Tax Advantages and Imperfect Competition in Auctions for Municipal Bonds*

Daniel Garrett
The Wharton School,
University of Pennsylvania

Andrey Ordin
University of Chicago Harris School
& University of Texas at Austin McCombs School

James W. Roberts
Duke University
& NBER

Juan Carlos Suárez Serrato
Duke University
& NBER

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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:

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

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, 2008-2015). 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 (2008-2015) 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	0.581	0.571	0.559	0.559	0.547
	(0.118)	(0.122)	(0.131)	(0.131)	(0.133)
	0.000	0.000	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid					
Effective Rate	-4.525	-5.082	-5.102	-5.100	-5.222
	(2.514)	(2.359)	(2.313)	(2.283)	(2.282)
	0.073	0.032	0.028	0.026	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, 2008-2015), 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 $\boldsymbol{N}$								
Effective Rate	0.581	0.557	0.642	0.581	0.574	0.583	0.566	0.545
	(0.118)	(0.107)	(0.156)	(0.118)	(0.103)	(0.117)	(0.107)	(0.125)
	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	-4.525	-4.813	-4.417	-4.553	-4.684	-4.663	-4.575	-5.901
	(2.514)	(2.350)	(2.425)	(2.474)	(2.464)	(2.565)	(2.548)	(2.315)
	0.073	0.041	0.069	0.066	0.058	0.070	0.073	0.011
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:

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

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:

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

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:

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

The first order condition for the profit maximization problem is:

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

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:

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

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:

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

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:

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

where $g(b_1, \dots, b_{n_j}; \theta)$ 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

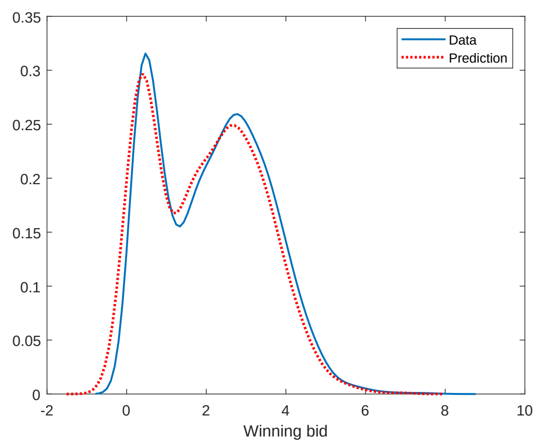
	Values ($\theta_{\tilde{v}}$)		Entry Costs (θ_d)		Unobs. Hetero. (θ_U)
	(1)	(2)	(3)	(4)	(5)
	$\widehat{\beta}$	$\widehat{\gamma}$	$\widehat{\kappa}_1$	$\widehat{\kappa}_2$	$\widehat{\sigma}_U$
Variable	Mean	StDev	Mean	StDev	StDev
Const	3.551	1.471	-16.053	20.589	0.449
	(0.028)	(0.008)	(0.730)	(1.108)	(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 changes, which forces him to further lower his bid. This is shown in the third row of the table, where we

[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.

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

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

[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.

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:

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

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.

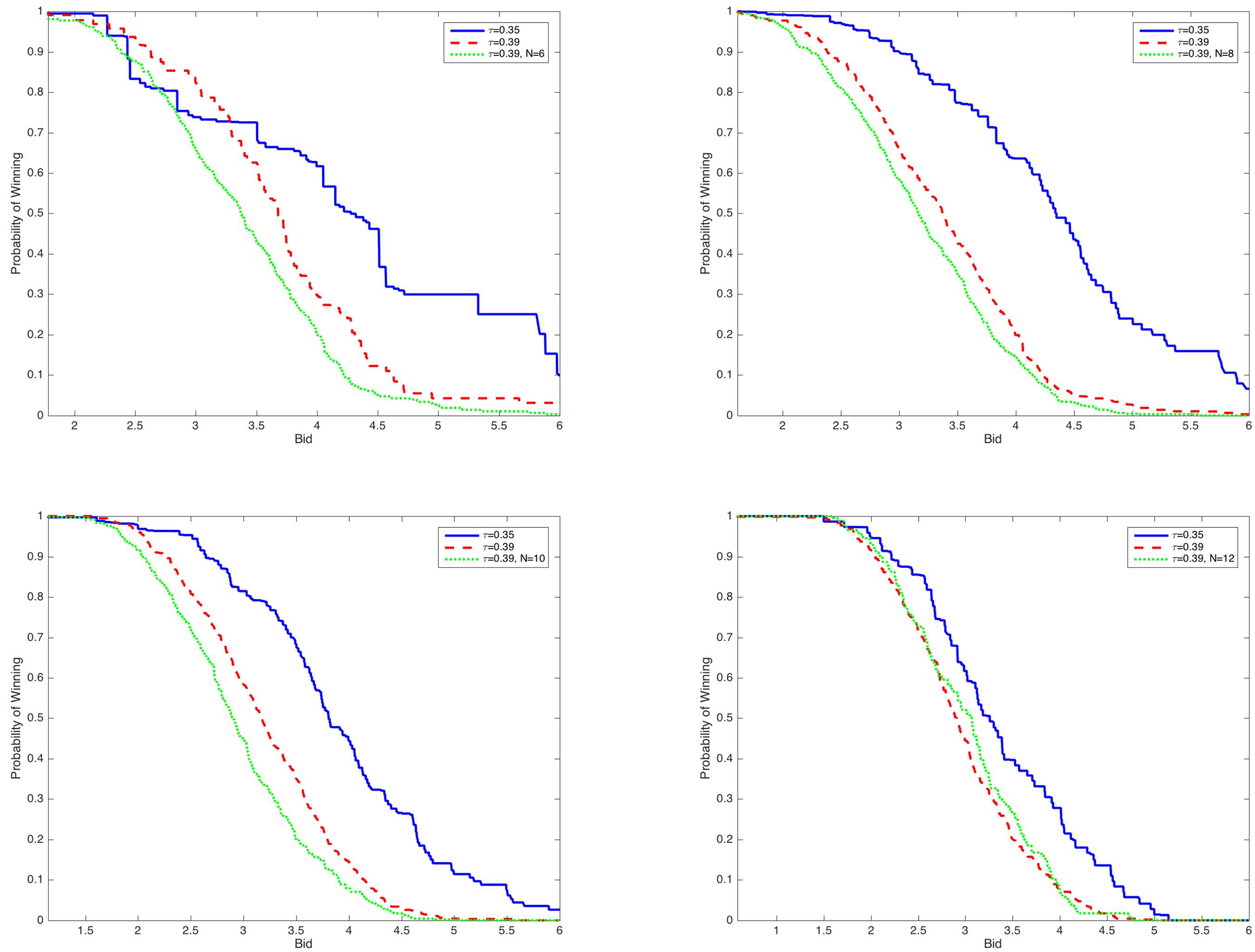
While the model imposes a parametric structure to incorporate a rich set of observables, we now show that the key interactions between taxes and the probability of winning an auction are evident in the raw data. Specifically, we show how changes in τ affect non-parametric estimates of the probability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

[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.

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

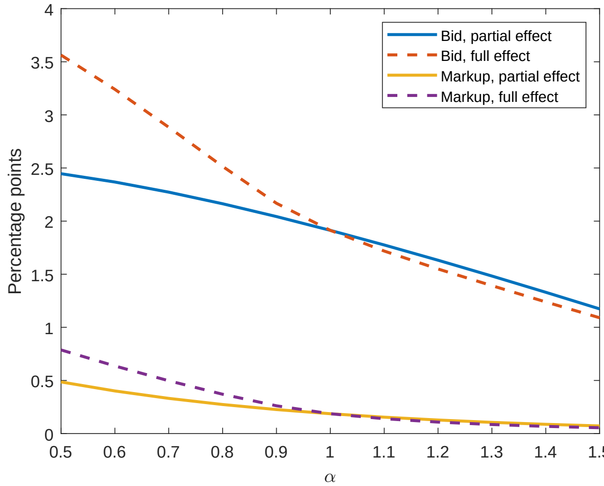
We now use our structural model to improve our understanding of the effects of tax policies and regulations on municipal bond auctions. Section 7.1 highlights the benefits of our structural model by quantifying how different policies that impact the tax advantage—e.g., state taxes, federal taxes, the 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.

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

[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 $\alpha = 0.73$.

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.27-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.

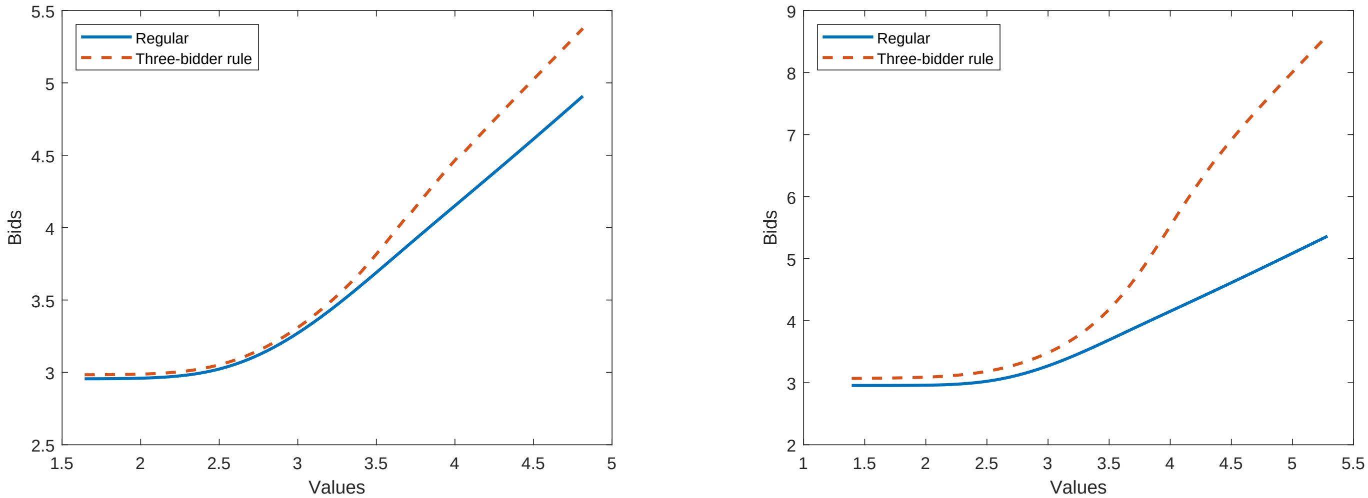
Our model provides an ideal framework to evaluate the effects of this type of regulation. First, our model captures the institutional feature of auction participants not knowing the number of other competitors when they submit their bids. Consequently, under the three-bidder rule, they will not know 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, though this case is much closer to the baseline scenario. The same can be said about the average markups

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

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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Online Appendix: Not For Publication

This appendix includes several sections of supplemental information. Appendix A contains variable definitions for all variables used in any part of the analysis and also has a precise derivation of useful formulas using TAXSIM variables. Appendix B describes the sample selection process. Robustness checks of the primary reduced-form results are presented in Appendix C. The derivation of the full model is shown in Appendix D, and robustness checks for alternative model specifications are presented in Appendix E. Appendix F provides additional details behind the three-bidder rule and of our simulations in Section 7.2. Appendix G lists several potential policy reforms that motivate our counterfactual simulations. Finally, Appendix H provides additional details underlying our cost-benefit calculations.

A Data Appendix

A.1 Variable Definitions

A.1.1 Tax Variables

1. State personal income tax rate. Effective top marginal personal income tax rate in each state derived from simulated tax returns with variation across states and years. This variable is already corrected for deductibility of federal taxes where applicable. Data from TAXSIM (Feenberg and Coutts, 1993).

2. Federal personal income tax rate. Effective top marginal personal income tax rate at the federal level derived from simulated tax returns. This variable is already corrected for the deductibility of state taxes, so there is variation across states and years. Data come from column labeled "wages" in TAXSIM (Feenberg and Coutts, 1993).

3. Effective personal income tax rate. The sum of state and federal personal income tax rates. Data from TAXSIM (Feenberg and Coutts, 1993).

A.1.2 Auction-Specific Variables

1. Bid. An interest rate stated in either TIC or NIC submitted by a bidder to an auction. Data from The Bond Buyer (2016); SDC Platinum (2016). This is scaled to be in basis points in Tables A.1 and 1.

2. Number of bidders. The number of bidders who submit bids in an auction. Data from The Bond Buyer (2016).

3. Number of potential bidders. The number of bidders who could have submitted bids in each auction. Data from The Bond Buyer (2016) and authors' calculation. See Section 2.3 for the explicit mathematical formulation.

4. Bidder and buyer. The names of banks submitting bids in each auction. The buyer is the bidder who submits the lowest bid. Data from The Bond Buyer (2016).

5. Issuer. The name and state of the municipality selling the bond package. Data from The Bond Buyer (2016); SDC Platinum (2016).

6. Years (2008-2015). Indicator for the year in which the auction takes place. Data from The Bond Buyer (2016); SDC Platinum (2016).

A.1.3 Maturity, Size, Quality, and Refund Controls

1. Maturity. The number of years between the auction and the maturity of the longest-maturity bond in the bond package. Data from The Bond Buyer (2016).

2. Size. The size in millions of USD of the bond package. Data from The Bond Buyer (2016); SDC Platinum (2016). In Tables 1 and A.8, the natural log of size is included instead of the level.

3. Refund. Indicators for different refund statuses including advance refunded, current refunded, or not refunded. Data from SDC Platinum (2016).

4. Quality. Indicators for bins of bond ratings assigned by either Moody's or S&P. Data from SDC Platinum (2016).

A.1.4 Political Party Controls

1. Governor. Percent of votes going to the Republican party in the most recent state election for governor without counting third-party votes. Data from Caesar and Saldin (2006) updated through 2010 and imputed for future years.

2. Senate. Percent of votes going to the Republican party in the most recent senate election in each state without counting third-party votes. Data from Caesar and Saldin (2006) updated through 2010 and imputed for future years.

3. President. Percent of votes going to the Republican party in the most recent presidential election in each state without counting third-party votes. Data from Caesar and Saldin (2006) updated through 2010 and imputed for future years.

4. Major Party Index (MPI). The average percent of votes over 50% going to the dominant political party across six major elections in each state, as calculated by Caesar and Saldin (2006). Data updated through 2010 and imputed for future years. MPI is not used in Table 1 but is part of the structural model controls used in Table A.8.

A.1.5 Other Tax Policy Controls

1. Sales tax rate. Percent sales tax rate charged by the state. Data collected by Suárez Serrato and Zidar (2016).

2. Corporate income tax rate. Percent corporate income tax rate charged by the state. Data collected by Suárez Serrato and Zidar (2016).

3. Sales tax apportionment weight. Sales apportionment factor for multi-state companies, which assigns a certain amount of a company's income to each state for corporate income tax purposes based on sales in that state. Data collected by Suárez Serrato and Zidar (2016).

4. Alternative minimum tax. Indicator for an alternative minimum tax in the state personal income tax code. Data from CCH (2008-2015).

5. Federal tax deductibility. Indicator for deductibility of federal taxes paid from state tax liability. Data from CCH (2008-2015).

6. Own bond interest exempt. Indicator for personal income tax exemption of municipal bond income from bonds that originate in the same state. Data from CCH (2008-2015).

7. Other bond interest exempt. Indicator for personal income tax exemption of municipal bond income from bonds that originate in other states. Data from CCH (2008-2015).

A.1.6 Government Spending and Economic Variables

1. Unemployment rate. The annual average percent of individuals currently looking for work in each state who do not have active employment. Data from Bureau of Labor Statistics (2017). The first difference of the unemployment rate is included in Table A.8.

2. Gross domestic product (GDP). The total economic activity in each state-year. Data from Bureau of Economic Analysis (2017). The first difference of the log of GDP is included in Table A.8.

3. State government spending. Total annual expenditures by the state government. Data from Census Bureau (1994-2014) with 2015 entries imputed.

4. State intergovernmental transfers. Total annual transfers from state to local governments. Data from Census Bureau (1994-2014) with 2015 entries imputed.

5. State interest payments. Total annual interest payments for all local governments and state agencies within a state. Data from Census Bureau (1994-2014).

6. 1-year LIBOR swap rate. The fixed rate paid on a 1-year interest rate swap. Data from Board of Governors of the Federal Reserve System (2018).

7. 7-day municipal VRDO yield. Variable rate demand obligation yields from the Securities Industry and Financial Markets Association (SIFMA). An index of yields on a sample of large, AAA-rated municipal bonds with variable rates. Data from SIFMA (2020).

A.2 Effective Rate Calculations

From TAXSIM, we obtain the variables for top marginal state and federal personal income tax rates, $\tilde{t}_s$ and $\tilde{t}_f$, respectively. Each of these variables is already defined such that after tax income (ATI) can be described as $ATI = Income(1 - \tilde{t}_f - \tilde{t}_s)$. The effective tax rate is simply $\tau \equiv 1 - ATI/Income = \tilde{t}_f + \tilde{t}_s$. However, the variables from TAXSIM already account for interactions of state and federal rates so they cannot be used directly for counterfactual simulations of changes in one rate or the other.

Let T_f be the total federal tax liability and T_s be the total state tax liability. State taxes are always deductible from federal tax liability so $T_f = t_f(Income - T_s)$. For all but eight states, federal taxes are not deductible from state tax liability so that $T_s = t_s Income$, which further implies $T_f + T_s = Income(t_f(1 - t_s) + t_s)$. In this case, ATI/Income is characterized as the following:

$$ATI/Income = 1 - (T_f + T_s)/Income = 1 - (t_f(1 - t_s) + t_s)$$

The effective rate for states that do not allow deduction of federal taxes is defined as $\tau = t_f(1-t_s)+t_s$. For states that do allow federal deduction, federal tax liability follows the same formula $T_f = t_f(Income - T_s)$, but state taxes are now $T_s = t_s(Income - T_f)$.

$$T_s = t_s(Income - t_f(Income - T_s))$$
$$T_s = t_s Income(1 - t_f)/(1 - t_s t_f)$$

This also complicates the federal tax burden.

$$T_f = t_f(Income - Ts)$$
$$T_f = t_f(Income - t_s Income(1 - t_f)/(1 - t_s t_f))$$
$$T_f = t_f Income(1 - t_s(1 - t_f)/(1 - t_s t_f))$$

Finding $1 - ATI/Income$ for these states with federal deductibility yields $\tau = t_f(1 - t_s(1 - t_f)/(1 - t_s t_f)) + t_s(1 - t_f)/(1 - t_s t_f)$. The remaining complication is finding t_s and t_f from $\tilde{t}_s$ and $\tilde{t}_f$ as presented by TAXSIM. t_f can be found by two equivalent methods: first, for states with no state-level personal income tax, $t_f = \tilde{t}_f$; and second, for states without federal deductibility, $t_f = \tilde{t}_f/(1 - \tilde{t}_s)$. For states without federal deductibility, the actual tax rate is trivially equivalent to the TAXSIM reported rate. For states with federal deductibility:

$$\tilde{t}_s = t_s(1 - t_f)/(1 - t_s t_f)$$
$$\tilde{t}_s = t_s - t_s t_f + \tilde{t}_s t_s t_f$$
$$\implies t_s = \tilde{t}_s/(1 - t_f + \tilde{t}_s t_f)$$

The underlying tax rates and the counterfactual effective rates can be calculated directly from t_s and t_f. If a state does not exempt interest on its own bonds, then state taxes are still paid on interest and the effective rate of the exemption is equal to the federal rate corrected for the state tax deduction.

B Sample

B.1 Construction

The combined Bond Buyer and SDC data represent 41,918 bonds issued in competitive auctions between February 2008 and June 2016 and worth a total of \$589.9 billion. There is significant variation in the structure of the bond packages on several different dimensions. Most notably, the size of the bonds varies from \$10,000 to \$950 million with a median value of \$4.05 million. A total of 91.8% of the market value comes from issuances of more than \$5 million. The interest rates paid by municipalities range from 0.005% to 8.5% with a median rate of 2.16%. Maturities range from less than one year to 40 years with a median maturity of 10 years.

Bonds can be funded by either general obligation (GO) or revenue (RV). GO bonds are paid back using any financing capacity of the municipality. GO bonds are more commonly used to finance roads, public schools, and low-income housing units that beneficiaries do not pay fees to utilize. Among the bonds in the combined data, 4,220 (10.07%) are RV bonds, and the remaining 37,698 (89.93%) are GO bonds.

From the total set of municipal bond auctions in our data, we create the sample that we analyze by dropping the following: RV bonds, bonds for which we lack important information (like maturity or size), bonds with a total size of less than \$5 million, taxable municipal bonds, and Build America Bonds (BABs).[62] The step-by-step outcomes of our sample construction are shown in Tables A.2 and A.3.

