino et al. (2017) find that municipalities do not react to rating changes by borrowing more often, and Gordon and Metcalf (1991) discuss that municipalities do not invest more in the presence of lower interest rates caused by the tax exemption in part due to caps on tax-exempt borrowing. Cestau et al. (2020) document how state and local regulations restrict the ability of many municipalities to choose their method of sale. Recently, researchers have also found that the supply of bonds by municipalities is not responsive to changes in risk due to climate change or to regulations that affect borrowing costs (e.g., Goldsmith-Pinkham et al., 2019; Garrett, 2020). These results are also consistent with the institutional setting, since many of these bonds are authorized by popular referenda or by public budgeting processes that limit municipalities' ability to respond by changing the size of the issuance or by issuing additional bonds.

closely resembles that of Li and Zheng (2009).[37]

Consider an auction for a municipal bond by some municipality or state. There are N potential risk-neutral bidders for this bond offering. The bond will be awarded to the bidder who submits the lowest bid b. Each bidder i has a private value v_i for the bond. The values have a linear structure of the form $v_i = \tilde{v}_i + u$, where $\tilde{v}_i$ are independent components and u is the bond-specific unobservable. The unobservable is assumed to be independent of the private components $\tilde{v}_i$ along with all auction-level observables, including N. The components $\tilde{v}_i$ are drawn independently from a twice continuously differentiable distribution $F(\cdot)$, with density $f(\cdot)$ that is strictly positive over the support $[\underline{v}, \overline{v}]$. We interpret bidder's value v_i as the net value of selling the bond in the secondary market, which may vary across bidders due to different bond-buying clientele networks and costs of marketing. To participate in the auction, each bidder must pay a private entry cost d_i, which is drawn from a twice continuously differentiable distribution $H(\cdot)$, with density $h(\cdot)$ that is strictly positive over the support $\left[\underline{d}, \overline{d}\right]$. Entry costs are assumed to be independent of bidder values as well as the number of potential bidders. We interpret these costs as including the cost of researching the bond for sale as well as the potential for resale opportunities in the secondary market, which can reasonably vary across bidders. Section 5 describes how we take this model to the data, where we allow the model primitives to depend on bond characteristics, including τ. For simplicity, we omit this dependence in the description of the model in this section.

The informational assumptions of the model are as follows. First, the number of potential bidders N is set possibly depending on the effective tax rate. At the entry stage, each of the N potential bidders knows his own entry cost d_i, the number of potential bidders N, the bond-specific unobservable u, and the distributions $F(\cdot)$ and $H(\cdot)$. If a bidder chooses to participate in the auction by paying d_i, the bidder learns his value v_i but not the total number of actual entrants, which we denote n.[38] As in other recent work on auctions for financial products (e.g., Hortaçsu et al., 2018), under the structure that we assume, bidders have private values that are independent conditional on the auction observables as well as the unobservable component u.[39]

We follow Li and Zheng (2009) in assuming that each potential bidder holds the belief that if he is the only entrant in the auction, then the seller will also submit a competing bid based on its own draw from the distribution $F(\cdot)$, and that if there is more than one entrant, then the seller will not submit a bid.[40]

[37] Appendix D provides additional details on the model derivation.

[38] Because the bidding platform does not allow bidders to observe the number of other participants, we assume n is not observed by bidders. However, the set of firms that bid in municipal bond auctions is relatively stable over time. For this reason, we assume that bidders know the number of potential bidders, N.

[39] When a bank wins an auction to be the underwriter of a municipal bond issue, it can hold some of the debt and sell the rest of the bond package to other institutional and individual investors. Bidders' values depend on their own demand for the bond and on the demand of the clientele with whom they deal. The networks through which different underwriters place bonds vary geographically and along other margins. For instance, Babina et al. (2015) show that tax exemptions for municipal debt create ownership segmentation by state because the interest is exempt in the issuing state and not other states. Similarly, Green et al. (2007) present evidence that individual investors have different levels of information, so different investors pay different prices for the same bond. Green et al. (2007) also present an overview of the process by which municipal bonds reach the secondary market and why underwriters may have idiosyncratic considerations. Given that banks do not have identical clienteles, in geographical terms or otherwise, banks' values would not be changed by knowing the values of other potential bidders in a given auction. Tang (2011) and Shneyerov (2006) use a set of municipal bond auctions from before the start of our sample to analyze questions of mechanism design without imposing informational assumptions on the bidders. Interestingly, Tang (2011) shows that making incorrect assumptions about bidder values has negligible impacts on expected revenue.

[40] This allows us to rationalize instances in our data where there is one participating bidder who submits a finite bid. Such an assumption is necessary since there is no Bayesian-Nash equilibrium bidding strategy with finite bids in low-bid auctions with an unknown number of competitors. This is due to the fact that, since there is always a chance that an entrant faces no

Stage 3: Bidding

We begin with the bidding stage of the model. Upon entry, a participating bidder faces an uncertain number of competing bidders. The bidder maximizes his expected profits by choosing his optimal bid b_i according to the strictly increasing equilibrium bidding strategy $\beta(\cdot)$, which depends on the bidder's expectation of the number of competitors he will face:

$$\pi(v_i|p^*) = \sum_{k=2}^{N} Pr^*\left[n=k\right](b_i - v_i)Pr(b_i < b_j, j=1,...,n, j \neq i) + Pr^*\left[n=1\right](b_i - v_i)Pr(b_i < b_s). \quad (3)$$

Here, $Pr^*(n=k)$ is the equilibrium probability that k bidders participate in the auction in which i has already decided to participate. It is given by:

$$Pr^*\left[n=k\right] = C_{N-1}^{k-1}(p^*)^{k-1}(1-p^*)^{N-k}, \quad (4)$$

which depends on an equilibrium entry probability p^* (defined below), and where C_{N-1}^{k-1} denote binomial coefficients. In the event that there is only one active participant, i.e., $n=1$, we assume that this participant competes against the seller. In the equation for profits above, bid b_s represents a virtual bid by the seller, and it is assumed to have the same distribution as the bid of a randomly chosen participant.

To derive the bidding strategy in the auction, it is useful to express the probability of winning $Pr(b_i < b_j, j=1,...,n, j \neq i)$ in terms of the bidders' valuations. In equilibrium with symmetric bidders, the probability of winning coincides with the probability of having the lowest private valuation, so:

$$Pr(b_i < b_j, j=1,...,n, j \neq i) = Pr(\tilde{v}_i < \tilde{v}_j, j=1,...,n, j \neq i) = \left(1 - F(\tilde{v}_i)\right)^{n-1}. \quad (5)$$

The first order condition for the profit maximization problem is:

$$\frac{1}{b_i - v_i} = \frac{\partial \beta^{-1}(b_i)}{\partial b_i} \frac{\sum_{k=1}^{N} Pr^*\left[n=k\right] f\left(\tilde{v}_i\right)\left(1 - F\left(\tilde{v}_i\right)\right)^{\max(k-2,0)} \max(k-1,1)}{\sum_{k=1}^{N} Pr^*\left[n=k\right]\left(1 - F\left(\tilde{v}_i\right)\right)^{\max(k-1,1)}}. \quad (6)$$

The equilibrium bidding function $\beta(\cdot,\cdot)$, where the two arguments correspond to the private component $\tilde{v}$ and the unobservable u, is characterized by the solution to this first order condition, subject to the upper boundary condition $\beta(\overline{v}, u) = \overline{v} + u$, and is given by:

$$\begin{aligned} \beta(\tilde{v}, u) &= \tilde{v} + u + \frac{\sum_{k=1}^{N} Pr^*\left[n=k\right] \int_{v-u}^{\overline{v}} \left(1 - F\left(q\right)\right)^{\max(k-1,1)} dq}{\sum_{k=1}^{N} Pr^*\left[n=k\right]\left(1 - F\left(v-u\right)\right)^{\max(k-1,1)}} \\ &\equiv \tilde{v} + u + \mu(v-u) = \tilde{v} + u + \mu(\tilde{v}), \end{aligned} \quad (7)$$

where $\mu(\tilde{v})$ is the bidder's markup.