After merging the SDC Platinum and Bond Buyer data, we are left with 15,354 auctions. Of those, 433 are dropped because they were issued in 2016, a year for which we do not have corresponding TAXSIM data, and 290 are dropped because the winning bid is missing. The final analysis sample is made up of

[62]The American Recovery and Reinvestment Act of 2009 created an additional class of taxable municipal debt: BABs. The return to the investor in BABs is taxable, but the federal government partially reimburses municipalities for the interest cost incurred. These bonds show up in the data from 2009-2011, but we exclude them from our analysis as demand for these bonds would not have been directly influenced by tax policy.

14,631 auctions from 2008 to 2015.

B.2 Bidders

The agents placing bids in the auctions that we study are registered and licensed municipal securities representatives working for investment banks. Following guidance by the MSRB, we treat all divisions within the same bank as a single bidder.[63,64] To participate in these auctions, a bank and the underwriting agents must meet several regulatory thresholds. The following is a list of several of the most prominent barriers to entry in this market.

- Rule G-3 says that any underwriter or other "municipal securities representative" must take and pass both the Securities Industry Essentials (SIE) Examination and the Municipal Securities Representative Qualification Examination (Series 52). Further, the principal of each group must also take and pass the Municipal Securities Principal Qualification Examination (Series 53). These credentials expire after two years of disuse.
- Rule A-12 requires that all brokers, dealers, and advisors register with the MSRB, paying a $1,000 one-time fee and a $1,000 annual fee.
- All underwriters are subject to examination every 4 years to make sure they are in compliance with all relevant MSRB rules according to Rule G-16.

Table A.5 describes the bidding frequency among 10 most frequent auction participants. Together, they account for about 50% of all bids submitted in our sample.

C Robustness of Reduced-Form Results

C.1 Additional Specifications Detailing Effect of Taxes on Winning Bid

Table A.8 builds on the main specifications presented in Table 1 with additional controls. Column (1) is the same across tables for comparison, with base controls including state and year fixed effects, maturity fixed effects, size controls, quality fixed effects, and refund status fixed effects. Column (2) presents a new specification that uses controls for state and year fixed effects, maturity fixed effects, corporate tax rates, property tax rates, sales tax rates, the major party index, and presidential, gubernatorial, and Senate voting records. Nebraska is missing MPI data so its 18 auctions are dropped from specifications with structural model controls. These are the same controls as those used in Section 5.4. Column (3) uses every control in the robustness table plus every control in Table 2. The estimated coefficients are very stable at between 6.5 and 6.7 basis points across all specifications without controls for the number of actual or potential bidders. With controls for actual and potential bidders shown in the third panel, the estimates still only vary from 4.5 to 5.4 basis points.

Table A.9 shows additional specifications of the regression equation estimated in Table 1. Columns (1) to (4) show different versions of the choice of standard errors. We use standard errors clustered at the state-year level in the main specifications, which are more conservative than standard errors clustered at

[63] When defining the relevant regulatory unit for municipal bond underwriters, MSRB Rule G-1 states that "All such geographic, organizational or operational units of the bank shall be considered in the aggregate as the separately identifiable department or division of the bank for purposes of this rule."

[64] In practice, we find that this affects only 7.7% of auctions in our estimation sample. These auctions have an average of 7.5 bidders, which makes them more competitive than the average auction with 5.6 bidders. The majority of these cases involve one bank. We only collapse more than one bid in 1.8% of auctions. The average number of bidders in these auctions is 11.

the state-month level and robust standard errors. Columns (5) and (6) show the robustness of the results to monthly and daily fixed effects, respectively. The specification in Column (7) expands the sample universe to include all bonds sold at auction, including those sold for less than $5 million. The specification including small bonds is weighted by size bins.

We show further results that explore additional potential threats to identification as well as potential biases due to variable measurement in Table A.10. One potential concern is that changes in the top marginal tax rate coincide with market trends in borrowing costs that are not captured by year fixed effects. Columns (2) and (3) of Table A.10 expand our baseline specification by including controls for interest rate risk and bond callability. Column (2) includes the swap rate between the 3-month and 1-year LIBOR, which is a strong proxy for bond market uncertainty (Board of Governors of the Federal Reserve System, 2018), as well as the SIFMA 7-day variable rate demand obligation yield for municipal debt (SIFMA, 2020), which proxies for market conditions in the municipal bond market. Both of these measures track market conditions at a high frequency, given that bond market conditions may vary widely within a given year. In Column (2), we estimate an effect of -6.347, which is very close to the result in our baseline specification from Table 1 in Column (1). In addition, in Column (3), we add a dummy variable for bond callability as well as fixed effects for the number of years until the first call date. These additional controls result in a coefficient equal to -6.721, which also lies in the range of the estimates in Table 1.

C.2 Panel Data and Event Study Analyses

We now exploit the panel dimension of our data to explore the identifying variation in the effective tax rate. To clarify the source of variation, we collapse our data to the issuer-year level and estimate our main specification in changes over time. This clarifies that our estimates are driven by bond auctions by the same issuer observed across periods with different tax rates. We take the first difference of Equation 2 and estimate the regression:

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

where the state fixed effects are absorbed in the difference. We restrict the sample of issuers to those with issues in at least three sets of consecutive years in 2008-2015, which leaves us with 4,692 issuer-year observations. Forty-eight percent of the issuer-years in this sample have an associated tax change. We display estimates of the first differences regression using year fixed effects, quality controls, refund controls, maturity controls, political controls, other state policy controls, and size controls in Panel (a) of Figure A.7. The estimate of β is -9.73 with a standard error of 2.59, which allows us to reject the hypothesis of a null effect with a p-value of 0.001.

We now show that the timing of the change in borrowing costs lines up with the change in taxes. In Panel (b) of Figure A.7, we present a placebo test that replaces $\Delta \tau_{st}$ with $\Delta \tau_{st+1}$ so that the tax changes happen in the future and should not be predictive of current borrowing costs. We estimate a placebo coefficient equal to 1.07 with a standard error of 2.76 and fail to reject a null effect with a p-value of 0.701. This shows that municipalities experience a reduction in borrowing costs immediately after the change in taxes and that borrowing costs do not predict tax changes. We provide further evidence that municipalities in states that changed taxes were not experiencing a secular decline in borrowing costs by estimating an event study in Appendix C.1; Figure A.17 shows that the results of the event study match our baseline results.

We also provide additional evidence that municipalities in states that changed taxes were not experiencing a secular decline in borrowing costs before a tax increase by estimating an event study of the form:

$$\Delta b_{1ist} = \sum_{j=-2,-1,0,1,2} \beta^{t-j} \Delta\tau_{st-j} + \Delta X_{ist}\Gamma + \Delta\varepsilon_{ist}.$$

Figure A.17 displays the estimates from this regression using tax changes from 2005 to 2016 and the average winning bids at the issuer-year level from 2008 to 2014. The limitation of the sample to issuers who issue in 5 consecutive years reduces the number of observations to 3,923 issuer-years, which severely hampers statistical power although the point estimates are nearly identical. The blue line with circle markers plots the result of this estimation when we include all of the leads and lags of the tax change variable. This line shows that there are no significant trends in borrowing costs prior to the tax change and that the greatest change in borrowing costs occurs after the tax change. Since the coefficients for the years before the tax change are not statistically significant (p-value 0.76), we focus on the orange line with diamond markers, which does not include pre-trends. The estimated effect is stable over time and centers around the coefficient from our main specification in levels, which equals -6.75 and which is depicted by the green lines with square markers. While this specification further restricts our data to those municipalities with many bond offerings, it clarifies that the reduced-form effect is identified by municipalities that issue bonds in periods with different tax rates, and the timing of the changes in tax rates and borrowing costs provides further evidence that our estimates are not driven by a spurious relation and can be interpreted as causal.

C.3 Assessing Definitions of Potential and Actual Bidders

Panel B in Table 1 shows that, using our preferred definition, the number of potential bidders is responsive to changes in the tax advantage. The primary definition of potential bidders is detailed in Section 2.3.

We now explore whether the main results hold for the number of actual bidders as well as for alternative definition of the number of potential bidders. "Actual bidders" refers to the number of unique entities that are observed bidding in a given auction. The alternative specification, referred to as "Definition 2," is the number of unique entities that participate in auctions held in the same state and month. This definition yields, on average, a much larger number than the baseline, Definition 1. Table A.11 shows that actual and potential participation is increasing consistently across both definitions. The effects on these panels are stable across specifications and are statistically significant at the 1% level in all cases. As expected, the values of the coefficient vary across definitions of potential bidders, as some definitions are broader and include bidders that may have very little chance of responding to the change in taxes.

C.4 Auction Participation by Bidder Type

Panel B in Table 1 shows that, using our preferred definition, the number of potential bidders is responsive to changes in the tax advantage. Here, we assign types for each underwriter depending on the geography, the timing, and the frequency of the bids it submitted in our sample. We then study which types of the bidders drive our results for the effect of taxes on the participation decisions of the agents.

Recall our baseline definition for the number of potential bidders.

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

Let t denote the type of the agent a participating in auction j. Now define the number of type t potential bidders as

$$N_{j,t} = n_{j,t} + \frac{\sum_{i \in G} \sum_{a \in i} \mathbb{1}(a \text{ is of type } t) \mathbb{1}(a \text{ not in } j) K\left(\frac{S_i - S_j}{h_S}\right) K\left(\frac{M_i - M_j}{h_M}\right)}{\sum_{i \in G} K\left(\frac{S_i - S_j}{h_S}\right) K\left(\frac{M_i - M_j}{h_M}\right)}.$$

This representation is helpful in understanding how different bidder types respond to a change in the effective tax rate. Below, we estimate regressions analogous to Panel B in Table 1 for $N_{j,t}$ rather than N_j. We perform this analysis for several types of bidders, namely:

1. all bidders. This is the baseline definition of N in Panel B of Table 1.
2. State-incumbents. Bidder a in auction j we call an incumbent if a participated in at least one of the auctions in the same state as j that was held prior to j.
3. Incumbents. Bidder a is an incumbent in auction j if a participated in at least one auction that was held prior to j.
4. Low frequency. This includes all agents that have submitted fewer than 10 bids over the entire sample.
5. One state. This includes agents that only ever bid within one state.
6. Top 10. This includes 10 of the most frequent bidders in the data, as summarized in Table A.5.

The prevalence of the different bidder types is reported in Table A.6. We find that it is common to see state-incumbent bidders in the data, as approximately 88% of an average set of potential bidders is comprised of bidders with such types. One-state bidders, on the other hand, are rare, suggesting that the most common bidder is one who participates in multiple auctions across multiple states.

Table A.7 summarizes our results for the regression analysis. We find that it is the state-incumbent bidders who drive our baseline results. When effective rates go up by 2 pp, the number of potential bidders increases approximately by 1 and the number of state-incumbent bidders also increases approximately by 1 on average, other things being equal. These state incumbents also represent the majority of the sample, as discussed above. At the same time, our results do not appear to hinge on, say, participation responses of the top 10 most frequent bidders, whose bids collectively account for roughly half our sample. These observations lend further credibility to the i.i.d. entry cost assumption we make for the structural model. We also deepen our analysis of bidder heterogeneity by setting up and estimating a model where the top 10 most frequent bidders have their own distributions of bond valuations and entry costs. This model, partly based on the results of this section, is discussed in Section E.

C.5 Effect of Taxes on Supply of Municipal Debt

We explore whether changes in the effective rate affect the supply of municipal bonds. Adelino et al. (2017) find that the supply of municipal debt increases at the local level when the cost of debt decreases on the intensive margin but not the extensive margin. Since we control for the size of the bond, we are primarily concerned with any supply response on the extensive margin, although we do not find any supply response on the extensive or intensive margins with the shock to borrowing costs induced by tax changes.

Table A.12 shows that the supply of municipal debt is not responsive to changes in effective tax rates. This table displays estimates from a series of regressions of the natural log of the number of bond offerings in each state-month on the effective tax rates as well as other state-level policy controls. The estimates suggest a 1 pp increase in the effective tax rate would lower issuance by 1.3 log points in the first specification or raise issuance by 0.7 log points in the final specification, but all coefficients are statistically insignificant. We find no evidence of a change in the supply of bonds.

C.6 Effect of Taxes on Issue Characteristics and Sale Method

We have shown that total borrowing is not changing in response to effective tax rates in Appendix C.5. However, it could still be the case that the type of bond that is sold is responsive to tax rates. We examine 6 different characteristics of bonds that could be changing in response to tax rates. First, the decision of whether to hold an auction or to negotiate a sale with an underwriter could potentially be influenced by the tax rate since competitive forces in the competitive sales are a function of tax rates. The share of bonds at the state level is not responsive to changes in personal income taxes, as we show in Tables A.13 and A.14 for share of issue count and par value, respectively. Cestau et al. (2020) document how state and local regulations restrict the ability of many municipalities to choose their method of sale. As an additional test of whether the method of sale is a margin that may be responsive to tax rates, we extend our baseline results from Table 1 by including an interaction for 17 states that have restrictions on more than 80% of their issues as determined by Figure 1 in Cestau et al. (2020). The results are shown in Table A.15. The states with restrictions on more than 80% of their bond issues display the same effect of taxes on borrowing as states with fewer restrictions on the method of sale, where one would be most concerned that municipalities or underwriters are able to adjust this margin.

We also look at the design of the bond issues to see whether the tax advantage impacts the term structure or financial controls that could affect the true interest cost. We test the years to maturity, a call provision indicator, a refund indicator, a rating indicator, and an indicator for whether a bond is bank qualified. We fail to find any response in the bond structure in response to changes in taxes, as shown in Table A.16.

C.7 Heterogeneous Effects by Bond maturity

The main reduced-form results in Table 1 assume that the coefficient of the effective rate on the borrowing cost is homogeneous across characteristics of the bonds. We explore whether this is a good assumption by allowing for the effect to vary by bond maturity. Figure A.5 shows the empirical distribution of bond maturity. If the effect of the tax advantage varies by bond maturity, the estimates in Table 1 may be biased. Figure A.6 shows the estimated coefficients of the effective rate on the winning bid by the maturity of the bond. This specification incorporates all of our main controls including bidder fixed effects and corresponds to Column (4) of Table 1. This figure shows that there is some variance in the effects, with larger effects in the first two years and more variable effects in later years. Table A.17 estimates the average partial effect and the effect from the fixed effect model using a weighting estimator in Gibbons et al. (2014). While the effects in Figure A.6 vary a great deal, the interactions between the maturity indicators and the effective rate are not statistically significant, according to the score test p-value. The APE and FE estimates are also not statistically different, according to the Hausman test p-value. The fraction due to competition is slightly smaller in the APE, 25%, versus 30% in the FE. These results suggest that the assumption of homogeneous coefficients is not biasing our main results.

C.8 Coefficient Stability Robustness Tests

In Tables 1 and A.8, we provide evidence of coefficient stability across several specifications with different sequentially added controls. However, Altonji et al. (2005) and Oster (2017) have pointed out that coefficient stability is not sufficient to show that omitted variable bias, or selection on unobservables, is not present. These papers introduce a new way to think about coefficient stability and several ways to test for the robustness of results.

The intuition is that the relative changes in the estimated coefficients when more regressors are added can be used to correct for omitted variable bias. Changes in the R^2 should be used to scale changes in the estimates of β when additional regressors are added sequentially. To test the validity of our coefficient stability as a signal of mitigated omitted variable bias, we implement one of the estimators from Oster (2017). The following is helpful notation used to define the estimator:

- $\dot{\beta}$ and $\dot{R}$. The estimates of β and R^2 from a regression with base controls.
- $\tilde{\beta}$ and $\tilde{R}$. The estimates of β and R^2 from a regression with additional controls.
- β^*. The bias-adjusted estimate of β.
- δ. "Coefficient of proportionality" or proportion of variation in the coefficient of the main variable of interest explainable by unobservables given the constraints on the data. If the estimate of β attenuates toward 0 as more controls are added, δ describes the ratio of the rate at which β approaches 0 relative to the change in variance explained. If the estimates of β grow in magnitude when more estimates are added, this coefficient will be less than 0 because there is no amount of importance that unobservables could have relative to observables to make the coefficient move backwards to 0 assuming that all potential controls that are actually unobservable would continue affecting the coefficient in a constant way as they are added up until all variation is explained. $\delta = 1$ implies that observable and unobservable variables have the same explanatory power over the outcome.
- R_{max}. The maximum R^2 attainable with perfect controls.

The parameters δ and R_{max} are not observable, so we assume that both are equal to one following the guidance of Oster (2017) while calculating bias-adjusted estimates. There are two primary ways to implement the estimator: 1) estimate β^* for a given δ and R_{max}, which we assume to both be equal to 1, or 2) estimate the δ that sets $\beta^* = 0$ given R_{max}. The former gives an unbiased estimate of the causal effect of the variable of interest on the dependent variable under the assumption that future controls that are currently unobservable affect the coefficient of interest in the same way as the most recently added controls, which is a remarkably strong assumption. The latter exercise of estimating δ such that $\beta^* = 0$ allows us to gauge the relative importance of unobservables that would be needed to negate the observed effect entirely. The following is the estimator from which corrected estimates can be calculated given δ or from which δ can be calculated for a given β^*:

$$\beta^* \approx \tilde{\beta} - \delta \left[\dot{\beta} - \tilde{\beta}\right] \frac{R_{max} - \tilde{R}}{\tilde{R} - \dot{R}}$$

We include calculations of both the δ that would be needed to set $\beta^* = 0$ and the β^* implied by the assumption that $\delta = 1$ in Table A.18. We set $R_{max} = 1$ for all specifications. The second to last row of the table is the estimate of δ, the relative importance of remaining unobservables to negate the estimated effect, and the final row is a bias-adjusted estimate of β^* assuming that additional unobservables would change the estimated coefficient by the same magnitude as the last variable added and that we could add enough variables to explain all of the variation in the winning bids.

For Columns (1) and (2), the estimates of δ are negative, implying that adding more variables will continue to increase the magnitude of the estimates, and the corrected estimates for $\delta = 1$ are greater than the original estimates. These results arise from the increase in the magnitude of the estimate when more controls are added while the R^2 has a very modest increase. In Column (3), the estimate attenuates toward 0 slightly with additional controls, which implies an estimate of $\delta > 0$. The estimate of δ is 113.9, which is much larger than the cutoff threshold of 1 suggested in Oster (2017). The interpretation of this estimate is that selection on unobservables would need to be 113.9 times more important than selection on observables for our results to be negated under the assumptions of the test. The results of this test highlight that selection on unobservables would need to be very large to negate the results presented in Tables 1 and 2. However, this exercise also highlights how sensitive this type of proportionality test is to changes in coefficients with small changes in the R^2, and we do not propose that the bias-adjusted estimates in Column (1) are the true effect of taxes on borrowing costs since the estimator relies on strong assumptions.

C.9 Effect of Interest Costs on Tax Rates (Reverse Causality)

As discussed in Section 3, there is a potential that states could adjust their tax rates to deal with changes in local borrowing costs, e.g., to raise revenue to cover past or future increases in interest rates. To investigate this possibility, we gather data from Census Bureau (1994-2014) on total interest payments made by governments in each state from 1994 to 2004 and regress tax rates on these interest payments as well as leads and lags of the interest payments. Tables A.19 and A.20 show that interest payments are not associated with changes in tax rates.

C.10 Elasticity Calculation Motivation and Robustness

The Fama (1977) model, referred to as the bank arbitrage hypothesis in Poterba (1986), provides the primary motivation for why we calculate elasticities with respect to the net-of-tax rate. Let b be the rate of return for municipal bonds that are tax exempt, and let r be the prevailing return on comparable taxable assets. A tax rate, τ, is paid out of returns on taxable assets, so the after-tax return is $(1-\tau)r$. In equilibrium, the after-tax returns on both asset classes must be equivalent:

$$b = (1-\tau)r$$
$$\ln(b) = \ln(1-\tau) + \ln(r).$$

Taking a total derivative and assuming that r is invariant implies:

$$\frac{db}{b} = \frac{d(1-\tau)}{(1-\tau)} \implies \frac{\frac{db}{b}}{\frac{d(1-\tau)}{(1-\tau)}} = \varepsilon^{b}_{1-\tau} = 1.$$

This simple notion of equilibrium provides us with a benchmark by which to judge the magnitudes of our estimates. In a market where changes in taxes are perfectly reflected in municipal borrowing costs, we would expect the elasticity of borrowing costs with respect to take-home rates to be equal to one.

Elasticities with respect to net-of-tax rates are common in other branches of public finance, notably in research on personal income taxes and labor (Feldstein, 1995; Saez et al., 2012) and corporate income taxation (Suárez Serrato and Zidar, 2016; Moretti and Wilson, 2017; Giroud and Rauh, 2019). While to our knowledge this specific elasticity has not been calculated before in an examination of municipal borrowing costs, this is a moment that is helpful for contextualizing the magnitude of the change in borrowing costs relative to benchmarks implied by classic models and for relations to other literatures. In Section 6, we illuminate the central economic mechanisms in our context by decomposing $\varepsilon^{b}_{1-\tau}$ into the equilibrium markup rate, m, the value elasticity, $\varepsilon^{v}_{1-\tau}$, and the markup elasticity, $\varepsilon^{\mu}_{1-\tau}$.

We now discuss sensitivity to how we calculate passthrough elasticities. Figure A.16 shows the distribution of elasticities across states normalized by the tax rates and net-of-tax rates in 2015. In both cases, almost all states have elasticities greater than unity. In the primary definition with net-of-tax rates, no states have elasticities of less than 1. When calculating elasticities with respect to tax rates, we find that only 7 states have elasticities just below 1, and all elasticities are above 0.88. These results show that our conclusion that borrowing costs have large elasticities with respect to tax advantages is not sensitive to focusing on the average tax rate or on the net-of-tax elasticity.

D Detailed Model Derivation

In this section, we consider an auction with N potential bidders. As with most standard results in the auctions literature, we assume here that the valuations of bidders are distributed over some compact support $[\underline{v}, \overline{v}]$, that they are jointly affiliated, and that their density $f(v)$ is continuously differentiable.

First, we assume the existence of a differentiable monotone equilibrium bidding strategy $\beta(v)$. Suppose some agent i decides to enter the auction. At the bidding stage, i solves the maximization problem:

$$\max_{v'} (\beta(v') - v_i)\mathbb{P}r[v_{-i} > v']$$

where v_{-i} denotes all values among the potential competitors. This problem essentially suggests that i optimally chooses to bid as if he had value v', while all other agents bid according to the strategy $\beta(\cdot)$. In the Nash equilibrium, it must be that $v' = v_i$.

This maximization problem generates the first order condition:

$$\beta'(v)\mathbb{P}r[v_{-i} > v] + (\beta(v) - v)\frac{\partial \mathbb{P}r[v_{-i} > v]}{\partial v} = 0$$

where $v' = v = v_i$ when $\beta(\cdot)$ solves for equilibrium. This is a first order differential equation for $\beta(\cdot)$. A slight complication arises due to the lack of a border condition that would allow us to solve the equation. We pick a specific equilibrium in which the participant with the highest valuation bids precisely his own valuation. In this case, the unique solution to the maximization problem can be represented as:

$$\beta(v) = v + \frac{\int_{v}^{\overline{v}} \mathbb{P}r[v_{-i} > s]ds}{\mathbb{P}r[v_{-i} > v]}.$$

This equation represents the unique monotone smooth equilibrium bidding strategy under our assumption $\beta(\overline{v}) = \overline{v}$.[65] We denote the corresponding profits as:

$$\pi(v) = (\beta(v) - v)\mathbb{P}r[v_{-i} > v].$$

Note that these profits implicitly depend on the probability with which agents enter the auction through the right-hand side expression $\mathbb{P}r[v_{-i} > v]$.

At the participation stage of the game, agent i facing costs d_i enters iff:

$$\int_{\underline{v}}^{\overline{v}} \pi(v)f(v)dv \geq d_i.$$

We assume that d_i are i.i.d., which allows us to define:

$$p^* = \mathbb{P}r\left(i \text{ enters the auction}\right) = \mathbb{P}r\left(d_i \leq \int_{\underline{v}}^{\overline{v}} \pi(v)f(v)dv\right) = H\left(\int_{\underline{v}}^{\overline{v}} \pi(v)f(v)dv\right),$$

where $H(\cdot)$ is the CDF of entry costs. With p^* defined, we impose the equilibrium restriction on the whole

[65] In fact, other equilibria with smooth bidding strategies are not as natural because they feature $\beta(\overline{v}) = +\infty$.

entry-bidding game in the form of:

$$\mathbb{P}r[v_{-i} > v] = C^0_{N-1}(1-p^*)^{N-1}(1-F(v)) + \sum_{j=1}^{N-1} C^j_{N-1}(1-p^*)^{N-1-j}\,(p^*)^j\,(1-F(v))^j,$$

which is a result of the assumption that in the absence of other entrants, the sole auction participant competes with the seller.

E Robustness of Structural Estimates

E.1 Factor Reduction

Here we discuss the robustness of our results to the first-stage procedure of regressing factors Z out of the bids.[66] As a reminder, we divide our controls into two categories: maturities and effective rates contained in X along with other variables, which include the controls used in Column (4) of our main regression 1, contained in Z. Our goal is to remove the shifts in the mean of bids due to Z out of the bids. The challenge is to control flexibly enough for X and the competitive pressure as expressed by the number of potential bidders N. Indeed, being shifters of the mean, Z affect the bids the same way regardless of how many bidders there are in the auction. On the other hand, X may be important for the dispersion of the bidder valuations, which would mean X could affect the markup parts of the bids, and the extent of this effect would be different depending on the level of N.[67]

Our approach is to set up the regression described in Equation 13 for a variety of functions $G(X,N)$. Writing $X = (M,\tau)$ to reflect that our controls here contain maturities and the effective rates, we have considered

$$G(M,\tau,N) = \sum_{n=\underline{N}}^{\overline{N}} \mathbb{1}(N=n) \times \begin{cases} M + M^2 + \tau + \tau^2 + \tau^3 + M\tau + M\tau^2 & \text{Baseline} \\ M + \tau & \text{Robustness 1} \\ M + M^2 + \tau + \tau^2 + M\tau & \text{Robustness 2} \\ (\tau+\tau^2) \times \sum\limits_{m=\underline{M}}^{\overline{M}} \mathbb{1}(M=m) & \text{Robustness 3} \\ \sum\limits_{t\subset[\underline{\tau},\overline{\tau}]} \mathbb{1}(\tau\in t) \times \sum\limits_{m=\underline{M}}^{\overline{M}} \mathbb{1}(M=m) & \text{Robustness 4} \end{cases} \tag{16}$$

where, for simplicity, we omit writing out the coefficients defining G, the symbol $\times$ denotes all possible combinations of the products of terms on the left and on the right, and the sum $\sum_{t\subset[\underline{\tau},\overline{\tau}]}$ spans over bins t each representing $1/10^{\text{th}}$ of the full range of τ. Thus, function G corresponding to Robustness 4 takes a unique value for each combination of the number of potential bidders, bond maturity, and each effective rate bin. In our baseline, for each level of N function G is quadratic in maturities and cubic in effective rates. After estimating the regression given by Equation 13 for each of these functions and thus deriving five different estimates $\hat{\delta}$, we re-estimate the entire model separately for each specification. To compare the results from this procedure with our baseline approach, consider Figure A.18. The figure shows that, as functions of the effective rates, the average winning bids and markups predicted by these different models are very close to each other.

[66]Here, we are talking about all bids in the data, not just the winning ones.

[67]In fact, as our results in Section 5.4 suggest, X does matter for the variance of the valuations and the markups.

E.2 Geographic Heterogeneity in Policy Simulations

We now explore how these proposals would affect different states. Figure A.8 plots the effects of setting $\alpha = 0.73$, as in the Obama proposal.[68] Panel (a) plots the observed average winning bids by state, and Panel (b) presents the simulated average winning bid by state after the excludability is capped but without the possibility of additional entry. Panel (c) simulates the effects of the reform allowing for an effect on potential entry. Panel (d) shows that the increase in winning bids ranges from 55 to 100 basis points. Overall, the Obama proposal implies larger increases in borrowing costs. To understand why effects vary across states, consider two important factors. First, since state taxes are deducted from federal taxes, changes in federal taxes have larger effects in states with low or no state income taxes. Indeed, we see large increases in states like South Dakota, Florida, New Hampshire, and Wyoming. Second, the effects of this reform would depend on the level of auction competition across the states, with low-competition states such as New York and New Jersey seeing larger increases in borrowing costs. Figure A.9 presents a similar analysis for the markups across states. While average markups are about 19 basis points, the reform leads to substantial increases in markups between 15 to 35 basis points, particularly due to the entry margin.

E.3 Alternative Model Specifications

We now show that our implications for passthrough elasticities, markups, and counterfactual policies are robust to different model specifications. The model fit and markups are presented in Table A.21 for all the robustness checks to the structural model. We estimate the following models:

S1 Baseline with more flexible $Pr(Entry)$. Here, we let the entry costs of the potential bidders depend on the maturity and effective rate. Our baseline parameterization thus extends to

$$\text{Entry Cost Distribution :} \quad h(d_j; \theta_d) = \quad ln\mathcal{N}(\kappa_1 + \kappa_2 M + \kappa_3 \tau, \kappa_4) \tag{17}$$

S2 Baseline with a different definition of N. Our original definition asserts that agents tend to bid for bonds with similar characteristics. The alternative we consider here is

$$N_j = \#\text{ of unique bidders in state } s(j) \text{ in month } m(j) \tag{18}$$

where j is auction j held in state s in month m. The parameterization of the model primitives is otherwise the same as in the baseline.

S3 A model where we parameterize the distribution of bids rather than values. Under our baseline approach, the response of the winning bids to changes in τ is restricted by the equilibrium bidding function that maps the valuations of the agents to their bids. An alternative approach from the auctions literature (rooted in Guerre et al. (2000)) allows us to estimate the dependence of bids on variables of interest directly and then recover estimates for the implied markups using the equilibrium first order conditions. The details of the model are provided below.

S4 A model with two heterogeneous bidder groups. The top 10 most frequent bidders, whose activity represents about half of all bids submitted in our sample, are gathered together in one group, while the rest of the bidders represent the second group. We let the entry costs and the distribution of agents' valuations vary by group. With this approach, we have more flexibility in predicting how the winning bid responds to changes in τ. In particular, when we study the full effects of tax rate changes, we let the number of potential bidders for each group to respond differently to shifts in τ. This model

[68] Note that Montana and Nebraska had no auctions in the sample from 2013 to 2015 and are excluded from the simulations.

is based on the approach where we parameterize the bids in the style of Athey et al. (2011). The details are provided below.

The estimation results are available in Tables A.22 through A.26. Across the tables, we observe that a) the response of the average bid to changes in τ is approximately the same and b) for higher τ, the variance of valuations/bids tends to get lower, which is suggestive of markups decreasing in τ.

Including the baseline model, the results for the main counterfactual simulations of interest are reported in Tables A.27 through A.30. We note that, both qualitatively and quantitatively, our results are robust to a number of natural extensions of our baseline approach as well as to radically different methods of estimation.

E.3.1 Alternative Model S3: Parameterization of bids

Here we describe a model with an alternative parameterization. The information structure and the order of actions of the agents are the same as in the baseline. Omitting the dependence on the observables, let us denote as $g(\tilde{b})$ and $G(\tilde{b})$, respectively, the density and the cumulative distribution function of the private components of bids defined as $\tilde{b} = b - u$. First, we note that:

$$f\left(\beta^{-1}(\tilde{b}, 0)\right) \frac{\partial \beta^{-1}(\tilde{b}, 0)}{\partial \tilde{b}} = g(\tilde{b}). \tag{19}$$

Plugging this expression into the first order condition delivered by Equation 6, we obtain:

$$\frac{1}{b_i - v_i} = \frac{\sum_{k=1}^{N} Pr^*\left[n = k\right] g(\tilde{b}_i) \left(1 - G(\tilde{b}_i)\right)^{\max(k-2,0)} \max(k-1,1)}{\sum_{k=1}^{N} Pr^*\left[n = k\right] \left(1 - G(\tilde{b}_i)\right)^{\max(k-1,1)}}. \tag{20}$$

Note that this allows us to define the markup as a function of $\tilde{b}$ according to:

$$\mu(\tilde{b}) = \frac{\sum_{k=1}^{N} Pr^*\left[n = k\right] \left(1 - G(\tilde{b}_i)\right)^{\max(k-1,1)}}{\sum_{k=1}^{N} Pr^*\left[n = k\right] g(\tilde{b}_i) \left(1 - G(\tilde{b}_i)\right)^{\max(k-2,0)} \max(k-1,1)}. \tag{21}$$

The idea of the approach is to estimate $g(\tilde{b})$ and $G(\tilde{b})$, then obtain estimates for $\tilde{b}_i$ given the observed bids, i.e., $\tilde{b}_i + u$, and thus construct estimates for the markups corresponding to the observed bids. We compute:

$$\mathbb{E}[u|b_1, \ldots, b_n] = \int_{-\infty}^{\infty} u \frac{f_U(u) g(b_1 - u, \ldots, b_n - u; \theta) du}{\int_{-\infty}^{\infty} f_U(w) g(b_1 - w, \ldots, b_n - w; \theta) dw} du \tag{22}$$

Our estimate for the winners' markups is then constructed as:

$$\hat{m}|b_1, \ldots, b_n = \mu\left(b_1 - \mathbb{E}[u|b_1, \ldots, b_n]\right). \tag{23}$$

To estimate the model, we assume:

$$\begin{aligned} \text{Bid Distribution:} \quad & g(\tilde{b}; \theta_{\tilde{b}}) &=& \overline{\mathcal{N}}(X_j\beta, e^{X_j\gamma}, X_j\delta, \infty) \\ \text{Entry Cost Distribution:} \quad & h(d_j; \theta_d) &=& ln\mathcal{N}(\kappa_1, \kappa_2) \\ \text{Unobservable Heterogeneity Distribution:} \quad & f_U(u; \theta_U) &=& \mathcal{N}(Z_j\Gamma, \sigma_U) \end{aligned}$$

where $\overline{\mathcal{N}}(\mu, \sigma, a, b)$ is a truncated normal distribution with mean μ, standard deviation σ, lower truncation point a and upper truncation point b,[69] $ln\mathcal{N}(c, d)$ is a log-normal distribution with location parameter c and scale parameter d, and $\mathcal{N}(e, f)$ is a normal distribution with mean e and standard deviation f.[70]

In the expression above, covariates X_j and Z_j are the same as in our baseline. In particular, X_j include potential bidders, maturities, and the effective rates, while Z_j 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 unobservable u is assumed to be independent of X_j conditional on Z_j.

We estimate the model using maximum likelihood. For a candidate $\theta = \{\theta_{\tilde{b}}, \theta_d, \theta_U\}$, the likelihood of observing the set of entry and bidding decisions in auction j is:

$$\begin{aligned}\mathcal{L}(\theta) &= \prod_{j=1}^{J} C_{N_j}^{n_j} \hat{p}_j(\theta)^{n_j}(1-\hat{p}_j(\theta))^{N_j-n_j} \int_{-\infty}^{\infty} f_U(u) g(b_1 - u, \ldots, b_{n_j} - u; \theta) du \\ &\text{s.t. } \mathbb{E}_{\tilde{v}_i}\pi(\tilde{v}_i|\hat{p}_j) = H^{-1}(\hat{p}_j;\theta) \quad \forall j = 1, \ldots, J.\end{aligned} \tag{24}$$

To evaluate the likelihood, we need to compute the expected profits of a potential entrant as a function of entry probability. This is done according to:

$$\begin{aligned}\mathbb{E}_{\tilde{v}_i}\pi(\tilde{v}_i|p) &= \int_{\underline{b}}^{\bar{b}} \mu(\tilde{b}_i) g(\tilde{b}_i) Pr(\tilde{b}_i < b_j \; \forall \, j \neq i) d\tilde{b}_i = \int_{\underline{b}}^{\bar{b}} \mu(\tilde{b}_i) g(\tilde{b}_i) \sum_{k=1}^{N} Pr^* [n=k] \left(1 - G(\tilde{b}_i)\right)^{\max(k-1,1)} d\tilde{b}_i \\ &= \int_{\underline{b}}^{\bar{b}} \frac{\left[\sum_{k=1}^{N} Pr^*[n=k] \left(1-G(\tilde{b}_i)\right)^{\max(k-1,1)}\right]^2}{\sum_{k=1}^{N} Pr^*[n=k]\left(1-G(\tilde{b}_i)\right)^{\max(k-2,0)} \max(k-1,1)} d\tilde{b}_i\end{aligned} \tag{25}$$

where the dependence on the entry probability p is contained in the probabilities of observing k active bidders $Pr^*[n=k]$.

E.3.2 Alternative Model S4: Heterogeneous bidders

As one of our counterfactuals, we split the bidders from our sample into two groups: the top 10 most frequent bidders and the rest. Should we find differences in both bidding and participation behavior across the two groups, our out-of-sample predictions about the average winning bid as well as the average markup could potentially be very different from the baseline results. The challenging part of this exercise is to estimate the two-stage model of auction participation and bidding with heterogeneous agents. We therefore follow the approach developed in Athey et al. (2011), where the authors rely on parameterizing the distribution of bids and the probabilities of entry for two types of agents.

Consider an auction with N_1 potential bidders of type 1 and N_2 potential bidders of type 2. Denoting

[69] Note that the observables in our model are b rather than $\tilde{b}$ and that their distribution is not truncated. Consequently, the standard MLE asymptotic results are valid for our parameter estimates. In practice, the variance of bids is typically low enough that $X\beta - \underline{\tilde{b}}$, where $\underline{\tilde{b}}$ is the lower truncation point of bids, is so large that having or not having the lower truncation threshold has virtually no impact on simulated bids. However, it is important to have truncation to ensure the existence of equilibrium in the model. Furthermore, the model itself predicts that, given some distribution of values, bids in equilibrium will naturally have some lower cutoff level.

[70] We model the unobservable heterogeneity as having unconstrained support, which is convenient for MLE. While this choice does allow the possibility of negative bids, our estimates suggest that this is very unlikely (with about a 0.02 probability that the winning bid is negative across our sample). For this reason, we are comfortable with this parameterization, since it is unlikely that truncating $f_U(\cdot)$ would materially impact our results.

as $g_i(\tilde{b})$ and $G_i(\tilde{b})$, respectively, the density and the cumulative distribution function of bids for group i, consider the bidding problem of a type 1 agent with private valuation v:

$$\max_b (b-v) \sum\sum_{k_1+k_2\geq 1}^{k_1\leq N_1, k_2\leq N_2} Pr(n_1 = k_1, n_2 = k_2)(1-G_1(b))^{k_1-1}(1-G_2(b))^{k_2} + (b-v)Pr(n_1 = 1, n_2 = 0)(1-G_1(b)) \tag{26}$$

where the second summand once again corresponds to the possibility of having no competitors; we assume that, in such a case, the bidder competes against the seller's virtual bid, distributed according to G_1. This problem leads to the first order condition similar to the one expressed in Equation 20:

$$\begin{aligned} \frac{1}{b-v} = & \frac{\sum\sum_{k_1+k_2\geq 1}^{k_1\leq N_1, k_2\leq N_2} Pr^*\left[n_1 = k_1, n_2 = k_2\right](k_1-1)g_1(b)(1-G_1(b))^{k_1-2}(1-G_2(b))^{k_2}}{\sum\sum_{k_1+k_2\geq 1}^{k_1\leq N_1, k_2\leq N_2} Pr(n_1 = k_1, n_2 = k_2)(1-G_1(b))^{k_1-1}(1-G_2(b))^{k_2} + Pr(n_1 = 1, n_2 = 0)(1-G_1(b))} \\ & + \frac{\sum\sum_{k_1+k_2\geq 1}^{k_1\leq N_1, k_2\leq N_2} Pr^*\left[n_1 = k_1, n_2 = k_2\right] k_2 g_2(b)(1-G_1(b))^{k_1-1}(1-G_2(b))^{k_2-1}}{\sum\sum_{k_1+k_2\geq 1}^{k_1\leq N_1, k_2\leq N_2} Pr(n_1 = k_1, n_2 = k_2)(1-G_1(b))^{k_1-1}(1-G_2(b))^{k_2} + Pr(n_1 = 1, n_2 = 0)(1-G_1(b))} \\ & + \frac{Pr(n_1 = 1, n_2 = 0)g_1(b)}{\sum\sum_{k_1+k_2\geq 1}^{k_1\leq N_1, k_2\leq N_2} Pr(n_1 = k_1, n_2 = k_2)(1-G_1(b))^{k_1-1}(1-G_2(b))^{k_2} + Pr(n_1 = 1, n_2 = 0)(1-G_1(b))} \end{aligned} \tag{27}$$

A similar expression can be written down for a type 2 bidder. The right-hand side of the equation above is the reciprocal of the markup function similar to the one defined in Equation 21. We compute the estimates for the unobservable according to Equation 23.