Stage 2: Entry

At the entry stage, bidders will decide to enter based on whether the expected payoff from participating (and bidding optimally thereafter) exceeds their realized entry cost d_i. The Bayesian-Nash equilibrium entry strategy is defined by a cutoff value d^*, such that bidders will enter if and only if $d_i < d^*$, which

competition, there is always an incentive to bid infinity. As in Li and Zheng (2009), the model can be altered to incorporate reserve prices, but like them, we focus on auctions without reserve prices to be consistent with the data.

implies that $p^* = H(d^*)$. Note that this cutoff is the same for all bidders, as, prior to entry, they have no information about their values. The equilibrium cutoff is determined by a zero profit condition for the potential entrant for whom $d_i = d^*$:

$$\mathbb{E}_{v_i}\pi(v_i|p^*(d^*)) = d^*, \tag{8}$$

where the dependence of p^* on d^* is explicitly denoted and the expectation is taken over the value v_i, which is realized upon entry.

Stage 1: Potential Entrants

While we find no supply-side response to changes in τ (i.e., no change in bond characteristics or issuance patterns; see Section 3.4), we document that shifts in effective tax rates can impact equilibrium outcomes by expanding or contracting the set of potential bidders (Section 3.2). To account for this effect, we let the *counterfactual* number of potential bidders be set according to:

$$N_j(\tau) = N_j + \phi(\tau - \tau_j), \tag{9}$$

where N_j and τ_j are the number of potential bidders and effective rate corresponding to auction j in the data. $N_j(\tau)$ represents the number of potential bidders that we would have observed in auction j had the effective rate been τ instead of τ_j.[41] When ϕ is not 0, changes in the tax advantage affect the number of potential competitors for each auction, which in turn affects the equilibrium markups, the equilibrium entry level, and, ultimately, the equilibrium auction-clearing bid. All of these effects arise in addition to the immediate impact of τ on the values described above.

Throughout the paper, we distinguish between two cases. First, in the case of $\phi = 0$, the number of potential bidders does not change in response to tax shifts. When $\phi = 0$, we refer to the effects of changes in τ on the outcomes of interest as *partial* effects. On the other hand, when ϕ is not zero, we refer to these results as *full* effects.

Tax Advantage Elasticity

In our empirical application, the distribution of values and, consequently, markups and bids depends on the tax rate τ. Noting the dependence on τ and assuming all other features of the bond and the auction to be fixed, Equation 7 implies:

$$\mathbb{E}_\tau b = \mathbb{E}_\tau v + \mathbb{E}_\tau \mu \tag{10}$$

where $\mathbb{E}_\tau$ stresses the dependence of the expectation on the value of τ. For instance, a change in the tax advantage $(1 - \tau)$ could signal to a bank that individual investors' demand for the bond will change, so that $\mathbb{E}_\tau v$ may be affected. Moreover, the strategic considerations in the optimal bidding function and zero profit conditions (Equations 7 and 8) may also impact equilibrium information rents, leading to changes in $\mathbb{E}_\tau \mu$ and $\mathbb{E}_\tau v$.

The expression above provides a simple way to decompose the change in a bidder's bid with respect to the tax advantage, $1 - \tau$. Suppose the effective rates change from their original level τ to some level τ' and

[41] In practice, we round up the right-hand side of Equation 9 to the nearest integer, and we set $N_j(\tau)$ to 2 whenever it is predicted to be less than 2.

denote $\Delta y(\tau)$ the corresponding change in the outcome $y(\tau') - y(\tau)$. We have:

$$\frac{\Delta \mathbb{E}_\tau b}{\Delta(1-\tau)} \frac{(1-\tau)}{\mathbb{E}_\tau b} = \frac{\Delta \mathbb{E}_\tau v}{\Delta(1-\tau)} \frac{(1-\tau)}{\mathbb{E}_\tau b} + \frac{\Delta \mathbb{E}_\tau \mu}{\Delta(1-\tau)} \frac{(1-\tau)}{\mathbb{E}_\tau b}. \tag{11}$$

Taking the limit $\Delta(1-\tau) \to 0$, we can rewrite this as

$$\varepsilon^b_{1-\tau} = (1-m)\varepsilon^v_{1-\tau} + m\varepsilon^\mu_{1-\tau}, \tag{12}$$

where m is the markup rate μ/b and ε are elasticities of the expectations of the model variables in $1-\tau$. This expression allows us to relate the model to the reduced-form results in Section 3 and to decompose the tax advantage elasticity of bids into the effects on values and markups, which we do in Section 6. In these calculations, we refer to $\varepsilon^b_{1-\tau}$ as the partial elasticity when $\phi = 0$, such that there is no impact of τ on N, and as the full elasticity when we account for the effect of tax changes on the set of potential bidders.

5 Structural Estimation and Implied Markups

We now outline the estimation of the model, discuss the estimation results, and describe the estimated equilibrium markups.

5.1 Parameterization

Consider an auction for municipal bond j with characteristics (X_j, Z_j) that are observable to the econometrician as well as the bidders. We parameterize the model as follows:

$$\begin{aligned}
\text{Value Distribution}: \quad f(\tilde{v}) &= \mathcal{N}(X_j\beta + Z_j\delta, e^{X_j\gamma}) \\
\text{Entry Cost Distribution}: \quad h(d_j) &= ln\mathcal{N}(\kappa_1, \kappa_2) \\
\text{Unobservable Heterogeneity Distribution}: \quad f_U(u) &= \mathcal{N}(0, \sigma_U)
\end{aligned}$$

where $\mathcal{N}(\mu, \sigma)$ is a normal distribution with mean μ and standard deviation σ and $ln\mathcal{N}(c, d)$ is a log-normal distribution with location parameter c and scale parameter d.[42] Under our assumptions, the bidders' private valuations are independent conditionally on X_j, Z_j, and u_j.

5.2 Estimation: First Step

We first note that the value of ϕ from Equation 9 is set to the estimate derived in our reduced-form regression in Column (4) for Panel B of Table 1.[43] Under our parameterization, bond characteristics in X_j impact the mean and variance of the value distribution. X_j includes bond maturities as well as the effective tax rate, as these are main features of our analysis. In contrast, we assume that factors Z_j only shift the mean of the value distribution and do not affect markups. As we describe below, Z_j includes state and year

[42] We model values and unobservable heterogeneity as having unconstrained support. While this choice departs from the assumption of constrained support in Section 4, it is convenient for MLE and is unlikely to matter in practice. For instance, while this choice does allow the possibility of negative bids, our estimates suggest that they are very unlikely (with about a 0.04 probability that the winning bid, which is the lowest bid in each auction, is negative across our sample). For this reason, we are comfortable with this parameterization, since it is unlikely that truncating $f_U(u)$ or $f(\tilde{v})$ would materially impact our results.

[43] Since our measure of N_j is derived from participation data, one concern is that our estimate of ϕ captures the impact of τ on the participation margin. As we show in Table A.11, increasing τ has a negative effect on the likelihood of participation. Since this effect is small in magnitude, it is unlikely that it significantly biases our estimate of ϕ.

fixed effects as well as other controls used in our reduced-form analysis. For computational tractability, we follow Shneyerov (2006) by parameterizing bids as follows:

$$b_{ij} = \delta Z_j + G(X_j, N_j) + u_j + \varepsilon_{ij}, \tag{13}$$

where b_{ij} is the bid of the i^{th} bidder in auction j and $G(X, N)$ is a flexible function of auction-level observables.[44] In our preferred specification, function G is cubic in effective rates, quadratic in maturities, and fully flexible in the number of potential bidders.[45] A sufficient identifying assumption here is that $\mathbb{E}[u_j + \varepsilon_{ij}|Z_j, X_j, N_j] = 0$.[46] We first estimate this regression using all bids in all auctions, which yields estimates of the δ coefficients. This approach greatly reduces the complexity of the model for entry and bidding, which we estimate below.