Our estimation strategy involves parameterizing the distributions of bids. Additionally, instead of imposing parametric restrictions on the costs of entry for the two bidder types, we directly parameterize the probabilities of entry as in Athey et al. (2011). Specifically, we assume:

$$\begin{aligned} \text{Bid Distribution:} \quad & g_i(\tilde{b}; \theta_{\tilde{b},i}) &=& \overline{\mathcal{N}}(X_j\beta_i, e^{X_j\gamma_i}, X_j\delta_i, \infty) \\ \text{Entry Probability Distribution:} \quad & \lambda_i(d_j; \theta_{d,i}) &=& \mathsf{Logit}(\kappa_i X_j) \\ \text{Unobservable Heterogeneity Distribution:} \quad & f_U(u; \theta_U) &=& \mathcal{N}(Z_j\Gamma, \sigma_U) \end{aligned}$$

where $i = 1, 2$ indexes the two bidder groups. As before, covariates X_j include potential bidders of both types, maturities, and effective rates, while Z_j 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. As usual, the unobservable is assumed to be independent of X_j conditional on Z_j. We estimate the model in two stages. First, we construct the likelihood of the probability of entry to recover $\theta_{d,i}$ as:

$$\mathcal{L}_{entry}(\theta_{d,i}) = \prod_{j=1}^{J}\prod_{i=1}^{2} C_{N_{i,j}}^{n_{i,j}} \Lambda(\kappa_i X_j)^{n_{i,j}} \left(1 - \Lambda(\kappa_i X_j)\right)^{N_{i,j}-n_{i,j}} \tag{28}$$

where $\Lambda(\cdot)$ is the logit cumulative distribution function and $n_{i,j}$ denotes the number of actual bidders of type i in auction j.

The second stage involves computing the likelihood for the bids.

$$\mathcal{L}_{bids}(\theta) = \prod_{j=1}^{J}\int_{-\infty}^{\infty} f_U(u) g_1(b_{1,j}-u, \ldots, b_{n_1,j}-u; \theta_{\tilde{b},1}) g_2(b_{n_1+1,j}-u, \ldots, b_{n,j}-u; \theta_{\tilde{b},2}) du. \tag{29}$$

Here, we denote as $b_{1,j}, \ldots, b_{n_1,j}$ the bids observed in auction j corresponding to type 1 bidders; consequently, bids $b_{n_1+1,j}$ through $b_{n,j}$ correspond to type 2 bidders. At this stage, we also assume for simplicity that the estimates for Γ are the same as the ones that we derive under the assumption of homogeneous bidders. Thus, we only need to estimate $\beta_i, \gamma_i, \delta_i$, and σ_U for $i = 1, 2$.

Estimation results are reported in Tables A.25 and A.26. Once the model is estimated, we proceed to the counterfactuals. Our simulations are performed in a way analogous to the approach we follow in the baseline as described in Section 7.1. As with the baseline, we also consider partial and full effects of taxes. In the model presented above, partial effects account for changes in the probabilities of entry and the distributions of bids for both bidder types. Full effects additionally account for changes in the number of potential bidders by type. The impact of effective tax rate shifts on the number of potential bidders we derive from our results discussed in Section C.4.

To compare the predictions of this model with heterogeneous bidder types against the baseline model, we evaluate the effects of changing the top marginal federal tax rate on the borrowing costs of the municipalities. The results for this model are reported in Table A.30, while the corresponding baseline results are reported in Table 6. We find that, relative to the baseline, the model discussed above tends to somewhat understate the markups; predictions about the changes in the winning bid, however, are very close for the two models.

F The Three-Bidder Rule

In this section, we provide additional details on the three-bidder rule analyzed in Section 7.2.

Section 148 of the Internal Revenue Code establishes an "arbitrage restriction" for tax-exempt municipal bonds sold by communities in the United States. The arbitrage restriction is intended to stop investors from using municipal bond interest to acquire "higher yielding investments," which in the case of municipal bonds means that the tax exemption does not apply to yields that are above the original yield on a municipal bond. The new IRS regulation comes into play in the municipal bond market through "issue prices" where the tax exemption for municipal bonds only applies to the yield of a bond if the yield is lower than it was at the original price—the price at which municipal bonds are sold, or expected to be sold, by final investors. If the issue price is high and the original yield is low relative to where the bond winds up trading in secondary markets, then the tax advantage of municipal bonds has relatively less value to investors.

Determining the issue price—and thus the yield that is tax exempt—is subject to regulation that can drive some bonds to trade with large portions of the yield being taxable despite the bond itself being tax exempt. Having some control over the initial price of a municipal bond is valuable because the issue price affects the maximum tax-exempt yield from a bond.[71] This variation in taxable yield on otherwise tax-exempt assets provides the basis for recent research about how taxes affect asset prices (Ang et al., 2010b) because many municipal bonds transition between taxable and tax-exempt price ranges on secondary markets. Bonds that are trading at a discount relative to their initial price have tax liabilities for the relative market discount while the initial yield is tax exempt. Since 1993, this tax on market discounts for municipal bonds has also included a *de minimis* threshold where the first portion of taxable income from otherwise tax-exempt assets is taxed as capital gains but returns due to further discounts are taxed as personal income.

Ang et al. (2010b) show that these tax considerations matter for how investors value bonds in secondary markets. However, the regulations that determine the initial price have been changing over time. Before 2017, the underwriter of a municipal bond would determine the initial price on the first date in which a binding contract was created for the sale of the bonds based on reasonable expectations of what the price

[71]During our sample period, there are also other considerations for which issue prices are very important, particularly with respect to advanced refunding issues. We abstract away from those issues for the following discussion because they affect only a very small portion of our sample. Flexibility in determining the issue price is valuable to both the issuer and underwriter, as it determines the tax shield.

would be for the sale of the first 10% of the principal value to investors, not including other broker-dealers. The existing regulations during our sample are written such that the bonds do not actually have to be sold at that price as long as the underwriter has a reasonable expectation that would be the price, so the initial price and maximum tax-exempt yield can be set before any bonds are sold.

In December of 2016, the IRS issued new rules about how initial prices are determined; these rules were implemented in June 2017 (Internal Revenue Service, 2016). For most municipal bonds underwriters are no longer allowed to set initial prices based on reasonable expectations but instead must follow one of three rules. The first rule is that the initial price is the price at which 10% of a bond is sold to the public. The second rule allows underwriters to "hold the offering price" by formally promising to sell a bond at a certain price to any willing buyer at the same price for at least five days or until at least 10% of the bond has been sold. The third rule allows issuers and underwriters to follow the old guidelines under which they can set a reasonable expectation of the price on the sale date as long as three potential underwriters submitted bids in a competitive auction.

In our setting, auction participants do not know the level of competition in advance. Consequently, under the three-bidder rule, they will not know their exact valuations for the bond until just after the auction. Here, we perform a series of counterfactuals showing how the rule affects the bidding strategies of the agents and, as a result, how their participation decisions change. We model the effects of the rule by tuning the valuation that the bidder has for the bond depending on the number of active auction participants. When the number of active bidders n is less than three, the effective rate changes from τ to $r\tau$ for various $r \in [0, 1]$, which, in turn, changes how the bond is valued by the bidders. This way we capture the idea that the three-bidder rule reduces the advantage associated with the bond.

Given that the change from τ to $r\tau$ happens after the bids are submitted and n is realized, we need to describe how the valuations of the bond are defined for the bidders. We define the bidder's ex ante valuation as:

$$v = \tilde{v} + u, \quad \tilde{v} = \begin{cases} \tilde{v}_{n<3} & \text{if } n < 3, \\ \tilde{v}_{n\geq 3} & \text{if } n \geq 3. \end{cases} \tag{30}$$

While $\tilde{v}_{n\geq 3}$ has the cumulative distribution function $F(\tilde{v}_{n\geq 3}; \tau)$, its low-competition counterpart has the cumulative distribution function $F(\tilde{v}_{n<3}; r\tau)$. To model the effects of the three-bidder rule, we assume that the respective quantiles of the two valuations are the same, that is:

$$F^{-1}(\tilde{v}_{n<3}; r\tau) = F^{-1}(\tilde{v}_{n\geq 3}; \tau). \tag{31}$$

Upon entry, the agent is assumed to learn his own v, which involves learning both $\tilde{v}_{n<3}$ and $\tilde{v}_{n\geq 3}$. 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. Writing $\beta(\tilde{v}, u) = \tilde{\beta}(\tilde{v}) + u$, we have:

$$\begin{aligned} \frac{\partial}{\partial \tilde{v}} \tilde{\beta}(\tilde{v}) = & \frac{(\tilde{\beta} - \tilde{v}_{n<3}) \sum_{k=1}^{2} Pr^*[n = k](1 - F(\tilde{v}))^{\max(k-2,0)} f(\tilde{v}) \max(k-1, 1)}{\sum_{k=1}^{N} Pr^*[n = k](1 - F(\tilde{v}))^{\max(k-1,1)}} \\ & + \frac{(\tilde{\beta} - \tilde{v}_{n\geq 3}) \sum_{k=3}^{N} Pr^*[n = k](1 - F(\tilde{v}))^{\max(k-1,1)} f(\tilde{v}) \max(k-1, 1)}{\sum_{k=1}^{N} Pr^*[n = k](1 - F(\tilde{v}))^{\max(k-1,1)}} \end{aligned} \tag{32}$$

This equation together with the border condition $\tilde{\beta}(\overline{v}) = \overline{v}_{n<3} Pr(n < 3 | n \geq 1) + \overline{v}_{n\geq 3} Pr(n \geq 3 | n \geq 1)$ delivers the bidding strategy.

Finally, we note that the expected profits of an auction participant with valuation v can be represented as:

$$\begin{aligned}\pi(v) &= Pr(n \leq 2)(\beta(v) - v_{n<3})(1 - F(v)) + \sum_{k=2}^{N-1} Pr(n = k+1)(\beta(v) - v_{n\geq 3})(1 - F(v))^k \\ &= (\beta(v) - v_{n<3})w_1(v) + (\beta(v) - v_{n\geq 3})w_2(v).\end{aligned} \tag{33}$$

In Section 7.2, we discuss how this representation relates to the shape of the equilibrium bidding function under the three-bidder rule.

G Proposed Reforms

There are several recent and current tax reform proposals at the federal level that would change the borrowing cost of municipalities and demand for municipal debt. Broadly speaking, the proposed reforms fit into 3 categories: changing the federal tax rate of the exemption, permanently introducing other types of subsidized municipal debt like Build America Bonds, and changing the scope of projects that are allowed to be tax exempt. The first of these categories is the primary focus of this paper and captures most of the reforms that have been proposed.

Both Democrats and Republicans have proposed plans in recent years to decrease the size of the tax exemption received by municipal bonds. In the Tax Cuts and Jobs Act of 2017, the top marginal rate was cut from 39.6% to 37%. Former President Obama proposed a larger cut to the municipal bond interest exemption in particular without necessarily adjusting the top statutory federal income tax rate. The Obama White House proposed a cap on the municipal bond exemption at 28% first in the American Jobs Act of 2011 and then in budget proposals in subsequent years (National Governors Association, 2012). These specific policy proposals provide the motivation for the choices of federal income tax rates in the counterfactual simulations at $\alpha = \frac{0.28}{0.386} \approx 0.73$ and $\alpha = \frac{0.37}{0.386} \approx 0.96$, where 0.386 is the average top marginal rate in the subsample for the years 2011-2015.

Other reforms to the supply of municipal bonds based on extending the availability of Build America Bond subsidies or tightening tax-exempt eligibility have been discussed by scholars and think-tanks but have not been formally proposed, to our knowledge. The suggestion of Puentes et al. (2013) that BABs are superior to traditional municipal bonds on several margins is echoed in some of the academic literature, including Liu and Denison (2014). Government Finance Officers Association (2000) discusses the potential effects of legislation in the spirit of the Tax Reform Act of 1986, which excluded many bond issues from qualifying for tax exemption.

H Costs and Benefits of Tax Reforms

As we discuss in Section 7.1, the effects stemming from the tax advantage associated with municipal bonds can be evaluated by comparing the fiscal cost of a tax subsidy with the change in the borrowing costs of municipalities. Our analysis starts from two key numbers: the expected tax expenditure over the next 10 years, namely \$500 billion, and the annual payments made by municipalities on their outstanding debt, which total \$122 billion. Recall that, in Section 7.1, we consider tax reforms that reduce the top marginal federal tax rates so that the effective tax rate is set to:

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

for different α. Note that, for a given value of α, the annual tax expenditure is reduced by $(1 - \alpha) \cdot \$50$ billion, while the annual interest payments on the municipal debt go up by $(b(\alpha)/b(1) - 1) \cdot \$122$ billion, $b(\alpha)$ denoting the average borrowing rate as a function of α. We use our model to evaluate $b(\alpha)$ and compute the increase in the interest payments from reduced effective tax rates. Finally, we compute the ratio:

$$\frac{\left(\frac{b(\alpha)}{b(1)} - 1\right) \cdot 122}{(1-\alpha) \cdot 50}$$

representing the effectiveness of the municipal bond tax advantage. We perform this computation using both the linear regression predictions for $b(\alpha)$ and the structural model. The regression prediction is based on our results in Column 4 of Table 1. The structural model is used to predict $b(\alpha)$ under both partial and full effects, as discussed in Section 4.

Figure A.21 describes our results. We can see that both the structural model and the regression make similar predictions for a wide range of α values. While the regression predicts a constant ratio of about 3.2, the structural model that accounts for the effect of taxes on the set of potential bidders forecasts a slightly higher effectiveness, with the ratio being closer to 4 for most values of α.

To understand the cost-efficiency implied by the regression model, note that, for a given α, the change in borrowing costs per dollar of debt payment is given by $b(\alpha) - b(1) = \beta t_f(1-t_s)(1-\alpha)$, where β is our estimate from Table 1. Relative to the reduction in the tax expenditure of $(1-\alpha) \cdot 50$, the effectiveness ratio is:

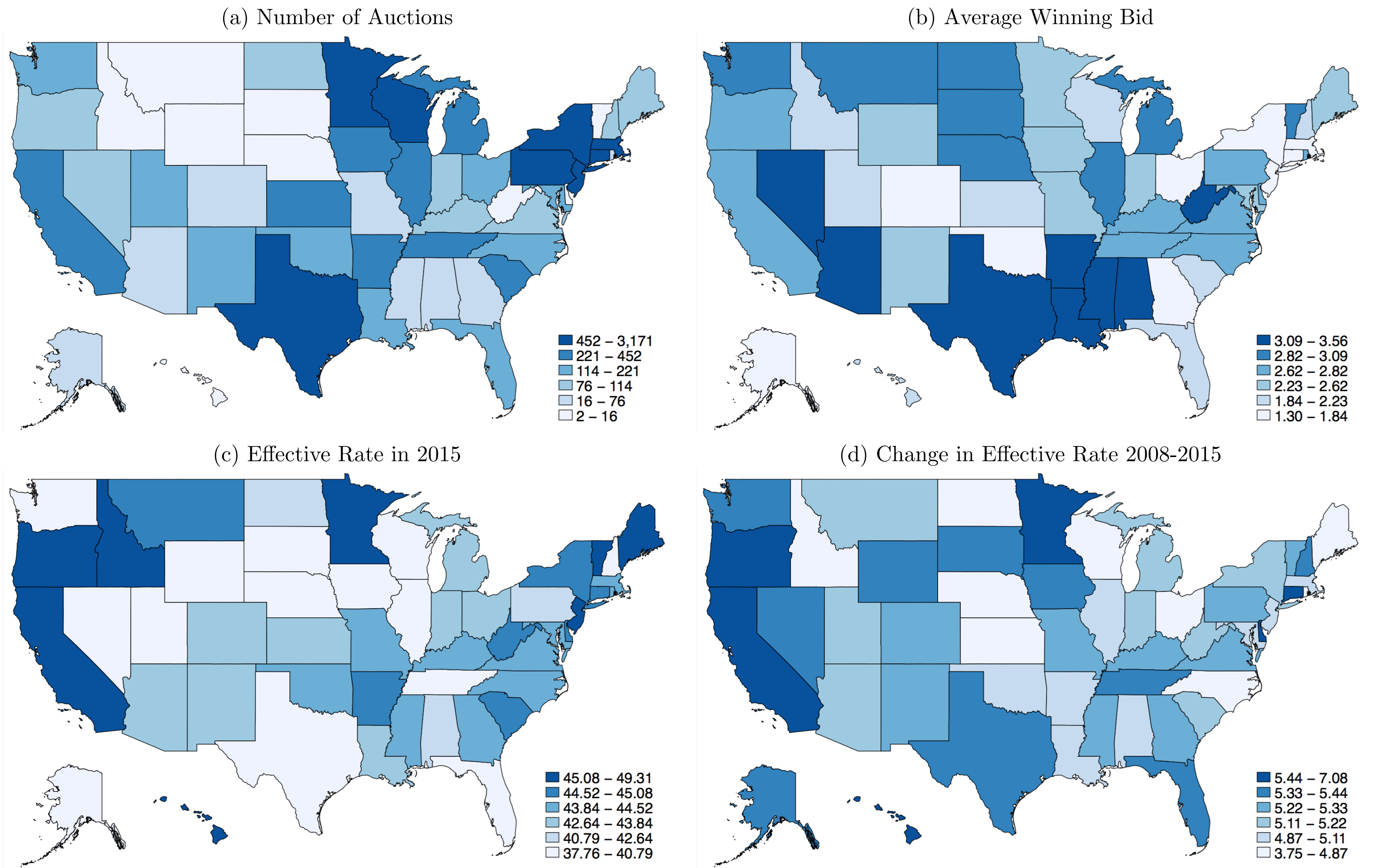
$$\frac{\left(\frac{b(\alpha)}{b(1)} - 1\right) \cdot 122}{(1-\alpha) \cdot 50} = \frac{\beta t_f(1-t_s) \cdot 122}{b(1) \cdot 50} = \frac{\varepsilon^b_{1-\tau} t_f(1-t_s) \cdot 122}{(1-\tau) \cdot 50},$$

where the last equality shows that we can write the effectiveness ratio in terms of the net-of-tax elasticity, $\varepsilon^b_{1-\tau} = \frac{\beta(1-\tau)}{b(1)}$. From this expression, it follows that our reduced-form estimate implies a cost-benefit calculation greater than one whenever:

$$\varepsilon^b_{1-\tau} > \frac{(1-\tau) \cdot 50}{t_f(1-t_s) \cdot 122} \approx 0.73.$$

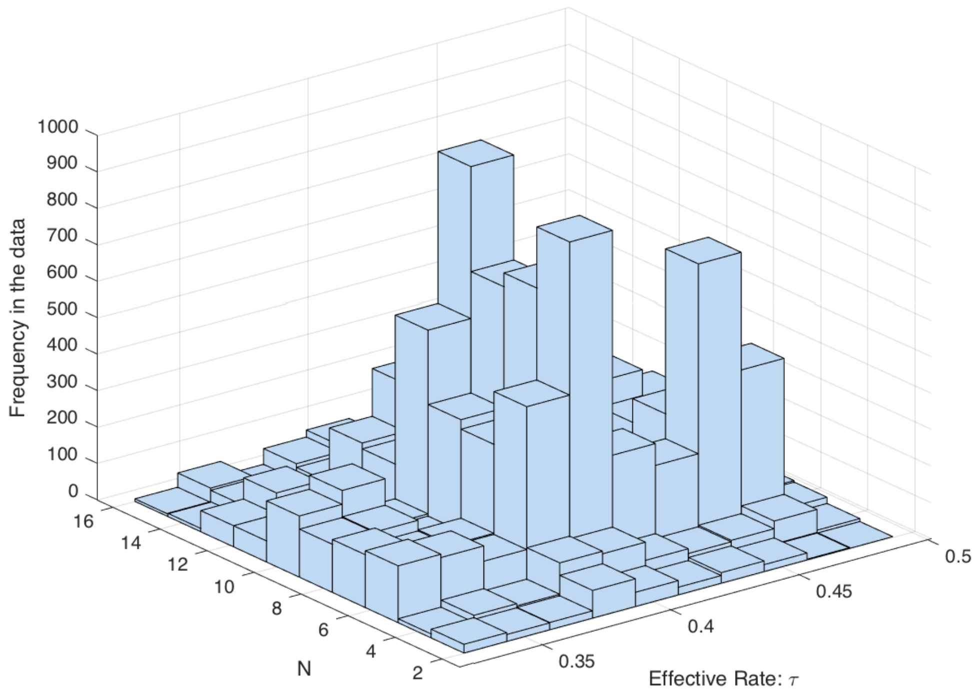
Appendix Graphs

Figure A.1: Maps of Summary Statistics



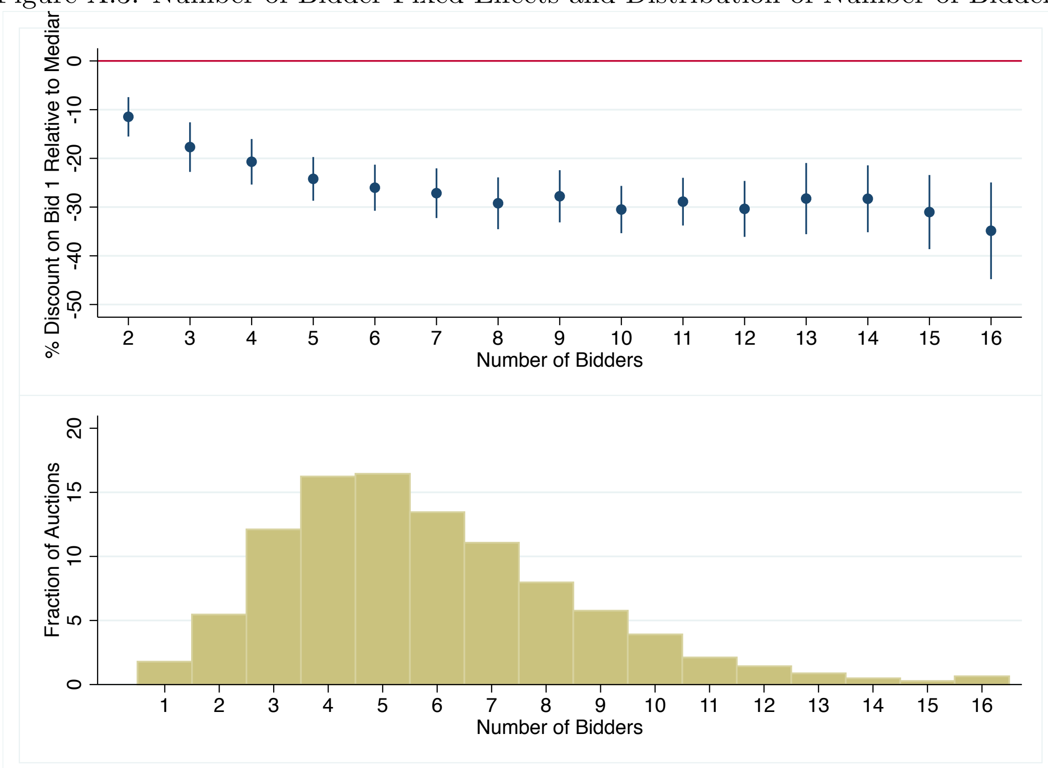
Notes: These maps show the spatial distribution of several important variables. Panel (a) shows the number of auctions in the estimation sample from each state, and Panel (b) shows the average winning bid or interest rate paid by the locality in percentage points. Panels (c) and (d) show the distribution of effective tax rates in percentage points and how those rates change over the sample period, respectively. The data are discussed in Section 2.3 and Appendix A. Additional descriptive statistics are listed in Table A.1.