5.3 Estimation: Second Step

Having fixed δ in the first step above, we then estimate the rest of the parameters $\theta = \{\beta, \gamma, \kappa_1, \kappa_2, \sigma_U\}$ using maximum likelihood. For a candidate θ, the likelihood of observing the set of entry and bidding decisions in auction j is:

$$\begin{aligned} \mathcal{L}(\theta) &= \prod_{j=1}^{J} C_{N_j}^{n_j} \hat{p}_j(\theta)^{n_j} (1 - \hat{p}_j(\theta))^{N_j - n_j} g(b_1, \ldots, b_{n_j}; \theta) \\ &= \prod_{j=1}^{J} C_{N_j}^{n_j} \hat{p}_j(\theta)^{n_j} (1 - \hat{p}_j(\theta))^{N_j - n_j} \int_{-\infty}^{\infty} \frac{f_U(u) \prod_{i=1}^{n} f(\beta^{-1}(b_i - u, 0)}{\prod_{i=1}^{n} \beta'(\beta^{-1}(b_i - u, 0), 0)} du \\ &\text{s.t. } \mathbb{E}_{v_i} \pi(v_i|\hat{p}_j) = H^{-1}(\hat{p}_j; \theta) \quad \forall\, j = 1, \ldots, J \end{aligned} \tag{14}$$

where $g(b_1, \ldots, b_{n_j}; \theta)$ is the joint density of bids in auction j, $\hat{p}_j(\theta)$ is the equilibrium entry probability associated with parameters θ, β' is the derivative of the bidding function in the first argument, and H^{-1} is the inverse of the cumulative distribution function of the entry costs. Given a guess of parameters, we derive the probability of entry along with the bidding function so as to simultaneously satisfy Equation 8 and Equation 7. The estimates $\widehat{\theta}$ are then recovered by maximizing the right-hand side in Equation 14.

We note that our model is close to the framework discussed by Gentry and Li (2014), who study non-parametric identification in auction models where potential bidders can observe a noisy and possibly independent signal of their value prior to entry. While our case differs in that we model entry costs as random with bidder-specific realization, the identification argument for our setup follows similar steps. Additionally, to identify the distribution of entry costs, we rely on variation in the number of potential bidders conditional on other auction observables, assuming this variation to be exogenous. To credibly study the impact of the effective rate and other policy tools (like the excludability of interest income from state taxation) on the issuer's total borrowing costs, we adopt a parametric estimation approach, which allows us to include an extensive set of covariates in the model.

[44] To see why this assumption is valid, recall that Equation 7 shows that bids are the sum of markups and values. Because δZ_j only impacts the mean of the value distribution, it does not affect the markup. Thus, δ in Equation 13 correctly recovers the effect of Z_j on the distribution of values.

[45] We consider a variety of functions $G(X_j, N_j)$ in Equation 13, estimating the entire structural model separately for each specification. As we discuss in Appendix E, our results remain largely robust to various choices of $G(X_j, N_j)$.

[46] As is standard (e.g., Krasnokutskaya and Seim (2011)), we assume that u_j is independent of X_j and the number of potential bidders N_j.

Table 3: MLE Coefficients for the Distributions of Values $\tilde{v}$, Entry Costs, and Unobservable Heterogeneity

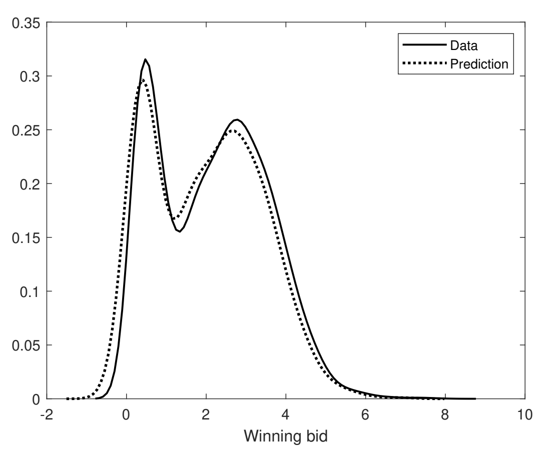
	Values ($\theta_{\tilde{v}}$)		Entry Costs (θ_d)		Unobs. Hetero. (θ_U)
	(1)	(2)	(3)	(4)	(5)
	$\widehat{\beta}$	$\widehat{\gamma}$	$\widehat{\kappa}_1$	$\widehat{\kappa}_2$	$\widehat{\sigma}_U$
Variable	Mean	StDev	Mean	StDev	StDev
Const	3.551	1.471	-16.053	20.589	0.449
	(0.028)	(0.008)	(0.730)	(1.108)	(0.002)
Maturity	0.131	-0.031			
	(0.0004)	(0.0002)			
Effective Rate: τ	-4.471	-5.046			
	(0.067)	(0.017)			

Notes: This table presents estimates from the baseline model for bidder valuations in percentage points and effective tax rates measured as fractions as described in Section 5. The additional controls are the same as those in Column (4) of Table 1. Standard errors are in parentheses.

5.4 Estimation Results

Estimation results for the baseline model are reported in Table 3. The baseline model includes the same set of controls as our reduced-form analysis, specifically Column (4) in Table 1.[47] The estimate for the effect of τ on the mean of the parameterized distribution of values, $\hat{\beta}$, implies that a 1 pp increase in τ leads to a 4.3 basis point decrease in values. We also find that τ has a negative effect on the standard deviation of the parameterized distribution of values, $\hat{\gamma}$. This implies that the dispersion in values decreases as the tax advantage increases, which tends to reduce equilibrium markups. To show that this result is not driven by our parametric assumptions, in Section 6, we follow a non-parametric approach and show that the variance of values within an auction is lower when the effective rates are high.

Figure 1: Simulated and Observed Winning Bids



Notes: This figure visually displays the goodness of fit of the model relative to the observed data in the distribution of bids. See Section 4 for the discussion of the model and Table 3 for the associated parameter estimates.

[47]To be exact, mean-shifters Z include state and year fixed effects along with sales, corporate, and property tax rates, political party measurements for Senate, president, and governor support, and, finally, the major party index. The estimation excludes auctions from the state of Nebraska (18 auctions) due to missing data. Table A.8 confirms that our reduced-form results are robust to using other sets of controls. X include effective rates and maturities.

The estimated model fits the data well. Figure 1 shows that the model fits the entire distribution of winner's bids across the sample.[48] Entry rates, n/N, are also well matched. For example, the average (median) probability of entry in the data is 0.701, and our model predicts it to be 0.736. Our estimate of the entry cost distribution implies that the average threshold entry cost in our data d^* is 0.05%.

While we believe that our model above presents a first order approximation of the economic forces in our setting, the model relies on a number of assumptions. To ensure that our results are not driven by these assumptions, we show in Appendix E that our results are robust to a number of alternative specifications of the structural model. First, we show that we obtain similar estimates with different specifications of Equation 13. Second, we extend our model by allowing the distribution of entry costs to depend on bond maturity and the effective tax rate, and we find similar results. Third, we show that we obtain similar results when we use an alternative definition of potential bidders, N, that includes all bidders in auctions held in the same state and month as potential bidders. Fourth, we obtain similar results when we follow Athey et al. (2011) by parameterizing bids rather than values. Finally, we also find similar estimates from a model that allows for heterogeneous bidder types that discriminate the top 10 most frequent bidders in the data from the rest of the bidders. Table A.21 shows that these alternative specifications yield similarly good model fits. As we show below, our estimates of markups and of the effects of policy changes are quite stable across these model specifications.

5.5 Estimated Markups

We now use the model estimates to construct equilibrium markups. For a given auction, our markup estimate is given by

$$\mathbb{E}\left[m|b_1,\ldots,b_n\right] = \mathbb{E}\left[\mu\left(\beta^{-1}(b_1-u,0)\right)\Big|b_1,\ldots,b_n\right]$$

where μ is the function defined in Equation 7.

Table 4 presents our model's estimates of bidder markups. The first row in Table 4 shows that markups are 18.7 basis points, on average. Note that the ratio of the expected markup to the average number of bidders is comparable to the entry cost threshold d^*. The average markup rate over the winning bid, m_1/b_1, is 23.6%. Table 4 also reports the dollar value of the markup over the life of the bond, $m_1 st$, with an average value of \$289,967.[49]

Our model predicts rich patterns of heterogeneity in markups. The remaining rows in Table 4 show that auctions for state bonds result in smaller markups, both in levels and as a percent of borrowing costs. However, since state bonds are larger and have longer maturities, the dollar value over the life of the bond is greater than average. We also find that bonds for school districts and smaller jurisdictions, such as cities and counties, have significantly larger markups. In particular, bonds issued by local governments are hurt in part by lower participation. On average, about five bidders submit bids for bonds issued by cities, towns, and villages, whereas more than eight typically submit bids for bonds issued by states. This

[48] The bi-modal distribution of winning bids evident in the figure stems from differing maturities, with the first hump being largely associated with maturities equal to one year. Thus, including maturities in our model proves crucial to matching these patterns in the data.

[49] The markups we find are in line with estimates of *ex post* surplus for winners calculated in Hortaçsu et al. (2018) in treasury auctions. They estimate surpluses between 0.7 and 22 basis points for primary dealers on maturities ranging from 52 weeks to 10 years.

Table 4: Summary of Average Estimated Markups by Issuer Type

	Markup (BP)	Markup Rate (%)	Markup Value ($)
Total	18.656	23.635	289,967
States and State Authorities	13.799	12.589	2,850,750
Counties, Parishes, and Colleges	17.236	20.437	356,447
School and Utility Districts	19.244	22.715	195,131
Cities, Towns, and Villages	18.968	26.381	150,241

Notes: This table showcases the average markups estimated in the structural model by issuer type. The row titled "Total" includes all issuers, including those for which an issuer type is not listed by SDC Platinum, while the other rows take the average of a subset of issuers by type. The markup is estimated directly from the model, the markup rate is the markup divided by the winning bid, and the markup value is the markup multiplied by size and maturity. The average bond issue has an estimated markup up of 18.7 basis points, which is 23.6% percent of their interest cost and adds up to $289,967 over the lifetime of the bond. The issuer types are organized from higher to more local levels of government. States and state authorities have lower markups on average that are a smaller percent of the total interest costs. The total value of the markups for these issuers is larger because their average issue size is larger. See Section 5 for more information.

suggests that there is substantial scope for lowering municipalities' borrowing costs by targeting auctions with high markup rates or with low participation.

6 Tax Incidence in Auctions

In this section, we explore in more depth the mechanisms by which the tax exemption for municipal debt affects bidder behavior and, consequently, borrowing costs. Our analysis characterizes the within-auction incidence. Based on the evidence in Section 3.4, we assume that the supply of bonds is not affected by changes in tax advantages. Equation 12 shows the basic intuition behind the effects that tax rates have on the borrowing costs. First, if there is perfect competition, $m = 0$ and $\varepsilon^b_{1-\tau} = \varepsilon^v_{1-\tau}$. Second, when $m > 0$, $\varepsilon^b_{1-\tau}$ may be greater than or less than one depending on the effect of changing taxes on markups and bidder values. For example, if $\varepsilon^v_{1-\tau} = 1$ and $\varepsilon^b_{1-\tau} > 1$, it must be the case that $\varepsilon^\mu_{1-\tau} > 1$.[50] This insight highlights the central role played by the responsiveness of markups to changes in taxes in determining how taxes pass through to borrowing costs.

The following example, shown in Table 5, decomposes this passthrough using our model and a representative auction from our data. Consider an auction with six potential bidders, $\tau = 0.35$, other observables set to their median realizations, and a bidder whose value is such that, according to our estimated model, he would submit a bid equal to the median bid in our data for auctions with these characteristics. At the original tax rate, the bidder has a value of 1.554 and an optimal bid of 1.886, which implies a markup rate of 18%. If τ increases from 0.35 to 0.39, his bid will change for a combination of reasons. First, his value will change, which will lead him to submit a lower bid, even when holding constant his probability of winning and the number of potential entrants in the auction. This is illustrated in the second row of the table, which shows that the optimal bid decreases from 1.886 to 1.843 ($\varepsilon^b_{1-\tau} = 0.374$), when the value drops from 1.554 to 1.479 ($\varepsilon^v_{1-\tau} = 0.792$). Second, because other bidders' values change, the bidder's probability of winning

[50] The case of $\varepsilon^v_{1-\tau} = 1$ can occur if one assumes that $v = \tilde{v}(1-\tau)$, where $\tilde{v}$ is the pre-tax value of a bond. However, we do not impose this restriction in our model.

Table 5: Elasticity Decomposition Illustration (Tax from 35% to 39%)

	N	Value v	Optimal b	$\varepsilon^{b}_{1-\tau}$	$\varepsilon^{\mu}_{1-\tau}$
1. Baseline	6	$v_0 = 1.554$	1.886		
2. Own-value Changes	6	$v_1 = 1.479$	1.843	0.374	
No Change to $Pr[win]$					
3. All-values Change	6	v_1	1.750	1.169	4.121
$Pr[win]$ reflects τ_1, N_0					
4. All-values + Entry	8	v_1	1.692	1.675	6.740

Notes: This table shows an example using the case of the median winning bidder in auctions with six potential bidders. An unobservable is chosen so as to match the median bid in simulation to the median bid in the data. The columns show the number of potential bidders, the value of the bidder, the optimal bid given the value, the intermediate elasticity of the bid, and the intermediate elasticity of the markups. The rows of the table decompose the change in the optimal bid for the median winning bidder. The first row shows the optimal bid for a value of 1.563, and the second row shows how the optimal bid changes if the tax rate increases by 4 percentage points but the probability of winning is held constant. The third row allows the bidder's own value as well as other bidders' values to change. The fourth row allows own and other bidder values to change and also allows other bidders to enter into the auction where the full elasticity of the bid is 1.625 and the full elasticity of the markup is 6.668. For more information, see Section 6.

changes, which forces him to further lower his bid. This is shown in the third row of the table, where we adjust the probability of winning to reflect the model-estimated winning probability at the new tax rate and original number of potential bidders. The optimal bid falls to 1.750, which implies a bid elasticity of 1.169. Finally, the four percentage point effective tax rate increase is associated with two more underwriters joining the pool of potential bidders (see Table 1). To capture the increased competition for the bond, we further adjust the probability of winning to reflect the model-estimated winning probability at the new tax rate and the new number of potential bidders. The last row shows that the increased competition further depresses the bidder's bid to 1.692, for a bid elasticity of 1.675.

The example in Table 5 also illustrates that as the tax rate increases, bidder markups decrease, from 0.35 in row one to 0.21 in row four. The large decline in these markups contributes to the greater-than-one passthrough elasticities on borrowing rates. In row three, when all but the effect of τ on N is allowed for, $\varepsilon^{\mu}_{1-\tau} = 4.121$. Once N is allowed to increase in τ, $\varepsilon^{\mu}_{1-\tau} = 6.740$.[51] This calculation highlights the importance of accounting for the impact of tax changes on markups as a contributing force to the overall effect on borrowing costs.

We now further explore how taxes impact markups and provide non-parametric evidence that these mechanisms are at play in the data. As made clear in Equation 7, a bidder trades off the benefit of increasing his bid and enjoying a greater markup over his value in the event that he wins the auction against the possibility that he loses the auction with this higher bid. Denoting the dependence of values—

[51] This example is broadly representative of the rest of our data. For instance, the average markup rate is 24% (relative to 18% in the example). Similarly, the bid elasticity in row four of Table 5 equals 1.68, which is similar to our reduced-form estimates in Table 1 and to the average model-based elasticity of 2.1. Finally, similar to our example, we find large markup elasticities with respect to the take-home rate.

and thus the probability of winning an auction—on the tax rate, it follows that:

$$b = v + \underbrace{\frac{\mathbb{P}r(v;\tau)}{-\frac{\partial}{\partial b}\mathbb{P}r(v;\tau)}}_{\text{Markup}},$$

where $\mathbb{P}r(v;\tau)$ is the equilibrium probability of winning the auction when a bidder's value is v and the tax rate is τ. The markup, or difference between a bidder's bid and the value, depends on the expected market share, given by $\mathbb{P}r$, and the slope of the inverse supply, given by $-\frac{\partial}{\partial b}\mathbb{P}r$. In a perfectly competitive auction, characterized by many bidders or by a lack of heterogeneity in bidder valuations, the expected market share for a given bidder who bids above his valuation is 0, and the inverse supply is vertical at this valuation. These forces eliminate the possibility for markups. As in monopsonistic settings, bidders in auctions with imperfect competition may shade their bids to manipulate the expected market share.[52] The fundamental expression of market power in this case is the ability of bidders to improve their expected surplus by shading their bid, which is controlled by the slope of the inverse supply.