Figure A.2: Frequency of Auctions by (N, τ) Pairs



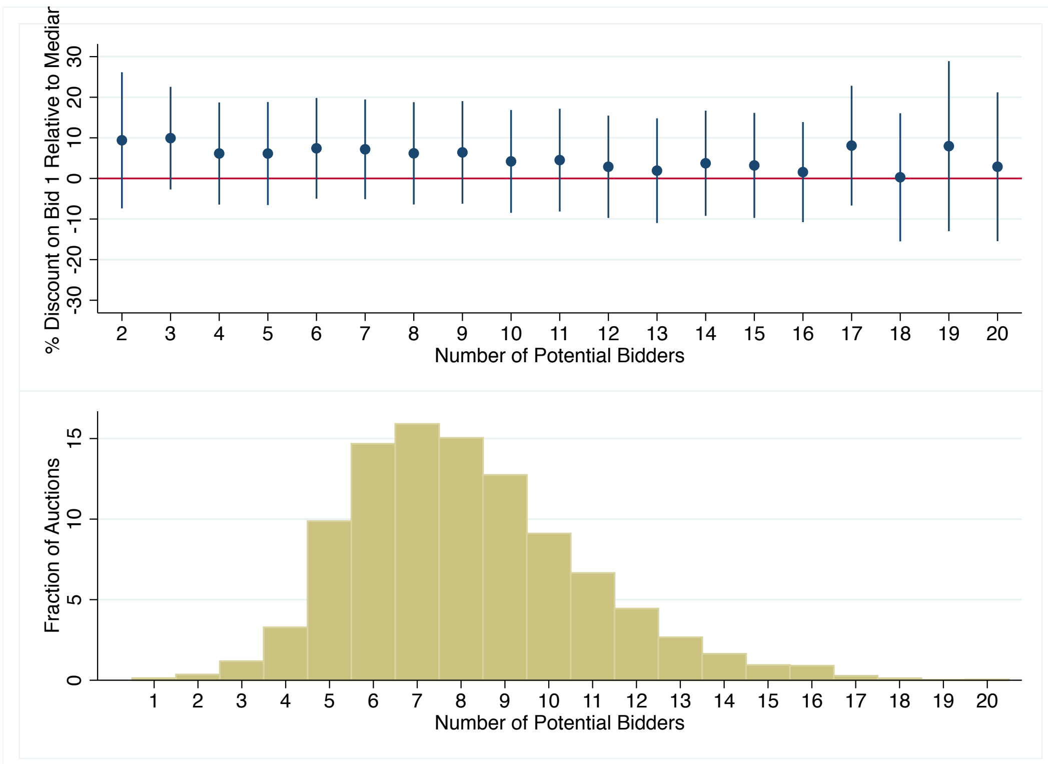
Notes: This figure shows the frequency of observations by number of potential bidders (N) and effective tax rate bins. We observe significant variation in the number of potential bidders even conditional on the level of effective tax rate. See Section 2 for more information about the data and variables.

Figure A.3: Number-of-Bidder Fixed Effects and Distribution of Number of Bidders



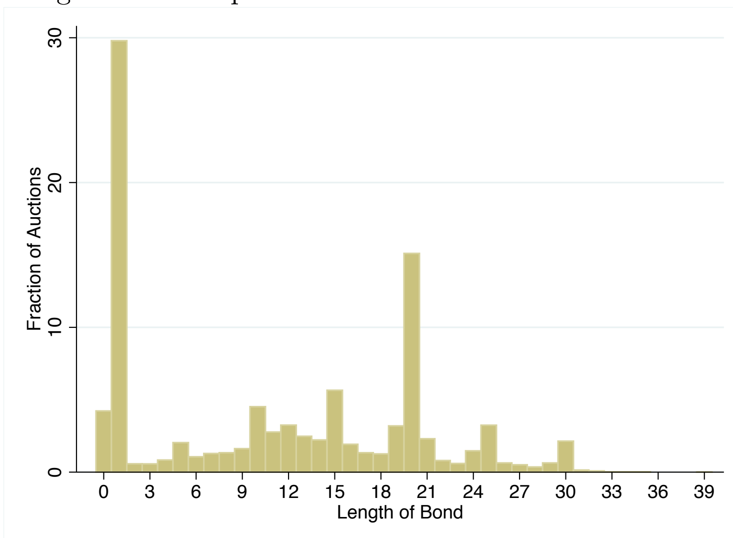
Notes: This figure shows the number-of-bidder fixed effect estimates from specification (4) of Table 1 normalized to the median bid in addition to the empirical distribution of the number of bidders in our sample. The reduced-form analysis is discussed in Section 3, and robustness checks are presented in Appendix C.

Figure A.4: Number-of-Potential-Bidder Fixed Effects and Distribution of Number of Potential Bidders



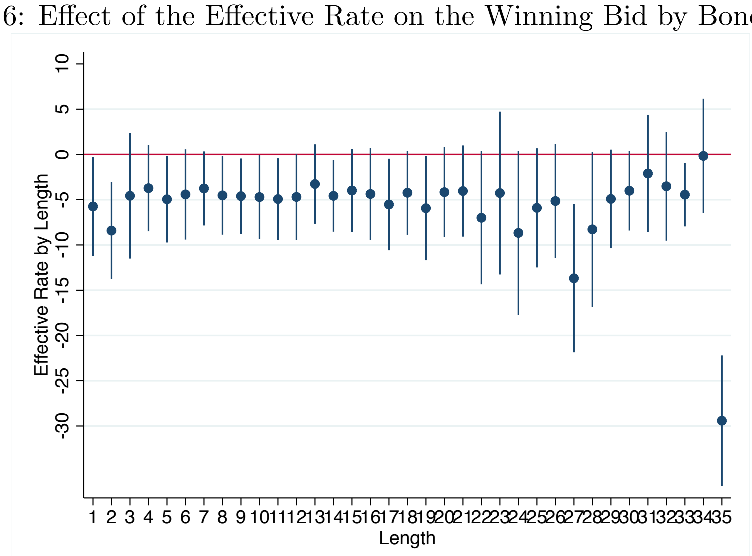
Notes: This figure shows the frequency of observations by the number of potential bidders (N) and the associated fixed effect estimates from Table 1, Column (4). See Section 3 for a discussion of the reduced-form model.

Figure A.5: Empirical Distribution of Bond Maturities



Notes: This figure shows the frequency of observations by bond maturity. We test for heterogeneity of the effect by bond maturity in the reduced-form model in Appendix C.

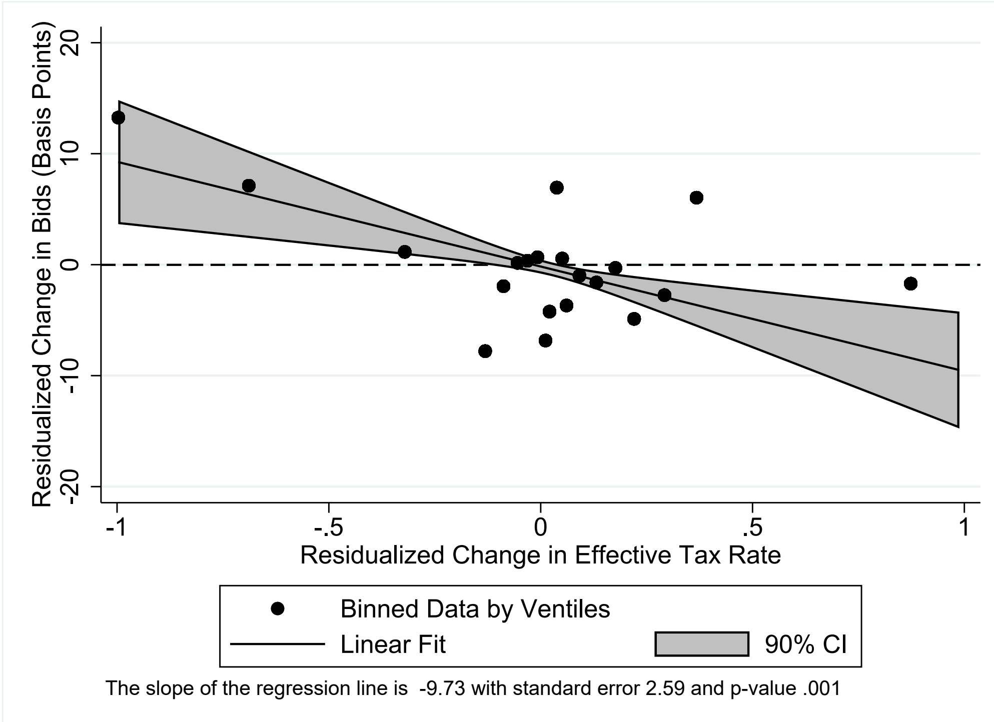
Figure A.6: Effect of the Effective Rate on the Winning Bid by Bond Maturity



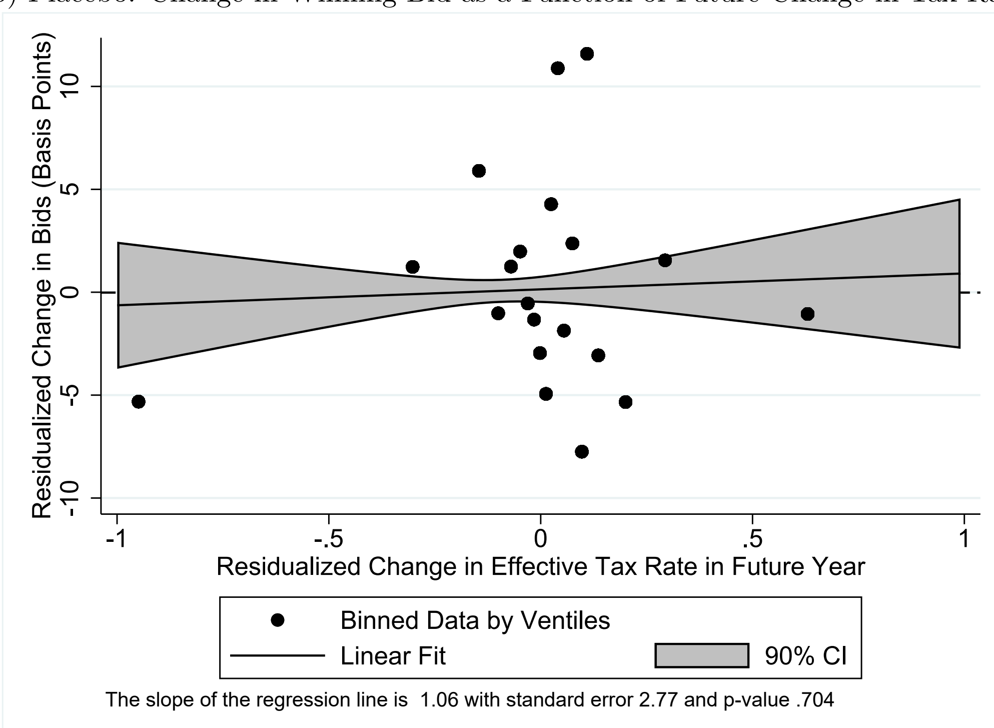
Notes: This figure shows the estimated coefficients of the effect of the effective rate on the winning bid. See Appendix C for more information and Table A.17 for the associated statistical tests.

Figure A.7: Binscatter of Change in Annual Average Borrowing Costs on Change in Tax Rate

(a) Change in Winning Bid as a Function of Current Change in Tax Rate



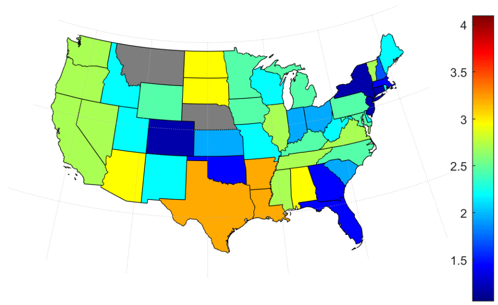
(b) Placebo: Change in Winning Bid as a Function of Future Change in Tax Rate



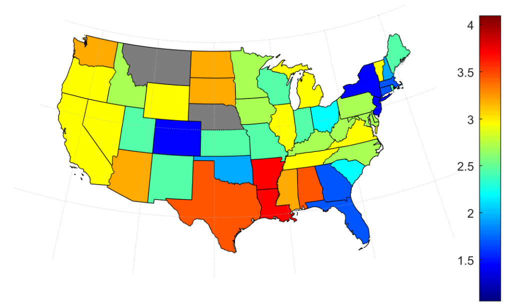
Notes: These figures show the results of the first differences regression of the winning bid, in basis points, on the change in effective tax rates, in percentage points, for a current tax change and a future tax change. Panel (a) shows the results of a regression of the change in bid on the change in the current tax rate for tax rate changes from 2008 to 2015. This regression finds a coefficient of -9.73 with a standard error of 2.59, which is close to the preferred regression estimates of -6.8. Panel (b) shows the results of a regression of the change in bid on the change in the tax rate in the following year ranging from 2009 to 2016. This placebo test finds a coefficient equal to 1.066, which is statistically indistinguishable from 0. The controls included in these regressions are the same as those used in Column (5) of Table 1. See Section 3 for more information.

Figure A.8: Effect of Capping Federal Excludability at 28% on Winning Bids

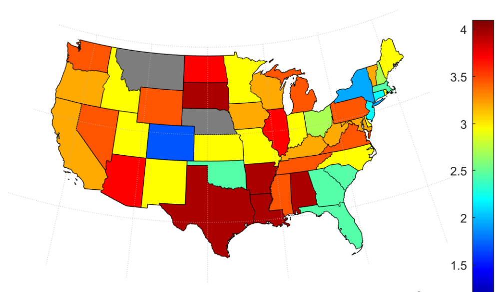
(a) Actual Average Winning Bid



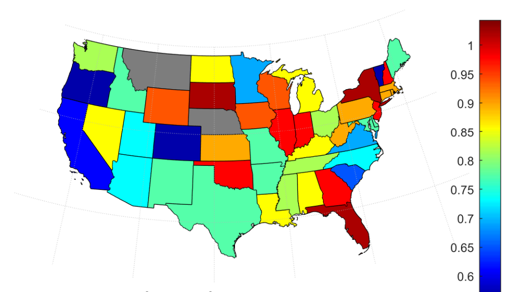
(b) Simulated Average Bid with Capped Excludability (No Entry Margin)



(c) Simulated Average Bid with Capped Excludability (With Entry Margin)



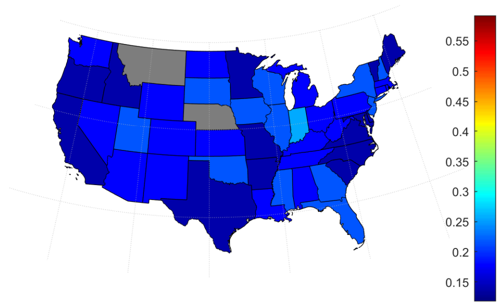
(d) Change between (a) and (c) (With Entry Margin)



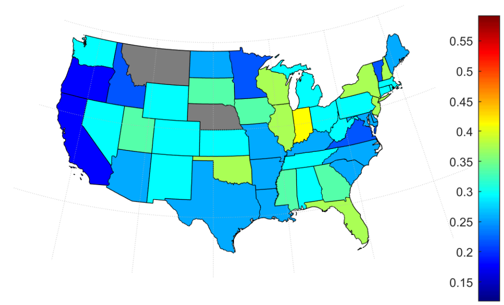
Notes: This figure shows spatial heterogeneity in the counterfactual estimates of the winning bids if the federal exclusion were capped at 28%. See Section 7.1 for additional discussion about the counterfactual analysis and Figure A.9 for the corresponding markups. The comparable estimates of the winning bids if the state exemption were eliminated are shown in Figure A.10. The average effects of the policy reforms are shown in Table 6, the parameter estimates are displayed in Table 3, and α-policy outcomes for borrowing rates and markups are shown in Figure 3.

Figure A.9: Effect on Markups of Capping Federal Excludability at 28%

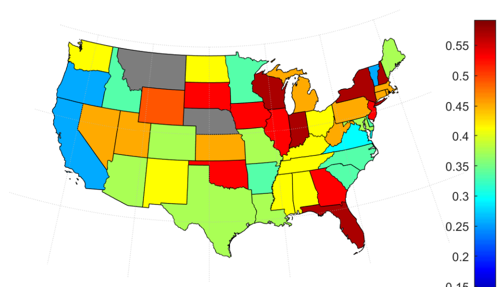
(a) Average Markup



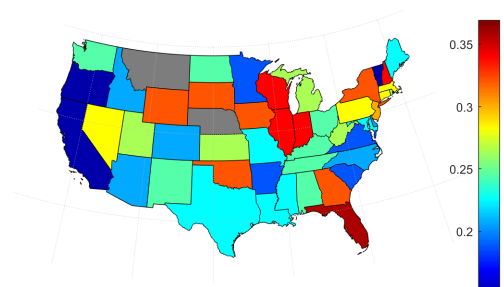
(b) Simulated Average Markup with Capped Excludability (No Entry Margin)



(c) Simulated Average Markup with Capped Excludability (With Entry Margin)



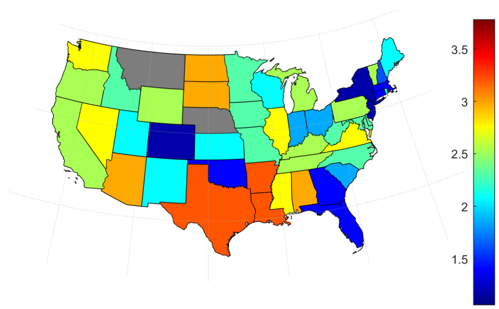
(d) Change between (a) and (c) (With Entry Margin)



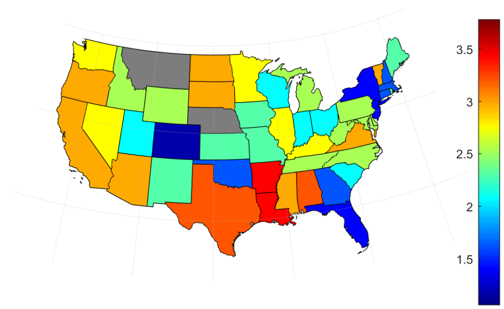
Notes: This figure shows spatial heterogeneity in the counterfactual estimates of markups if the federal exclusion were capped at 28%. See Section 7.1 for additional discussion about the counterfactual analysis and Figure A.8 for the corresponding bids. The comparable estimates of markups if the state exemption were eliminated are shown in Figure A.11. The average effects of the policy reforms are shown in Table 6, the parameter estimates are displayed in Table 3, and α-policy outcomes for borrowing rates and markups are shown in Figure 3.