Therefore, the question of how taxes affect markups—and, consequently, the cost of borrowing via Equation 12—hinges on how taxes affect the probability associated with a bidder winning an auction at any particular submitted bid. Specifically, the elasticity of markups with respect to taxes can be decomposed as follows:

$$\varepsilon^{\mu}_{1-\tau} = \underbrace{\varepsilon^{\mathbb{P}r}_{1-\tau}}_{\text{change in own market share}} + \underbrace{\varepsilon^{-1/\frac{\partial}{\partial b}\mathbb{P}r}_{1-\tau}}_{\text{change in inverse supply slope}}. \tag{15}$$

An increase in the tax advantage may decrease markups (and borrowing rates) by decreasing the market share for a given bidder and by increasing the slope of the inverse supply. Intuitively, if greater tax advantages increase the number of actual bidders, the expected market share will decrease. To interpret $\varepsilon^{-1/\frac{\partial}{\partial b}\mathbb{P}r}_{1-\tau}$, consider that the slope in the inverse supply is driven by heterogeneity in the valuations for bonds. If larger tax advantages lead to a selection of bidders with less heterogeneous valuations for the bond, this will lead to a positive value of $\varepsilon^{-1/\frac{\partial}{\partial b}\mathbb{P}r}_{1-\tau}$. This is consistent with results from Babina et al. (2015), who show that there is a higher degree of tax-induced ownership segmentation in states with a larger tax advantage for municipal bonds. Intuitively, since only residents of the issuing state receive the full tax benefit, as the state tax rate increases, it is more likely that residents of the state own the bonds and that the distribution of their valuations is more compressed. This is also consistent with our structural estimates in Section 5.4, where we find that an increase in τ is associated with a smaller variance of the distribution of bids.

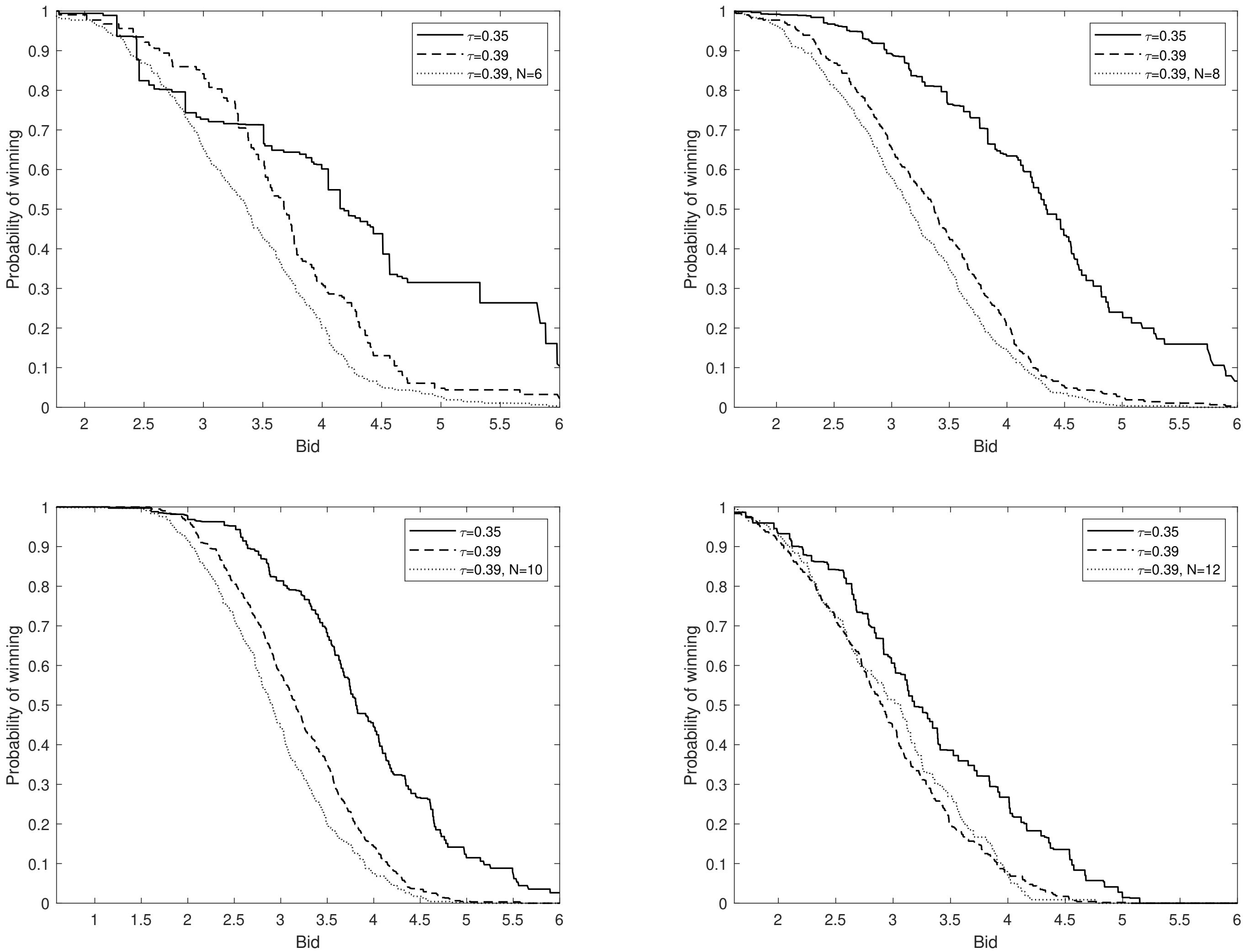
While the model imposes a parametric structure to incorporate a rich set of observables, we now show that the key interactions between taxes and the probability of winning an auction are evident in the raw data. Specifically, we show how changes in τ affect non-parametric estimates of the probability of winning. We begin by estimating the probability of winning an auction using the kernel estimator:

$$\widehat{\mathbb{P}r[b_{-i} > b|}N,\tau] = \frac{\sum_j \frac{1}{n}\mathbb{1}(b_j > b)K\left(\frac{\tau_j-\tau}{h_\tau}\right)}{\sum_j K\left(\frac{\tau_j-\tau}{h_\tau}\right)},$$

where j is an indicator for each auction and $\mathbb{1}(b_j > b)$ is an indicator that b is below all bids in auction j. $K(\cdot)$ is a kernel that assigns weights to the auctions based on observable characteristics, in this case

[52] We use the phrase "shade" as it is common in the literature on first-price auctions, even though in this low-bid setting, bidders seek to inflate their bid above their value.

Figure 2: Non-Parametric Estimates of the Probability of Winning



Notes: These figures show the non-parametric estimates of the winning probability for a given bid conditional on a bond maturity of between 13 and 26 years, which corresponds to approximately 40% of the data and nearly half the total par value of the issued bonds. The non-parametric estimates here are also used to estimate optimal bids and elasticities for a given value. Figure A.20 shows that these estimates are robust to regressing out all controls from column (4) of Table 1. See Section 6 for more information about these estimates and the discussion of optimal bid responses.

τ_j. Following Li et al. (2000), we use triweight kernels with bandwidth $h_\tau = c \cdot std(\tau) \cdot (J)^{-1/5}$, where J denotes the number of auctions, $std(\tau)$ measures the standard deviation of τ, and $c \approx 3$ is the kernel-specific constant.

Figure 2 plots this estimated probability for different values of N and τ. The fundamental expression of market power in our setting is the ability of bidders to trade off higher surplus for a smaller expected market share. The data reveal whether bidders may profit from such strategic bidding by showing that the probability of winning has a finite slope around the winning bid. The solid blue lines correspond to estimated probabilities of winning for the mean value of $\tau = 0.35$ and for $N = 4, 6, 8, 10$. These lines show that auctions for municipal bonds are far from the ideal of perfect competition, as the finite slope allows bidders to strategically shade their bids. As one would expect, the probability of winning has a steeper slope when bonds have a larger number of potential bidders.

The green dotted and red dashed lines in Figure 2 show that the intuition from the example in Table 5 is apparent in the raw bidding data. For each value of N, the red dashed line plots the estimated probability of winning with a higher $\tau = 0.39$. These plots show that auctions with larger tax advantages have reduced scope for markups since both the probability of winning decreases and the slope of this probability becomes steeper along most of its domain. As discussed above, higher effective rates also lead to increases in N. In particular, a reform that increases τ from 0.35 to 0.39 would also lead the average N to increase by about two additional potential bidders. The green dotted lines plot the probability of winning with a higher rate and the accompanying increase in N. Highlighting the intuition from the representative bidder above, these graphs show that the scope for markups is further reduced by the indirect effect of the tax advantage on the level of competition.[53]

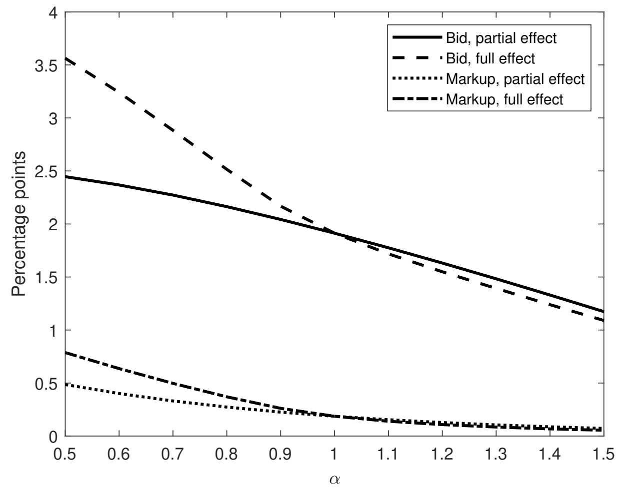
The results from this section highlight the value of measuring markups with our auction model, as this allows us to show that the effect of the tax advantage on the winning bids is driven by a large effect on equilibrium markups. Moreover, this mechanism is not dependent on the parametric structure that we use in the estimation, as the non-parametric estimates of the probability of winning show that the interaction between taxes and imperfect competition is visible in the raw data.

7 Counterfactual Policy Analysis

We now use our structural model to improve our understanding of the effects of tax policies and regulations on municipal bond auctions. Section 7.1 highlights the benefits of our structural model by quantifying how different policies that impact the tax advantage—e.g., state taxes, federal taxes, the SALT deduction—help determine borrowing rates and markups in municipal bond auctions. Section 7.2 further showcases the value of our model by studying the effects of regulations that condition the value of the tax advantage on the number of bidders in municipal bond auctions.

[53] The non-parametric approach that we follow in this exercise has a number of limitations. First, the curse of dimensionality prevents us from non-parametrically controlling for most of the observables. Figure A.20 shows that these estimates are robust to regressing out all controls from column (4) of Table 1. Second, in contrast to our structural model, this approach does not control for unobserved auction-specific heterogeneity. Nonetheless, we stress that the key feature of the data that the distribution of bids in the auction tends to shrink when τ increases is confirmed by our structural model results, by this exercise, and by all the robustness checks that we perform as described in Appendix E.

Figure 3: α-Policy Outcomes for Borrowing Rates and Markups



Notes: This figure shows counterfactual bids for different ratios of the current federal exemption. $\alpha = 0.5$ is equivalent to cutting the exemption in half, and $\alpha = 2$ would double the exemption by subsidizing municipal bond interest income by an amount equal to the federal tax rate in addition to the exemption. See Section 7.1 for additional discussion and Figures A.8 and A.9 for the spatial distribution of counterfactual changes associated with $\alpha = 0.73$.

7.1 Tax Policies and Borrowing Rates

The tax advantages enjoyed by the holders of municipal bonds are the subject of intense debate. Several federal reforms have been proposed that directly or indirectly deal with the growing tax expenditure from the exemption of municipal bond interest. We provide a survey of the proposed reforms in Appendix G. In this section, we evaluate reforms that modify the tax advantage by changing the effective rate used in our analysis. Examples of reforms include the repeated proposals by the Obama administration to limit the exemption to 28% and the Tax Cut and Jobs Act of 2017 (TCJA17), which lowered the top federal rate to 37% and limited the state and local tax (SALT) deduction. We fit these reforms into a general approach that evaluates the consequences of a change in federal tax rates by parameterizing the effective tax rate as follows:[54]

$$\tau(\alpha t_f, t_s) = \alpha t_f(1 - t_s) + t_s \times \mathbb{1}(Tax\ Exempt)^{State}.$$

Relative to the average federal rate from 2011 to 2015, the Obama proposal corresponds to $\alpha = 0.73 \approx 0.28/0.386$, and the TCJA17 sets $\alpha = 0.96 \approx 0.37/0.386$. We can also consider the effect of a *super-exemption* of municipal bond interest by evaluating reforms that set $\alpha > 1$. Additionally, we use the model to evaluate the impact of other policies such as removing the exemption of municipal bond interest income from state taxation (for those states that currently have such an exemption) and to consider the elimination of the SALT deduction. Finally, we study the total effect of the TCJA17, as the decrease in marginal rates and limiting of SALT affect borrowing costs in opposite directions.

[54]This formula is exact whenever states do not allow for the deductibility of federal taxes from state taxes. We modify the formula accordingly for the few states that allow this deduction. Note that state taxes are always deducted from federal taxation.

Table 6: Average Effects of Counterfactual Policy Reforms

(a) Bids and markups simulated on sample data for different policies

	(1)	(2) Trump Proposal	(3) Obama Proposal	(4) No State Exclusion	(5) No SALT	(6) TCJA17
	$\alpha = 1$	$\alpha = 0.96$	$\alpha = 0.73$			$\alpha = 0.96$
Winning Bid						
Partial (No Potential Entry)	1.91	1.97	2.24	2.09	1.83	1.89
Full	1.91	2.02	2.79	2.35	1.79	1.88
Markups						
Partial (No Potential Entry)	0.19	0.20	0.31	0.25	0.17	0.18
Full	0.19	0.22	0.46	0.32	0.16	0.18

(b) Percentage change from $\alpha = 1$

	(1) Trump Proposal	(2) Obama Proposal	(3) No State Exclusion	(4) No SALT	(5) TCJA17
	$\alpha = 0.96$	$\alpha = 0.73$			$\alpha = 0.96$
Winning Bid					
Partial (No Potential Entry)	2.77%	17.16%	9.49%	-4.19%	-1.18%
Full	5.39%	46.00%	23.04%	-6.32%	-1.67%
Markups					
Partial (No Potential Entry)	7.94%	67.59%	32.09%	-9.98%	-2.41%
Full	15.46%	148.03%	70.25%	-15.69%	-3.88%

Notes: This table shows counterfactual bids and markups under two policy proposals: one limiting the federal exemption to 73% and the other to 96% of its current level. The last three columns represent simulations under which the state tax exemption for municipal bonds is lifted, the SALT deduction is repealed, or the SALT deduction is repealed and the exemption is limited to 96% of its current level. The linear model refers to the predictions based on the estimated reduced-form effect of tax rates on the winning bids. Section 4 discusses the setup of the model, while Section 7.1 discusses the counterfactual simulations. Robustness checks for four additional specifications are discussed in Appendix E, with the results presented in Tables A.27 to A.30.

We begin by focusing on changes to the federal tax code that limit or expand the exemption of municipal bond interest income from federal taxation. Specifically, we vary α and simulate auction outcomes for two different cases: when shifts in τ are assumed to have no impact on N and when they are assumed to affect N. We simulate the effect of this policy change on every auction from 2013 to 2015 and present the average of the simulated effects in Figure 3.

In this graph, values of $\alpha < 1$ correspond to decreases in the tax advantage and values of $\alpha > 1$ to increases in the tax advantage through increases in the tax rate or through a form of super-exemption. As the tax advantage is decreased from $\alpha = 1$, we see an increase in both the winning bids and the markups, with larger effects corresponding to a full reform that allows for changes in N.[55] While the effects on the winning bid are close to being linear in α, the full effects on markups (dashed purple line) are convex in α.

Table 6 presents average effects of the proposals from the Obama and Trump administrations. Cutting taxes according to the Trump proposal would lead to an increase in borrowing costs of 5.39%. Close to half of this effect would be driven by the effect of the tax change on the number of potential bidders, N. One advantage of our structural model over our reduced-form analysis is that it allows us to go beyond studying the effects on average bids to consider impacts on equilibrium markups, which are not observed in the data. Our simulations show that, if we hold the number of potential bidders constant, the Trump proposal would increase markups by 7.94%. Allowing taxes to impact the number of potential bidders would lead to an increase in markups of 15.46%.

One way to assess the effectiveness of the tax advantage of municipal bonds is to compare the change in borrowing costs for municipalities to the fiscal cost of the subsidy. Given the annual municipal interest payments in the amount of \$122 billion (U.S. Census Bureau, 2020), the Trump reform would imply an additional \$6.4 billion in interest payments by state and local governments.[56] Without further behavioral responses, the reduction in the tax expenditure over the next decade would be close to \$20 billion ($\approx (1 - 0.96) \times \$500$ billion). On a yearly basis, this subsidy represents a gain of \$3.2 ($\approx \frac{6.4}{2}$) in state and local funds for every dollar of federal funds. This subsidy would thus improve welfare as long as the marginal cost of public funds for the federal government is not 3.2 times greater than the marginal value of providing public goods from municipal bonds.[57]

Our model elucidates the different economic mechanisms that contribute to this cost-effectiveness. Consider first the effect of the Trump proposal on auction competitiveness. If we remove this effect (by focusing on the partial increase in borrowing costs of 2.77%), our cost-effectiveness number decreases from \$3.2 to \$1.7 ($\approx \frac{2.77\% \times 122}{2}$). Consider now the effect of the Trump proposal on markups. Continuing with the partial case, Table 6 shows that markups increase 7.94%. Suppose, for illustrative purposes, that markups were not affected by the Trump proposal. Borrowing costs would then only increase by 1.98%, such that every

[55] As we discuss above, we ensure that there are always at least 2 potential bidders. Figure A.19 shows that we obtain similar counterfactuals when we drop bond issues affected by this truncation.