Figure A.10: Effect of Removing State Excludability on Winning Bids

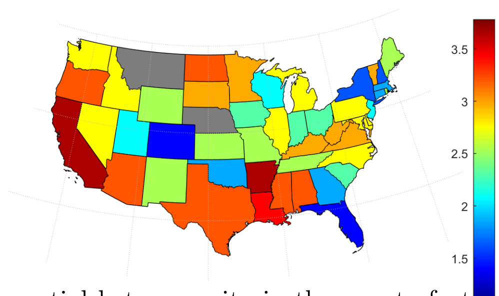
(a) Actual Average Winning Bid



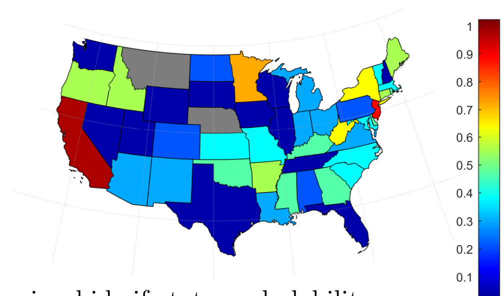
(b) Simulated Average Bid with Excludability Removed
(No Entry Margin)



(c) Simulated Average Bid with Excludability Removed
(With Entry Margin)



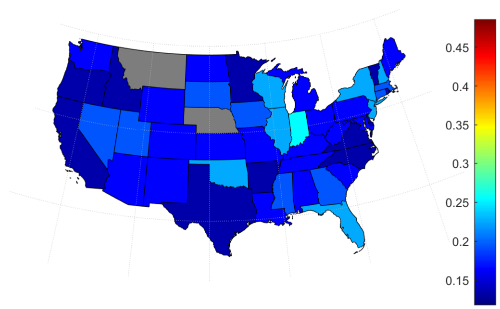
(d) Change between (a) and (c)
(With Entry Margin)



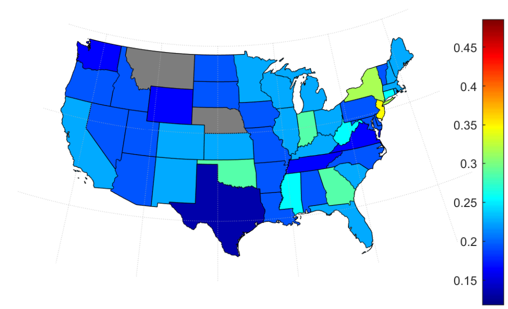
Notes: This figure shows spatial heterogeneity in the counterfactual estimates of the winning bids if state excludability were removed. See Section 7.1 for additional discussion of the counterfactual analysis and Figure A.11 for the corresponding markups. The comparable estimates of the winning bids in the case of elimination of the state exemption are shown in Figure A.10. The average effects of the policy reforms are shown in Table 6, the parameter estimates are displayed in Table 3, and α-policy outcomes for borrowing rates and markups are shown in Figure 3.

Figure A.11: Effect of Removing State Excludability on Markups

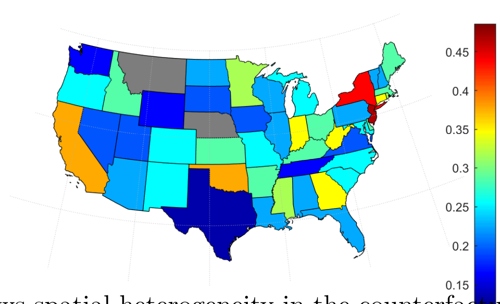
(a) Average Markup



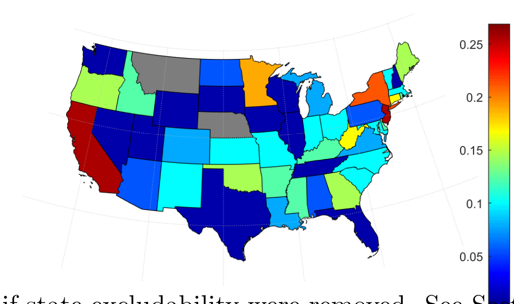
(b) Simulated Average Markup with Excludability Removed (No Entry Margin)



(c) Simulated Average Markup with Excludability Removed (With Entry Margin)



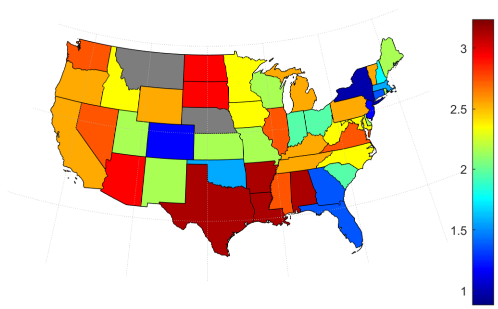
(d) Change between (a) and (c) (With Entry Margin)



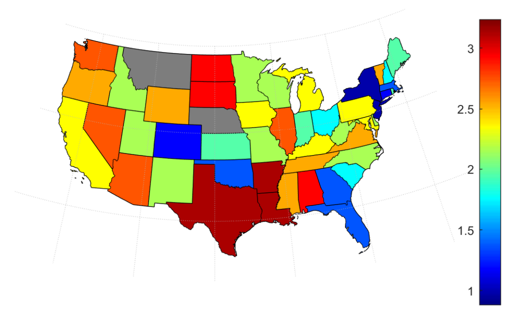
Notes: This figure shows spatial heterogeneity in the counterfactual estimates of markups if state excludability were removed. See Section 7.1 for additional discussion on the counterfactual analysis and Figure A.10 for the corresponding bids. The comparable estimates of markups in the case of the elimination of the state exemption are shown in Figure A.11. The average effects of the policy reforms are shown in Table 6, the parameter estimates are displayed in Table 3, and α-policy outcomes for borrowing rates and markups are shown in Figure 3.

Figure A.12: Effect of Repealing the SALT Deduction on Winning Bids

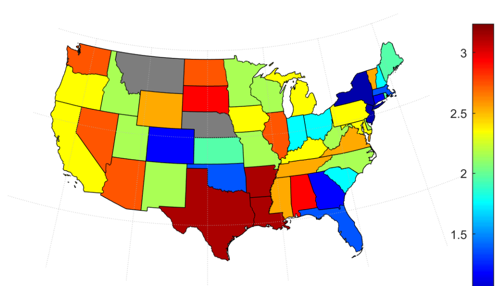
(a) Actual Average Winning Bid



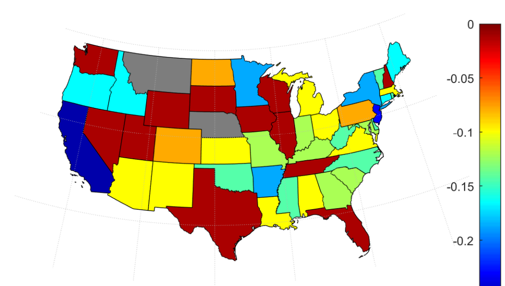
(b) Simulated Average Bid with SALT Repealed (No Entry Margin)



(c) Simulated Average Bid with SALT Repealed (With Entry Margin)



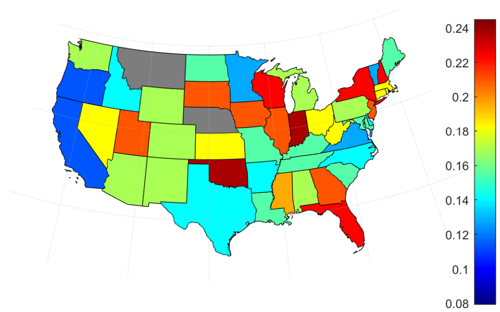
(d) Change between (a) and (c) (With Entry Margin)



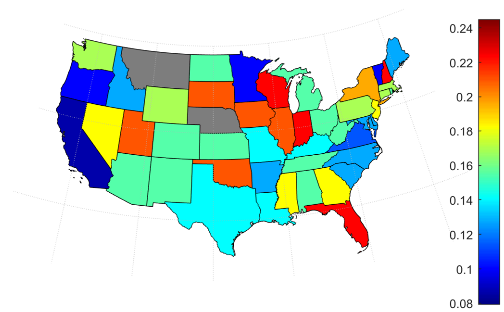
Notes: This figure shows spatial heterogeneity in counterfactual estimates of the winning bids if the SALT deduction were removed. See Section 7.1 for additional discussion on the counterfactual analysis and Figure A.13 for the corresponding markups. The comparable estimates for the case of the elimination of the state exemption are shown in Figure A.10. The average effects of the policy reforms are shown in Table 6, the parameter estimates are displayed in Table 3, and α-policy outcomes for borrowing rates and markups are shown in Figure 3.

Figure A.13: Effect of Repealing the SALT Deduction on Markups

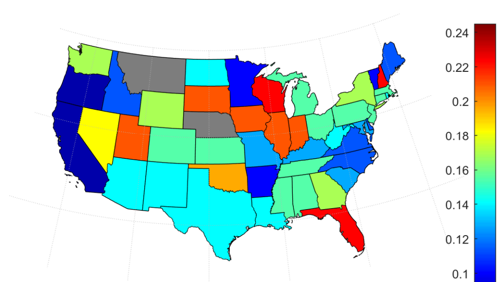
(a) Average Markup



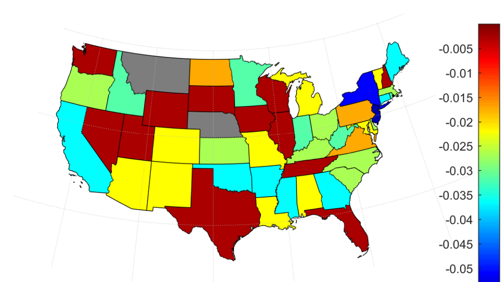
(b) Simulated Average Markup with SALT Repealed
(No Entry Margin)



(c) Simulated Average Markup with SALT Repealed
(With Entry Margin)



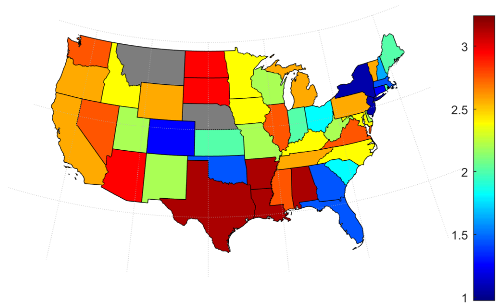
(d) Change between (a) and (c)
(With Entry Margin)



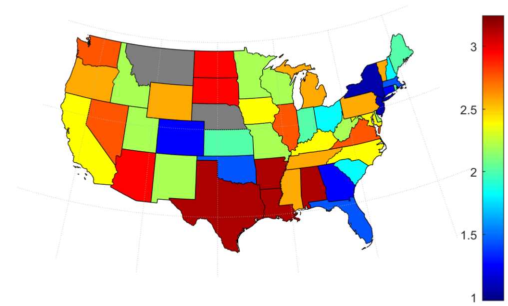
Notes: This figure shows spatial heterogeneity in the counterfactual estimates of markups if the SALT deduction were removed. See Section 7.1 for additional discussion on the counterfactual analysis and Figure A.12 for the corresponding bids. The comparable estimates of markups for the case of the elimination of the state exemption are shown in Figure A.11. The average effects of the policy reforms are shown in Table 6, the parameter estimates are displayed in Table 3, and α-policy outcomes for borrowing rates and markups are shown in Figure 3.

Figure A.14: Effect of Repealing the SALT Deduction and Capping Federal Excludability at 37% on Winning Bids

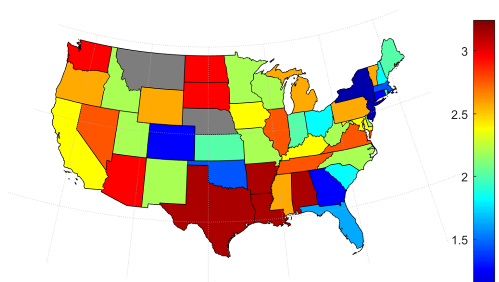
(a) Actual Average Winning Bid



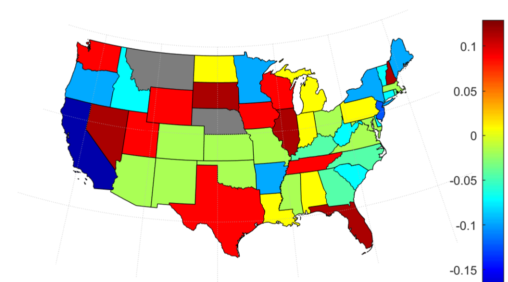
(b) Simulated Average Bid with SALT Repealed and Excludability Capped (No Entry Margin)



(c) Simulated Average Bid with SALT Repealed and Excludability Capped (With Entry Margin)



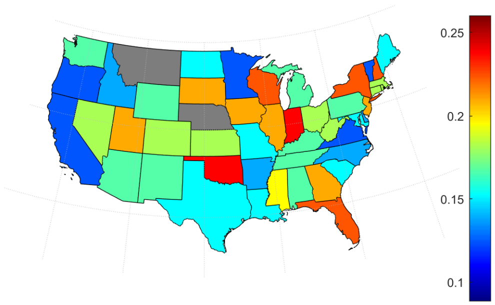
(d) Change between (a) and (c) (With Entry Margin)



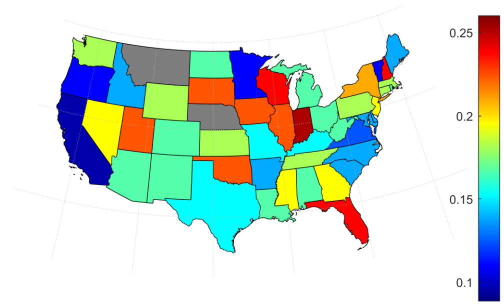
Notes: This figure shows spatial heterogeneity in the counterfactual estimates of the winning bids if the SALT deduction were removed and federal excludability were capped at 37%. See Section 7.1 for additional discussion on the counterfactual analysis and Figure A.15 for the corresponding markups. The comparable estimates of winning bids for the case of the elimination of the state exemption are shown in Figure A.10. The average effects from the policy reforms are shown in Table 6, the parameter estimates are displayed in Table 3, and α-policy outcomes for borrowing rates and markups are shown in Figure 3.

Figure A.15: Effect of Repealing SALT and Capping Federal Excludability at 37% on Markups

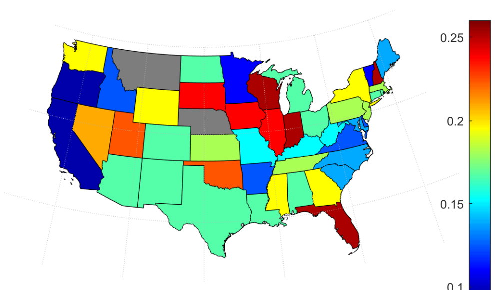
(a) Average Markup



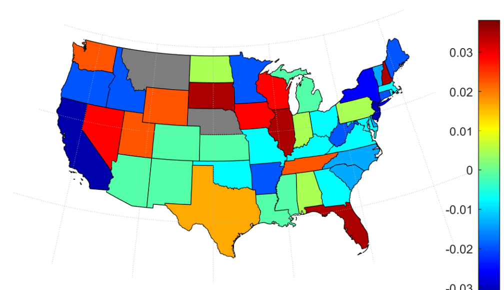
(b) Simulated Average Markup with Excludability Capped (No Entry Margin)



(c) Simulated Average Markup with Excludability Capped (With Entry Margin)

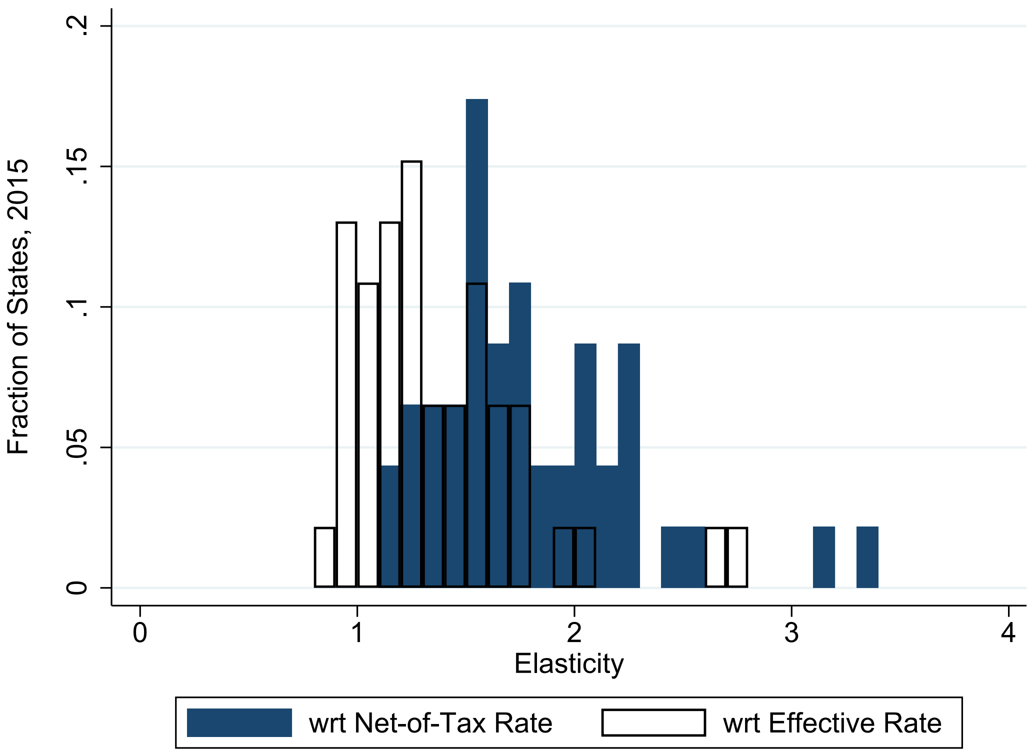


(d) Change between (a) and (c) (With Entry Margin)



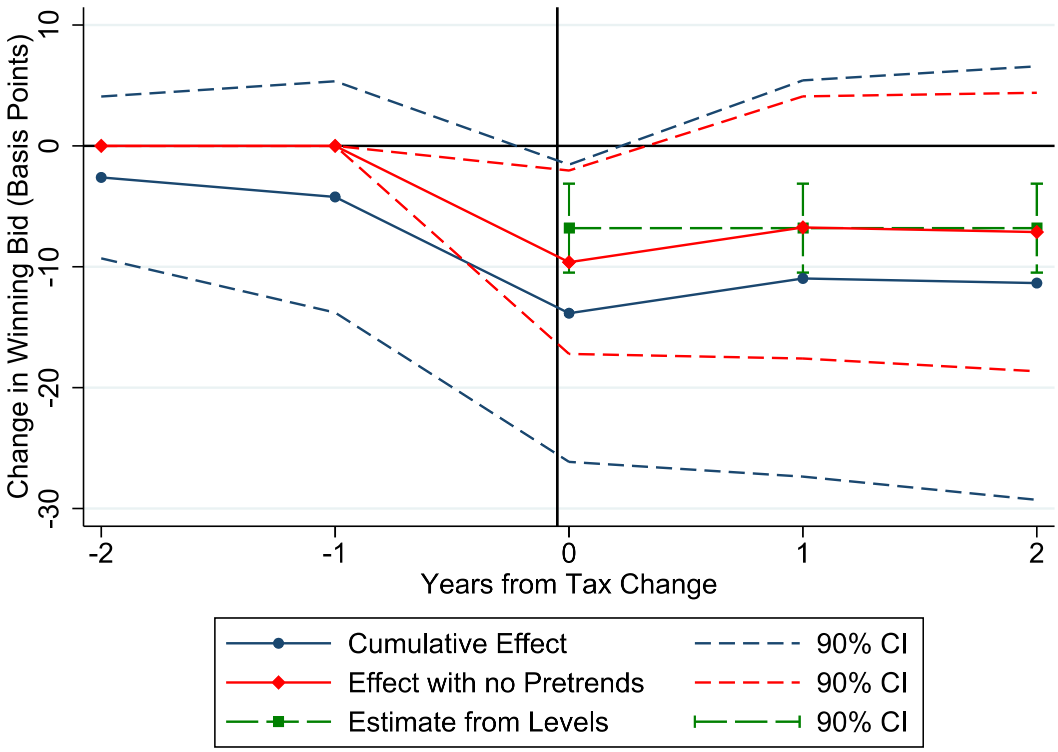
Notes: This figure shows spatial heterogeneity in the counterfactual estimates of markups if the SALT deduction were removed and federal excludability were capped at 37%. See Section 7.1 for additional discussion on the counterfactual analysis and Figure A.14 for the corresponding bids. The comparable estimates of markups in the case of the elimination of the state exemption are shown in Figure A.11. The average effects from the policy reforms are shown in Table 6, the parameter estimates are displayed in Table 3, and α-policy outcomes for borrowing rates and markups are shown in Figure 3.