[56] We assume here that an effective tax reduction would have the same effect on borrowing costs for bonds sold via negotiations as it would for bonds sold via auctions.

[57] This calculation assumes that the increase in borrowing costs does not also increase the federal tax expenditure and ignores the externality on state governments, which would also see an increased tax expenditure. Further, the federal government is not likely to recoup the full reduction in tax expenditure because of behavioral substitution away from municipal bonds toward other investment instruments, as described by Poterba and Verdugo (2011), so \$20 billion is an upper bound on the revenue cost of the tax expenditure. These forces imply that the efficiency ratio of 3.2 is a lower bound. We also assume the total value of issuances to be fixed, which is in line with the results from Section 3.4.

dollar of tax savings would only increase municipal borrowing costs by \$1.21 ($\approx \frac{1.98\% \times 122}{2}$). These calculations show that the effects of changes to tax advantages on both auction competitiveness and markups are crucial determinants of the cost-effectiveness of these policies.[58] Figures A.8-A.9 explore how these proposals would affect different states and show that the effects on borrowing costs and markups are highly heterogeneous across the states.

We perform two additional tax policy analyses. First, we consider the effects of eliminating the excludability of municipal bond interest income at the state level. As shown in Table 6, if this policy were enacted, average borrowing costs would rise by about 23% and markups by about 70%. Figures A.10-A.11 showcase the heterogeneous effects of this policy. While eliminating the state exemption leads to an increase in the importance of the federal subsidy, this potential reform results in an overall decrease in the subsidy. As expected, we find that states with higher taxes would see larger increases in borrowing costs.

Lastly, we investigate the effects of policy changes motivated by the TCJA17. We find that eliminating the SALT deduction results in higher effective rates, which are then accompanied by lower markups and borrowing rates. Table 6 shows that, on average, our model predicts that borrowing costs would fall by about 6%. Figures A.12-A.13 show that this decrease would be concentrated in states with higher taxes, as these states are the biggest beneficiaries of the SALT deduction. While the lower tax rates in the TCJA17 would increase borrowing costs for municipalities, changes to the SALT deduction would dominate this effect. Overall, our model estimates suggest that the TCJA17 will lead to a 1.7% reduction in borrowing costs and a 3.9% reduction in markups.

In Tables A.37-A.30, we show that all of these counterfactual policy analyses are robust across different versions of our structural model.

7.2 Competition in Municipal Bond Auctions

We now use our structural model to study the effects of a real-word regulation that limits the value of the tax advantage depending on the degree of competition in bond auctions. While the tax advantage for municipal bonds depends on both state and local tax policies, the majority of the cost of the subsidy is borne by the federal government. The IRS therefore has an interest to regulate the maximum tax-exempt yield of municipal bonds. Historically, this maximum tax-exempt yield was set by underwriters based on their "reasonable expectations" of the price at which they believed they would be able to sell bonds to investors. In 2017, the IRS restricted the flexibility of underwriters to determine the maximum tax-exempt yield for bonds sold through auctions with fewer than three bidders.[59] The new regulation therefore limits the tax advantage of bonds sold in auctions with fewer than three bidders.

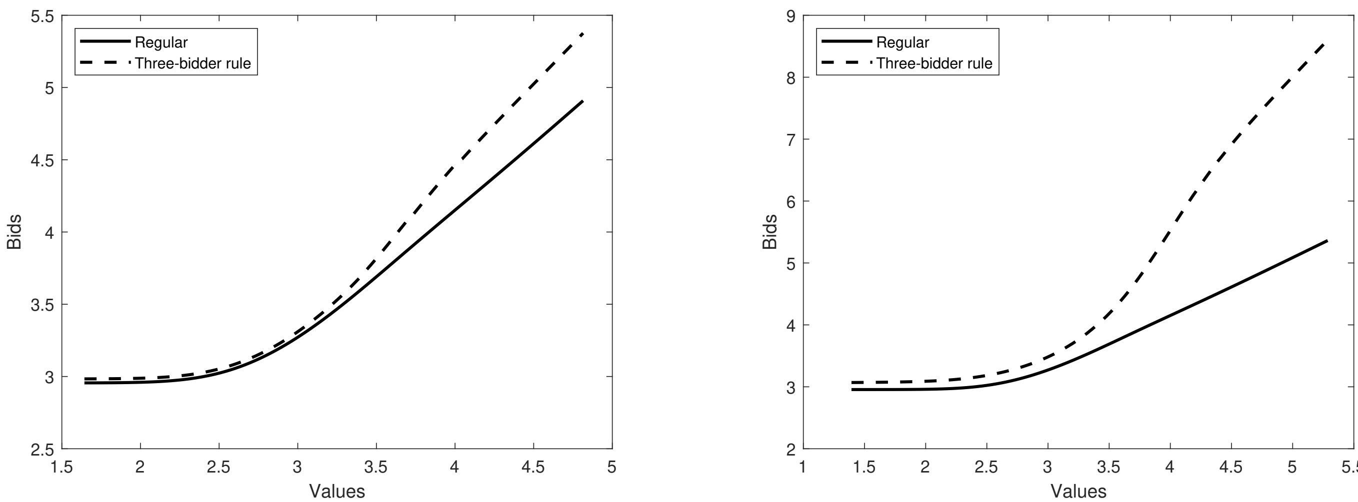
Our model provides an ideal framework to evaluate the effects of this type of regulation. First, our model captures the institutional feature of auction participants not knowing the number of other competitors when they submit their bids. Consequently, under the three-bidder rule, they will not know their exact valuations

[58]This calculation is in line with a linear extrapolation of the results of Table 1 that imply a ratio of 3.2. Appendix H provides further details on these types of calculations including the impact of varying α.

[59]Internal Revenue Service (2016) states that "the public bidding process for pricing municipal bonds in competitive sales itself provides a sufficient basis to achieve the best pricing for issuers." The choice of 3 bidders as the threshold to determine which sales are sufficiently competitive to be eligible for the continued use of reasonable expectation prices is derived from other regulations governing guaranteed investment contracts. The rules governing the determination of issue prices are related to the arbitrage restriction for tax-exempt bonds described in Section 148 of the Internal Revenue Code. We provide further details in Appendix F.

Figure 4: Bidding Functions under the Three-Bidder Rule

(a) Tax-Shield Reduction: $r = 0.9$ (b) Tax-Shield Reduction: $r = 0.5$



Notes: These figures show the bidding strategies in auctions with full tax advantage and auctions where the tax advantage changes from τ to $r\tau$ if the number of participants is less than 3. The left figure corresponds to $r = 0.9$, and the right figure corresponds to $r = 0.5$. See Section 7.2 for details.

for the bond until just after the auction. Second, our model accounts for the fact that auction participants consider the profits they earn in the eventuality that they win the auction when deciding how to bid and whether to participate in the auction.

We model the effects of this regulation by letting the bond valuations vary with the number of active bidders n. When n is less than 3, the extent of the tax shield provided by the bond is reduced. We represent this change as a shift in the effective rate from τ to $r\tau$, and we vary the reduced tax shield for values of $r \in [0, 1]$, which affects how the bond is valued by underwriters. Specifically, we define the bidder's ex ante valuation as:

$$v = \mathbb{I}(n < 3)\tilde{v}_{n<3} + \mathbb{I}(n \geq 3)\tilde{v}_{n\geq 3} + u,$$

where $\mathbb{I}(n < 3)$ denotes the event that $n < 3$. While $\tilde{v}_{n\geq 3} \sim F(\tilde{v}_{n\geq 3}; \tau)$, the cumulative distribution function of its low-competition counterpart, $F(\tilde{v}_{n<3}; r\tau)$, depends on the reduced tax advantage $r\tau$. This extended version of our model captures the dependence of the tax advantage on the ex post level of competition as well as the impact of the regulation on bidding and participation strategies.[60]

Consider first how this regulation impacts bidding strategies. Figure 4 shows the bidding strategies $\beta(v)$ in a representative auction for a bond with characteristics set to sample medians and $N = 4$ potential bidders. We illustrate how the equilibrium bidding strategy changes relative to our baseline model for the two values of $r = 0.5, 0.9$. The figure shows that, for all values, the strategy in the three-bidder rule case always lies above the baseline function, which reflects how the change in the tax advantage impacts

[60] Upon entry, the agent learns his own v, which involves learning both $\tilde{v}_{n<3}$ and $\tilde{v}_{n\geq 3}$. We assume that bidders have the same competitiveness relative to other bidders in both cases, i.e., the quantiles of the two valuations are the same: $F^{-1}(\tilde{v}_{n<3}; r\tau) = F^{-1}(\tilde{v}_{n\geq 3}; \tau)$. The derivation of the equilibrium bidding strategy as well as the equilibrium probability of entry follows the same argument as in Section 4 with the distinction that the winner's valuation is a function of n. Appendix F provides additional details.

Table 7: Effects of the Three-Bidder Rule on Bids, Markups, and Entry Rates

	Mean bid	Mean markup	Mean Pr(entry)
Tax advantage shift: $\tau \to 0.9\tau$			
Regular	1.963	0.227	0.733
Three bidder rule	1.970	0.234	0.734
Reduced advantage	2.113	0.282	0.737
Tax advantage shift: $\tau \to 0.5\tau$			
Regular	1.963	0.227	0.733
Three bidder rule	2.007	0.271	0.735
Reduced advantage	2.565	0.676	0.750

Notes: This table shows counterfactual bids, markups, and entry rates for two policies: a tax shield reduction for low-competition auctions and a universal tax shield reduction. The effective tax rate τ changes to the level of $r\tau$ whenever the number of bidders is less than 3 in the first case, and it changes to $r\tau$ permanently in the second case. The regular case where the tax rate remains fixed at the level observed in the data is also included. The simulations are based on the municipal bond auctions held in 2015. For details, see Section 7.2.

a bidder's value for the bond. This figure also allows us to infer the impact of the regulation on bidder markups. For sufficiently small—i.e., competitive—values, the bidding function under the three-bidder rule is very close to the baseline bidding function where values do not depend on the number of participants. As valuations increase, however, so does the difference between the two functions. Starting from approximately $v = 3.5pp$, the bids under the three-bidder rule are appreciably larger than the regular bids, and this increase is driven by a rise in markups.

To clarify why the regulation can impact bidder markups, it is convenient to represent the expected equilibrium profit for a bidder with valuation v as:

$$\pi(v) = (\beta(v) - v_{n<3})w_1(v) + (\beta(v) - v_{n\geq 3})w_2(v)$$

where w_1 and w_2 are positive weights related to the probability of winning under low and high competition, respectively. When the agent has a relatively low valuation, $w_2(v)$ is relatively large compared to $w_1(v)$, so the agent behaves as if he is competing against a high number of participants. Conversely, the first term matters more when the agent has a high valuation, as his chance of winning decreases quickly in the number of competitors n. For this reason, agents with high valuations behave as if the auction is guaranteed to have a very low n, which leads them to submit high markups.

The logic behind Figure 4 suggests that this regulation can significantly raise borrowing costs for municipalities. However, this only happens when the auction winner has a particularly high valuation for the bond. To understand how frequently this would happen and to quantify the overall impact of the policy, we simulate counterfactual outcomes for all bond auctions held in 2015.[61] We consider three scenarios: the tax advantage is τ exactly as in the data, the tax advantage is permanently reduced to $r\tau$ for different $r \leq 1$, and, finally, the tax advantage is reduced when there are fewer than three bidders. Table 7 reports the results. The average winning bid under the three-bidder rule always lies between the other two extremes,

[61] As the three-bidder rule was implemented in June 2017, the closest year to the policy change in our sample is 2015.

though this case is much closer to the baseline scenario. The same can be said about the average markups as well as average entry probabilities. In the case where $r = 0.5$, the three-bidder rule raises borrowing costs by 2.2%, and this increase is driven by a 19.4% increase in bidder markups. As suggested by Figure 4, the three-bidder rule would have the strongest impact in auctions with low numbers of potential participants. Because only 7% of auctions have fewer than three bidders, this is a relatively rare occurrence. Nonetheless, while average costs are not severely affected by the policy, we find that in 7.6% of the cases, borrowing costs increase by more than 10%. The regulation therefore introduces a significant risk of increased borrowing costs for municipalities where the three-bidder rule has a high likelihood of binding.

8 Conclusion

The excludability of municipal interest income from taxation is one of the largest tax expenditures faced by the U.S. Treasury. Advocates of this policy argue that the tax advantage of municipal bonds is crucial to lowering the borrowing rates of municipal governments, which use these funds to finance public goods, services, and infrastructure. Critics of this policy argue that top-income individuals are its largest beneficiaries, that the cost to the U.S. Treasury is large and continues to grow, and that these subsidies do not lower borrowing costs for governments.

This paper sheds light on this important debate by analyzing municipal bond auctions and by pointing to the role of imperfect competition in determining the effects of tax subsidies on borrowing costs. Contradicting critics of the policy, our reduced-form estimates show that changes to tax policy have large effects on governments' borrowing costs, which are summarized by an average passthrough elasticity that is greater than unity.

We use an empirical auction model to provide three insights into how taxes affect auctions for municipal bonds. First, we use the model to quantify equilibrium markups. The estimated markups are larger for smaller jurisdictions and school districts and in auctions with few bidders, which suggests that there is substantial scope for reducing the borrowing costs of municipalities by targeting those with high markups. Second, we show that the passthrough of taxes to borrowing costs is driven by the interaction between tax policy and imperfect competition and, in particular, by the effects of taxes on markups. We provide non-parametric evidence that, as the tax advantage for municipal bonds increases, bidders are less able to extract information rents in the form of markups. This effect is responsible for the greater-than-unity passthrough elasticity that we find in our reduced-form analysis.

Finally, we use the model to simulate the effects of a number of policies, both proposed and implemented. First, we study the policies proposed by the Obama and Trump administrations and evaluate how different components of the Tax Cuts and Jobs Act of 2017 will affect municipal borrowing costs. We find that reductions in the tax advantage for municipal bonds translate to substantial increases in both borrowing rates and markups. The increase in borrowing costs is 3.2 times as large as the reduction in the federal tax expenditure, suggesting that the tax advantage for municipal bonds is an efficient mechanism to subsidize public good provision at the local level. While different provisions in the Tax Cuts and Jobs Act of 2017 may serve to raise or lower borrowing costs, we find that, overall, the legislation may result in small reductions in borrowing costs. Second, we investigate how a recently implemented IRS rule that reduces the tax advantage of municipal bonds sold in auctions with fewer than three bidders affects the strategies of the bidders and the borrowing rates of the municipalities. We find that the rule introduces significant distortions to the bids submitted by underwriters with relatively large valuations for the bonds. While the level of competition in the auctions tends to be high enough that such underwriters rarely win, the rule can lead to significant increases in borrowing costs for municipalities where the rule is likely to bind.

Our analysis contributes to the economics literature by pointing out an important case where taxation and imperfect competition interact to generate large policy responses and by estimating a structural model linking equilibrium bidding behavior and tax policy to analyze an economically important market. Overall, this paper provides a reassessment of the reason why tax advantages for municipal bonds lower borrowing costs for state and local governments: they encourage the participation of bidders in municipal bond auctions and stimulate more competitive bidding by existing bidders, with both of these dynamics serving to lower markups and borrowing rates. This implies that, in addition to reconsidering the role of tax incentives, future policies that aim to improve the functioning of the market for municipal bonds may consider other instruments that directly deal with the limited competition for these bonds in the primary market.

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Data Availability Statement

Some of the data underlying this article were provided by third parties. As documented in Online Appendix A, this includes the data from Thomson Reuters as well as The Bond Buyer. The first data set is available through the *New Municipal Issues* category of the SDC Platinum database. The second data set can be acquired through the bond sales results archive of Bond Buyer's Market Data. The DOI for the replication package is 10.5281/zenodo.6518450 and the package can be accessed via https://doi.org/10.5281/zenodo.6518450.