Figure A.16: Winning Bid Elasticity Heterogeneity by State, 2015



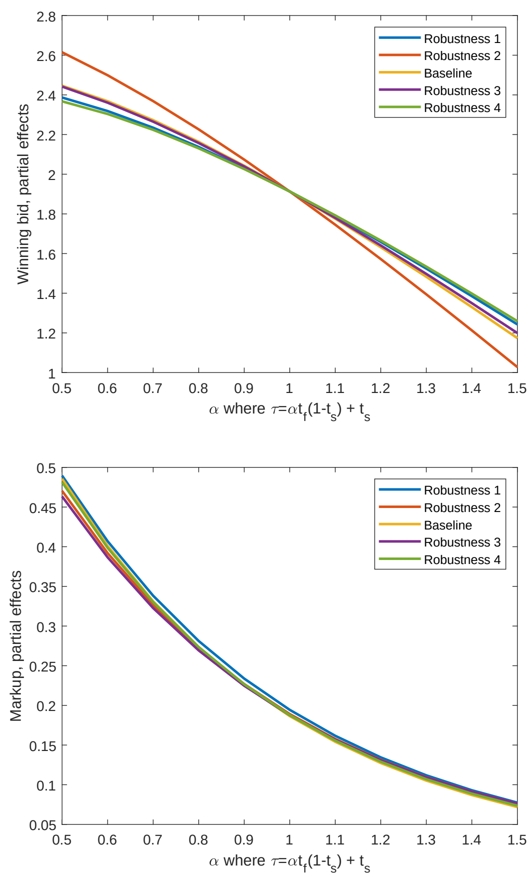
Notes: This figure shows winning bid elasticities with respect to takehome rates, one minus the tax rate, and effective tax rates in 2015. The elasticities with respect to takehome rates are all greater than 1. The elasticities with respect to effective rates are all greater than 1 except for 7 states with elasticities between 0.88 and 1. We prefer the elasticities with respect to takehome rates since they have an interpretation relative to a model of market equilibrium with taxable and tax-exempt assets, but note that both definitions are very similar quantitatively and qualitatively. See Section C.10 for more information.

Figure A.17: Cumulative Effect of a Tax Change at Year $t = 0$



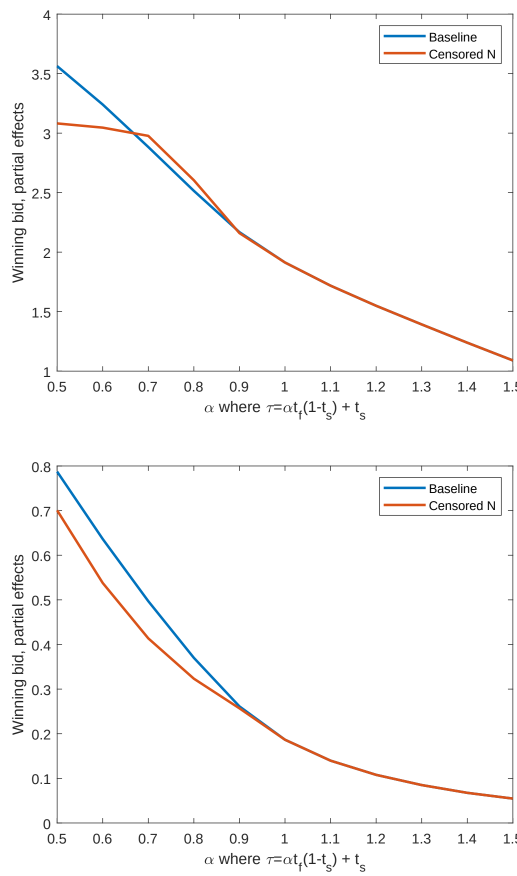
Notes: This figure shows the results of the event study regression of a change in bid on several leads and lags of a change in the effective tax rate. The first line shows the total cumulative effect of a tax change event on the average winning bid in each year surrounding the event. In the period of the tax change, the borrowing cost is 13.85 basis points lower on average for each percentage point of the effective rate tax increase, and the long-run effect is -11.35 basis points. The second line shows the cumulative effect of the tax change without pretrends. The effect in the year of the tax change is 9.62 basis points, while the long-run effect is 6.75 basis points. The controls included in these regressions are the same as those used in Column (5) of Table 1. Figure A.7 shows the results of a regression of changes without the inclusion of leads and lags of tax changes. See Section 3 for more information.

Figure A.18: α-Policy Outcomes for Borrowing Rates and Markups across Robustness Checks



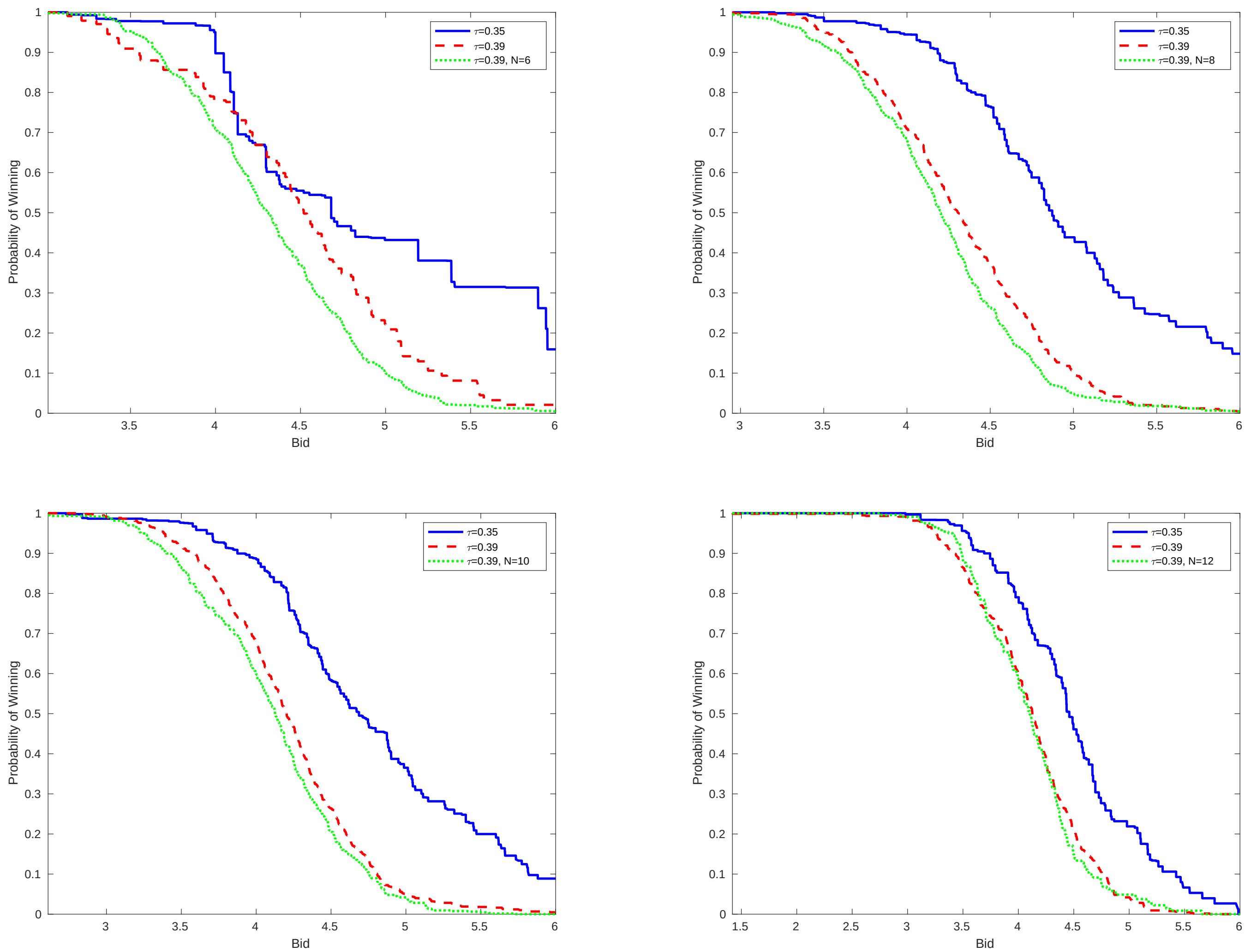
Notes: Robustness of α-policy simulations for various specifications of the first-stage regression: winning bids (top) and markups (bottom). See Figure 3 for the detailed baseline results and Appendix E for details.

Figure A.19: α-Policy Outcomes for Borrowing Rates and Markups Excluding Auctions with Low Potential Bidders



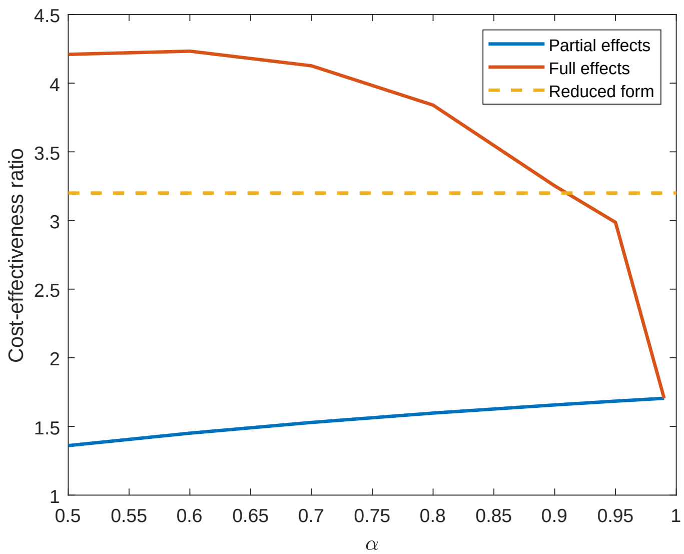
Notes: Robustness of α-policy simulations to excluding auctions with a low number of potential bidders. This figure shows that our counterfactual results are not driven by the truncation of counterfactual values of $N < 2$. The red lines report the average across auctions where N would not need to be truncated and the blue lines report results for all auctions in the sample, as in Figure 3.

Figure A.20: Non-Parametric Estimates of the Probability of Winning: Robustness to Additional Controls



Notes: These figures show the non-parametric estimates of the winning probability for a given bid conditional on a bond maturity of between 2 and 17 years, which is the middle third of the maturity distribution. In the first stage, various factors including state and year fixed effects are regressed out of the bids. Next, these plots are generated using the winning bid after the first stage. The controls included in the first stage are discussed in detail in Sections 5.1 and 5.2.

Figure A.21: Effectiveness of the Municipal Bond Tax Advantage



Notes: The figure illustrates the ratio of the increase in interest payments on municipal debt and the federal tax expenditure reduction. For more details, see Appendix H.

Appendix Tables

Table A.1: Descriptive Statistics

	Mean	SD	5^{th}	25^{th}	50^{th}	75^{th}	95^{th}
Bond Characteristics							
Refund Issue	0.767	0.423	0.00	1.00	1.00	1.00	1.00
Moody's or S&P Information	0.657	0.475	0.00	0.00	1.00	1.00	1.00
Maturity	11.186	9.062	1.00	1.00	11.00	20.00	25.00
Size of Auction (Million Nominal USD)	25.824	54.954	5.25	7.16	10.00	20.36	90.00
Auction Characteristics							
Observed Bidders	5.907	2.667	2.00	4.00	5.00	7.00	11.00
Potential Bidders	8.192	2.651	5.00	6.00	8.00	10.00	13.00
Auction Outcomes							
Winning Bid (in Basis Points)	213.882	135.450	23.82	78.30	220.10	317.90	430.54
Standard Deviation of Bids in Auction	15.428	16.547	2.72	6.37	10.65	18.21	45.06
State Characteristics							
Sales Tax Rate	5.664	1.328	4.00	4.50	6.00	6.50	7.00
Corporate Income Tax Rate	7.108	2.709	0.00	6.50	7.50	9.00	9.99
Sales Tax Apportionment Weight	77.839	24.598	33.34	50.00	93.00	100.00	100.00
Property Tax Rate	1.619	0.511	0.74	1.20	1.79	2.03	2.27
Alternative Minimum Tax (Dummy)	0.429	0.495	0.00	0.00	0.00	1.00	1.00
Federal Taxes Deductible	0.038	0.190	0.00	0.00	0.00	0.00	0.00
Muni Interest Exempt	0.804	0.397	0.00	1.00	1.00	1.00	1.00
Governor Vote (R)	0.477	0.102	0.31	0.39	0.50	0.54	0.66
Senate Vote (R)	0.433	0.112	0.28	0.32	0.44	0.51	0.65
Presidential Vote (R)	0.442	0.079	0.37	0.37	0.43	0.48	0.59
Tax Characteristics							
State Personal Income Tax Rate	6.160	3.069	0.00	5.00	6.85	8.97	10.44
Federal Personal Income Tax Rate	35.293	2.959	31.86	32.61	34.30	38.06	40.79
Effective Marginal Income Tax Rate	40.872	3.638	34.30	38.74	40.79	43.96	46.21

Notes: More information regarding the definitions of variables included in this table is provided in Appendix A.

Table A.2: Waterfall Table for SDC Data

	SDC Dropped	Total
SDC Platinum total	.	264,671
Dropping negotiated	157,758	106,913
Dropping <5 million	59,889	47,024
Dropping revenue	7,486	39,538
Dropping taxable and BABs	1,694	37,844
Dropping pre-2008	18,726	19,118
Dropping duplicates	124	18,994

Notes: This table shows observations that were dropped in each step of the data cleaning procedure for the SDC Platinum data. See Appendix B for details.

Table A.3: Waterfall Table for Bond Buyer Data

	BB Dropped	Total
Bond Buyer total	.	109,327
Dropping missing sale date	1	109,326
Dropping <5 million	46,728	62,598
Dropping negotiated	40,692	21,906
Dropping duplicates	278	21,628

Notes: This table shows observations that were dropped in each step of the data cleaning procedure for the Bond Buyer data. See Appendix B for details.

Table A.4: Waterfall Table for Data Merge

	Merged Dropped	Total
Merged bond packages	.	15,354
Dropping 2016	433	14,921
Dropping missing bids	290	14,631

Notes: This table shows the merge between the SDC Platinum and Bond Buyer data. See Appendix B for details.

Table A.5: Top 10 Bidders

Name	NumBids	Share in total, %	Cumulative, %
ROBERT W BAIRD	6,791	7.98	7.98
JPMORGAN	5,006	5.88	13.86
JEFFERIES	4,758	5.59	19.44
JANNEY MONTGOMERY	4,632	5.44	24.88
TD BANK	4,060	4.77	29.65
OPPENHEIMER	3,795	4.46	34.11
PIPER JAFFRAY	3,774	4.43	38.54
HUTCHINSON SHOCKEY	3,663	4.30	42.84
MORGAN STANLEY	3,527	4.14	46.99
BA MERRILL LYNCH	2,743	3.22	50.21

Notes: This table shows the top 10 bidders in the final sample. For more details on the sample construction, see Section B.

Table A.6: Composition of Potential Bidders

	Mean	SD	Q25	Q50	Q75
N	8.13	2.67	6	8	10
State-incumbent	7.14	3.59	5	7	9
Incumbent	7.42	3.65	6	7	9
Low-freq	.31	.50	0	0	1
One-state	.53	.70	0	0	1
Top 10	3.27	1.46	2	3	4

Notes: This table shows the prevalence of different bidder types within the set of potential bidders. For a discussion, see Section C.4.

Table A.7: Effect of Changes in Tax Rates on Potential Bidders by Bidder Type

	(1) N	(2) State incumbent	(3) Incumbent	(4) Low frequency	(5) One State	(6) Top 10
Effective Rate	0.556***	0.550***	0.418***	0.128***	0.180***	0.149***
	(0.137)	(0.169)	(0.147)	(0.0339)	(0.0406)	(0.0560)
N	14613	14613	14613	14613	14613	14613
R^2	0.323	0.541	0.539	0.324	0.523	0.376

Notes: This table shows how different bidder types respond to shifts in effective tax rates. Controls include the same variables as in column 4 of Table 1, namely maturity, quality, refund indicator, political party, personal, business, sales, and property taxes. The effect on the state-incumbent bidders is on par with the baseline effects in Panel B of Table 1. For a discussion, see Section C.4.

Table A.8: Reduced-Form Effects of the Effective Rate on the Winning Bid and Number of Potential Bidders: Robustness Checks Part 1

	(1)	(2)	(3)
Unconditional Effect of Effective Rate on Bid			
Effective Rate	-6.531	-6.659	-6.738
	(2.527)	(2.182)	(2.218)
	0.010	0.002	0.003
Effect of Effective Rate on *N*			
Effective Rate	0.581	0.523	0.519
	(0.118)	(0.121)	(0.127)
	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid			
Effective Rate	-4.525	-4.704	-5.475
	(2.514)	(2.248)	(2.285)
	0.073	0.037	0.017
Observations	14,631	14,613	14,613
Median Bid	221.2	221.0	221.0
Median Effective Tax	40.79	40.79	40.79
Elasticity (Median)	1.748	1.784	1.805
	(0.677)	(0.585)	(0.594)
	0.010	0.002	0.002
Base Controls	Y		Y
Structural Model Controls		Y	Y
Bidder Fixed Effects			Y
Issuer Fixed Effects			Y
Unemployment Rate			Y
Gross Domestic Product (log)			Y
State Government Spending (log)			Y
State Intergov Spending (log)			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 of winning bid, in basis points, on the effective tax rate, in percentage points. The base controls include state, year, maturity, quality, and refund status fixed effects in addition to effective rate, which is the same as in Column (1) in Table 1. See 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.

Table A.9: Reduced-Form Effects of the Effective Rate on the Winning Bid and Number of Potential Bidders: Robustness Checks Part 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Unconditional Effect of Effective Rate on Bid								
Effective Rate	-6.806	-6.806	-6.806	-6.806	-5.381	-5.323	-5.459	-6.456
	(1.048)	(2.187)	(2.244)	(2.879)	(2.123)	(2.127)	(2.414)	(0.664)
	0.000	0.002	0.003	0.022	0.012	0.013	0.024	0.000
Effect of Effective Rate on *N*								
Effective Rate	0.547	0.547	0.547	0.547	0.499	0.503	0.564	0.436
	(0.050)	(0.119)	(0.133)	(0.128)	(0.122)	(0.109)	(0.151)	(0.031)
	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	-5.222	-5.222	-5.222	-5.222	-4.299	-4.251	-3.617	-5.047
	(0.999)	(1.980)	(2.282)	(2.836)	(2.215)	(2.190)	(2.480)	(0.633)
	0.000	0.008	0.023	0.072	0.053	0.053	0.146	0.000
Observations	14,631	14,631	14,631	14,631	14,631	14,631	11,745	34,868
Median Bid	221.2	221.2	221.2	221.2	221.2	221.2	203.0	193.8
Median Effective Tax	40.79	40.79	40.79	40.79	40.79	40.79	40.83	40.79
Elasticity (Median)	1.822	1.822	1.822	1.822	1.440	1.425	1.591	1.971
	(0.280)	(0.585)	(0.601)	(0.771)	(0.568)	(0.569)	(0.704)	(0.203)
	0.000	0.002	0.002	0.018	0.011	0.012	0.024	0.000
Robust Standard Errors	Y							
SE Cluster State-Month		Y						
SE Cluster State-Year			Y		Y	Y	Y	Y
SE Cluster State				Y				
Monthly Fixed Effects					Y			
Daily Fixed Effects						Y		
Dropping 2008-09							Y	
Including Small Bonds								Y

Notes: This table presents more estimates corresponding to Table 1 with regressions of winning bid, in basis points, on the effective tax rate, in percentage points. All specifications in this table include state, year, maturity, quality, and refund status fixed effects and size, which are the same controls as in Table 1, Column (5). Columns (1) to (4) show the results with different calculations of standard errors–robust, state-month clusters, state-year clusters, and state clusters. Columns (5) and (6) use month and day fixed effects instead of year fixed effects. The years 2008 and 2009 are omitted from the sample in Column (7). Column (8) includes the whole universe of competitive bonds including those smaller than $5 million and weights bonds according to size bins. See 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.

Table A.10: Reduced-Form Effects of the Effective Rate on the Winning Bid and Number of Potential Bidders: Robustness Checks Part 3

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Unconditional Effect of Effective Rate on Bid							
Effective Rate	-6.531	-6.347	-6.664	-6.394	-6.599	-6.388	-5.486
	(2.527)	(2.445)	(2.531)	(2.849)	(2.564)	(2.496)	(2.442)
	0.010	0.010	0.009	0.025	0.010	0.011	0.025
Effect of Effective Rate on *N*							
Effective Rate	0.581	0.578	0.582	0.393	0.594	0.615	0.548
	(0.118)	(0.116)	(0.117)	(0.216)	(0.120)	(0.111)	(0.114)
	0.000	0.000	0.000	0.070	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid							
Effective Rate	-4.525	-4.400	-4.663	-4.357	-4.664	-4.173	-3.624
	(2.514)	(2.454)	(2.515)	(2.588)	(2.542)	(2.483)	(2.394)
	0.073	0.074	0.064	0.093	0.067	0.094	0.131
Observations	14,631	14,631	14,631	14,631	14,168	13,184	14,631
Median Bid	221.2	221.2	221.2	221.2	217.9	215.0	221.2
Median Effective Rate	40.79	40.79	40.79	29.15	40.79	40.83	39.62
Elasticity (Median)	1.748	1.699	1.784	2.048	1.793	1.758	1.497
	(0.677)	(0.654)	(0.677)	(0.912)	(0.697)	(0.687)	(0.667)
	0.010	0.009	0.008	0.025	0.010	0.010	0.025
Primary Controls	Y	Y	Y	Y	Y	Y	Y
Muni Market and Swap Price Controls		Y					
Callable Controls			Y				
90th Percentile Income Tax Rate				Y			
States and State Agencies Excluded					Y		
States Without Tax Exemption Excluded						Y	
Federal Tax Rate Held Constant							Y

Notes: This table presents more estimates corresponding to Table 1 with regressions of winning bid, in basis points, on the effective tax rate, in percentage points. The base controls include state, year, maturity, quality, and refund status fixed effects in addition to the effective rate, which is the same as in Column (1) in Table 1. See 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.

Table A.11: Robustness of Regression of the Number of Potential Bidders on the Effective Rate

	(1)	(2)	(3)	(4)	(5)
Effect of Effective Rate on Number of Bidders					
Effective Rate	0.363	0.345	0.335	0.340	0.315
	(0.093)	(0.095)	(0.099)	(0.101)	(0.098)
	0.000	0.000	0.001	0.001	0.002
Effect of Effective Rate on N (Definition 1)					
Effective Rate	0.561	0.554	0.542	0.550	0.547
	(0.120)	(0.124)	(0.131)	(0.132)	(0.133)
	0.000	0.000	0.000	0.000	0.000
Effect of Effective Rate on N (Definition 2)					
Effective Rate	1.373	1.413	1.411	1.467	1.345
	(0.333)	(0.337)	(0.347)	(0.346)	(0.343)
	0.000	0.000	0.000	0.000	0.000
Effect of Effective Rate on Number of Bidders / N (Definition 1)					
Effective Rate	-0.007	-0.009	-0.010	-0.009	-0.012
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
	0.038	0.008	0.007	0.009	0.002
Year Fixed Effects	Y	Y	Y	Y	Y
State Fixed Effects	Y	Y	Y	Y	Y
Maturity and Size Controls	Y	Y	Y	Y	Y
Quality and Refund Controls	Y	Y	Y	Y	Y
Political Party Controls		Y	Y	Y	Y
Personal Income Tax Base Controls			Y	Y	Y
Sales Tax Controls				Y	Y
Business and Property Tax Controls					Y

Notes: Section 2 discusses the data and the primary definition of potential bidders. The second definition of N is the total unique bidders in the state-month for each auction. A version of the structural model using the second definition of N is discussed in Appendix E. The fourth panel of this table shows estimates of the baseline specification where the outcome is the participation rate, $\frac{n}{N}$, and highlights that entry is decreasing in τ conditional on N. Standard errors clustered at the state-year level are in parentheses, and p-values are listed below the standard errors.

Table A.12: Effect of the Effective Rate on the Supply of Bond Auctions

	(1)	(2)	(3)	(4)
Effective Rate	-0.013	-0.011	0.006	0.007
	(0.037)	(0.039)	(0.042)	(0.041)
	0.736	0.782	0.880	0.868
Observations	2,905	2,905	2,905	2,905
ln(Bonds) Median	1.386	1.386	1.386	1.386
Effective Rate Median	39.190	39.190	39.190	39.190
Monthly Fixed Effects	Y	Y	Y	Y
State Fixed Effects	Y	Y	Y	Y
Political Party Controls		Y	Y	Y
Personal, Business, and Prop. Tax Controls			Y	Y
Sales Tax Controls				Y

Notes: This table shows regressions of the supply of municipal debt as measured by the natural log of the number of bond offerings on effective tax rates in percentage points. The specifications mirror the specifications used in Table 1 except only state-level variables are used. The dependent variable is the natural log of the number of bond issues in a given state-month so zeros are not included. However, the failure to reject the zero effect is robust to OLS in levels, Poisson, and defining the dependent variable as the natural log of the count plus one. Column (1) controls for state and month fixed effects. Column (2) adds controls for political parties, while Column (3) additionally adds personal income tax bases, corporate tax rate and base controls, and average property tax rates. All of the controls mentioned above and sales tax rates are included in Column (4). See Section 3 and Appendix C for more information. Standard errors clustered at the state-year level are shown in parentheses, with p-values listed below the standard errors.

Table A.13: Effect of the Effective Rate on the Share of Issues Sold via Auction

	(1)	(2)	(3)	(4)
Effective Rate	-0.005	-0.002	-0.003	-0.003
	(0.015)	(0.017)	(0.018)	(0.018)
	0.739	0.922	0.870	0.874
Observations	400	400	400	400
R^2	0.918	0.918	0.919	0.919
Dependent Var. Mean	0.339	0.339	0.339	0.339
Effective Rate Mean	39.962	39.962	39.962	39.962
Year Fixed Effects	Y	Y	Y	Y
State Fixed Effects	Y	Y	Y	Y
Political Party Controls		Y	Y	Y
Personal, Business, and Prop. Tax Controls			Y	Y
Sales Tax Controls				Y

Notes: This table shows estimates of regressions with the dependent variable equal to the share of issues sold in a state-year via auction. The independent variable is the effective tax rate in percentage points. The goal of this exercise is to test whether state shares of bonds sold via auction are responsive to tax rates given that tax rates change auction participation. We fail to find evidence that the share of bonds sold via auction is responsive to tax rates in any specification. See Section 3 and Appendix C for more information. Standard errors clustered at the state-year level are shown in parentheses, with p-values listed below the standard errors.

Table A.14: Effect of the Effective Rate on the Share of Par Value Sold via Auction

	(1)	(2)	(3)	(4)
Effective Rate	-0.006	-0.005	-0.004	-0.004
	(0.019)	(0.019)	(0.019)	(0.019)
	0.765	0.801	0.836	0.828
Observations	400	400	400	400
R^2	0.796	0.796	0.799	0.800
Dependent Var. Mean	0.253	0.253	0.253	0.253
Effective Rate Mean	39.962	39.962	39.962	39.962
Year Fixed Effects	Y	Y	Y	Y
State Fixed Effects	Y	Y	Y	Y
Political Party Controls		Y	Y	Y
Personal, Business, and Prop. Tax Controls			Y	Y
Sales Tax Controls				Y

Notes: This table shows estimates of regressions with the dependent variable equal to the share of par value of bonds sold in a state-year via auction. The independent variable is the effective tax rate in percentage points. The goal of this exercise is to test whether state shares of total debt sold via auction are responsive to tax rates given that tax rates change auction participation. We fail to find evidence that the share of par value of municipal bonds sold via auction is responsive to tax rates in any specification. See Section 3 and Appendix C for more information. Standard errors clustered at the state-year level are shown in parentheses, with p-values listed below the standard errors.

Table A.15: Regressions of Borrowing Costs on Taxes, Heterogeneity by Restrictions on Method of Sale

	(1)	(2)	(3)	(4)	(5)
Effective Rate	-6.660	-7.007	-7.114	-7.097	-7.089
	(2.518)	(2.409)	(2.323)	(2.307)	(2.300)
	0.009	0.004	0.002	0.002	0.002
Effective Rate X Restricted Sales	0.130	0.014	0.377	0.362	0.360
	(0.871)	(0.843)	(0.811)	(0.808)	(0.807)
	0.882	0.987	0.642	0.654	0.656
Observations	14,631	14,631	14,631	14,631	14,631
Mean Winning Bid	215.2	215.2	215.2	215.2	215.2
Mean Effective Rate	40.86	40.86	40.86	40.86	40.86
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 shows estimates of regressions with the dependent variable equal to the winning bid, replicating Table 1. The independent variable is the effective tax rate in percentage points. The difference in this table is that the effective rates are also interacted with an indicator equal to one if states have some method of sale restrictions on more than 80% of their issues according to Cestau et al. (2020) during our sample. See Section 3 and Appendix C for more information. Standard errors clustered at the state-year level are shown in parentheses, with p-values listed below the standard errors.

Table A.16: Effect of the Effective Rate on Bond Package Characteristics

	(1)	(2)	(3)	(4)	(5)
	Maturity	ln(Size)	Callable	Rated	Qualified
Effective Rate	0.071	0.014	0.010	0.002	0.028
	(0.101)	(0.011)	(0.009)	(0.007)	(0.018)
	0.484	0.211	0.279	0.771	0.119
Observations	14,631	14,631	14,631	14,631	14,631
Mean Outcome	11.2	2.6	0.6	0.7	0.4
Mean Effective Rate	40.86	40.86	40.86	40.86	40.86
Year and Issuer Fixed Effects	Y	Y	Y	Y	Y
Political Party Controls	Y	Y	Y	Y	Y
Personal, Business, Prop., and Sales Tax	Y	Y	Y	Y	Y
Maturity Control		Y	Y	Y	Y
Size Control	Y		Y	Y	Y
Credit Rating Controls	Y	Y	Y		Y

Notes: This table shows estimates of regressions for different bond characteristics as a function of effective personal income tax rates in percentage points. The outcomes are maturity (years), natural log of par value, an indicator for a call provision, an indicator for credit rating and an indicator for bank-qualified bonds in Columns (1) through (5), respectively. We fail to find any statistically significant affect of taxes on any observable bond characteristics. See Section 3 and Appendix C for more information. Standard errors clustered at the state-year level are shown in parentheses, with p-values listed below the standard errors.

Table A.17: Effect of the Effective Rate on the Winning Bid: APE and FE

	(1) No Controls for Number of Bidders	(2) Controls for Number of Bidders
Average Partial Effect		
Effective Rate	-6.417	-4.786
	(2.425)	(2.411)
	0.008	0.047
Fixed Effect Estimate		
Effective Rate	-6.531	-4.525
	(2.517)	(2.501)
	0.009	0.070
Observations	14,631	14,631
Score p-value (Interactions)	0.000	0.000
Hausman p-value (APE=FE)	0.846	0.613
Percentage diff (APE-FE)/FE	0.017	-0.058
	(0.088)	(0.126)
	0.843	0.649
Percentage Due to Competition (APE)		0.254
Percentage Due to Competition (FE)		0.307

Notes: Standard errors are shown in parentheses, with p-values below the standard errors. See Appendix C for information about testing for heterogeneous effects in length. This table presents the estimates that correspond to Figure A.6 and shows the Hausman test p-value for the difference between the average partial effect and fixed effect estimates, which is nonsignificant at conventional levels.

Table A.18: Oster Coefficient Stability Tests

	(1)	(2)	(3)
	Table 2, (1)	Table 2, (1)	Table 2, (5)
Effective Rate	-6.531	-6.531	-6.806
	(2.527)	(2.527)	(2.244)
	0.010	0.010	0.003
R^2	0.898	0.898	0.899
	Table 2, (5)	Table A.7, (3)	Table A.7, (3)
Effective Rate	-6.806	-6.738	-6.738
	(2.244)	(2.218)	(2.218)
	0.003	0.003	0.003
R^2	0.899	0.953	0.953
Observations	14,631	14,613	14,613
δ such that $\beta^* = 0$	$[< 0]$	$[< 0]$	113.424
Corrected β^*	-34.614	-6.915	-6.679

Notes: Standard errors clustered at the state level are shown in parentheses, and p-values are below the standard errors. This table uses an estimator from Oster (2017) to test how much selection on unobservables is needed to negate the results in Tables 1 and A.8. Each cell represents the results of a previously estimated model. Following Oster (2017), this table performs 2 calculations for each comparison across specifications. First, we estimate the δ that sets $\beta^* = 0$ given $R_{max} = 1$. Columns (1) and (2) show that no amount of unobserved heterogeneity would negate the observed coefficients. The δ shown in Column (3) implies that selection on unobservables would need to be 113.4 times more important than selection on observables for our results to be negated. Second, we estimate β^* assuming that $\delta = 1$ and $R_{max} = 1$ and show the coefficients in the last row. These estimates show the coefficients are largely increasing as more controls are added. For more information, see Appendix C.8.

Table A.19: Effect of Interest Payments on the Effective Rate, Lags

	(1)	(2)	(3)	(4)	(5)
Percent Change in Interest Payments, Period t	-0.055	0.014	-0.000	-0.057	-0.076
	(0.111)	(0.110)	(0.115)	(0.127)	(0.126)
	0.624	0.899	0.999	0.658	0.548
Percent Change in Interest Payments, Period $t-1$				-0.057	-0.072
				(0.125)	(0.133)
				0.649	0.594
Percent Change in Interest Payments, Period $t-2$					0.108
					(0.097)
					0.270
N	1100	1100	1100	1050	1000
Year Fixed Effects		Y	Y	Y	Y
State Fixed Effects			Y	Y	Y

Notes: Standard errors clustered at the state level are shown in parentheses, and p-values are below the standard errors. This table regresses tax rates in percentage points on the percent change in government interest payments from 1994 to 2014 at the state level. This test of potential reverse causality fails to find evidence of any impact of previous and current interest costs on borrowing rates. For more information, see Appendix C.9.

Table A.20: Effect of Interest Payments on the Effective Rate, Leads

	(1)	(2)	(3)	(4)	(5)
Percent Change in Interest Payments, Period t	-0.055	0.014	-0.000	-0.052	0.018
	(0.111)	(0.110)	(0.115)	(0.125)	(0.121)
	0.624	0.899	0.999	0.681	0.880
Percent Change in Interest Payments, Period $t+1$				-0.165	-0.136
				(0.125)	(0.120)
				0.194	0.262
Percent Change in Interest Payments, Period $t+2$					0.049
					(0.111)
					0.662
N	1100	1100	1100	1050	1000
Year Fixed Effects		Y	Y	Y	Y
State Fixed Effects			Y	Y	Y

Notes: Standard errors clustered at the state level are shown in parentheses, and p-values are below the standard errors. This table regresses tax rates in percentage points on the percent change in government interest payments from 1994 to 2014 at the state level. This test of potential reverse causality fails to find evidence of any impact of current and future interest costs on borrowing rates. For more information, see Appendix C.9.

Table A.21: Simulations on In-Sample Observables, Average Moments from Models S1 through S4

Statistic	S0	S1	S2	S3	S4
Model Fit					
Winning Bid in Data: b_1	2.15	2.15	2.15	2.15	2.15
Simulated Winning Bid: b_1	1.99	1.98	1.95	2.07	2.08
Entry Probability in Data: n/N	0.70	0.70	0.34	0.70	0.70
Simulated Entry Probability: n/N	0.74	0.73	0.31	0.72	0.70
Simulation Results					
Markup: m_1	0.19	0.20	0.21	0.17	0.19
Markup Rate: m_1/b_1	0.24	0.25	0.25	0.20	0.25
Entry Cost Threshold: d^*	0.05	0.06	0.05	0.49	

Notes: This table shows model fit and simulation results for in-sample observations from each of the variants of the baseline model. The simulation results regarding markups from the baseline model are displayed in Table 4. The model fit is still very similar to the baseline specification, and markups are close. The first robustness specification allows for more flexible entry costs. The second specification uses the definition of a potential bidder as all unique bidders in a state in a given month. The third specification is based on parameterizing the bids directly. The fourth specification allows for a heterogeneous distribution of valuations and entry costs across the bidders. Section 4 discusses the setup of the model, while Appendix E contains information about the specification of and reasoning behind each of the model robustness checks.

Table A.22: Maximum Likelihood Estimates: Model with Flexible Entry Costs S1.

	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	3.783	1.458	-9.817	18.374	0.462
	(0.048)	(0.010)	(1.139)	(1.516)	(0.003)
Maturity	0.129	-0.033			
	(0.0005)	(0.0002)			
Effective Rate: τ	-4.918	-4.869			
	(0.116)	(0.025)			

Notes: The additional controls are the same as in Column (4) of Table 1. This table presents estimates from model S1 with flexible entry costs as described in Section E. Standard errors are in parentheses.

Table A.23: Maximum Likelihood Estimates: Model with Alternative Definition of Potential Bidders N S2.

	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	3.624	1.493	-0.515	5.087	0.439
	(0.044)	(0.013)	(0.071)	(0.116)	(0.002)
Maturity	0.130	-0.032			
	(0.0004)	(0.0002)			
Effective Rate: τ	-4.568	-5.060			
	(0.106)	(0.032)			

Notes: The additional controls are the same as in Column (4) of Table 1. This table presents estimates from model S2 where potential bidders for each auction are defined as all bidders active in the same state in the same month. The model is described in Section E. Standard errors are in parentheses.

Table A.24: Maximum Likelihood Estimates: Model with Parameterized Bids S3.

	Bids ($\theta_{\tilde{b}}$)			Entry Costs (θ_d)		Unobs. Hetero. (θ_U)
	(1)	(2)	(3)	(4)	(5)	(6)
	$\widehat{\beta}$	$\widehat{\gamma}$	$\widehat{\delta}$	$\widehat{\kappa}_1$	$\widehat{\kappa}_2$	$\widehat{\sigma}_U$
Variable	Mean	StDev	Threshold	Mean	StDev	StDev
Const	3.8372	0.7043	1.0379	-10.7578	15.8368	0.4679
	(0.0222)	(0.0119)	(0.0032)	(0.0066)	(0.0055)	(0.0095)
N	-0.0310	-0.0743	0.0249			
	(0.0057)	(0.0015)	(0.0084)			
Maturity	0.1255	-0.0402	0.1232			
	(0.0017)	(0.0005)	(0.0025)			
Effective Rate: τ	-4.2345	-3.3020	-2.7152			
	(0.0336)	(0.0037)	(0.0003)			

Notes: The additional controls are the same as in Column (4) of Table 1. This table presents estimates from model S3 where bids are parameterized directly. The model is described in Section E. Standard errors are in parentheses.

Table A.25: Maximum Likelihood Estimates. Model with Heterogeneous Bidders S4. Bidder Group 1.

	Bids ($\theta_{\tilde{b}}$)			Unobs. Hetero. (θ_U)
	(1)	(2)	(3)	(4)
	$\widehat{\beta}$	$\widehat{\gamma}$	$\widehat{\delta}$	$\widehat{\sigma}_U$
Variable	Mean	StDev	Threshold	StDev
Const	3.285	0.842	1.227	0.471
	(0.046)	(0.021)	(4.213)	(0.0001)
N		-0.069		
		(0.0004)		
$1/N$	2.569		4.992	
	(0.117)		(15.812)	
$1/(N_1+1)$	0.065			
	(0.034)			
Maturity	0.125	-0.037	0.113	
	(0.0004)	(0.0002)	(1.138)	
Effective Rate: τ	-4.231	-4.052	-4.934	
	(0.108)	(0.047)	(11.539)	

Notes: The additional controls are the same as in Column (4) of Table 1. This table presents estimates from model S4, which allows for heterogeneity among bidders, breaking all auction participants into two groups: the top 10 most frequent bidders and the rest. These estimates describe the bidders from the first group. The model is described in Section E. Standard errors are in parentheses.

Table A.26: Maximum Likelihood Estimates. Model with Heterogeneous Bidders S4. Bidder Group 2.

	Bids ($\theta_{\tilde{b}}$)			Unobs. Hetero. (θ_U)
	(1)	(2)	(3)	(4)
	$\widehat{\beta}$	$\widehat{\gamma}$	$\widehat{\delta}$	$\widehat{\sigma}_U$
Variable	Mean	StDev	Threshold	StDev
Const	3.295	0.536	0.042	0.471
	(0.046)	(0.016)	(5.613)	(0.0001)
N		-0.077		
		(0.0003)		
$1/N$	1.840		1.780	
	(0.120)		(6.510)	
$1/(N_1+1)$	0.071			
	(0.031)			
Maturity	0.125	-0.041	0.072	
	(0.0004)	(0.0001)	(0.665)	
Effective Rate: τ	-4.126	-2.730	0.000	
	(0.109)	(0.036)	(11.889)	

Notes: The additional controls are the same as in Column (4) of Table 1. This table presents estimates from model S4, which allows for heterogeneity among bidders, breaking all auction participants into two groups: the top 10 most frequent bidders and the rest. These estimates describe the bidders from the second group. The model is described in Section E. Standard errors are in parentheses.

Table A.27: Average Effects from Counterfactual Policy Reform: Model with Flexible Entry Costs S1.

(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	2.30	2.12	1.82	1.89
Full	1.91	2.03	2.86	2.39	1.78	1.88
Markups						
Partial (No Potential Entry)	0.19	0.21	0.32	0.26	0.18	0.19
Full	0.19	0.22	0.47	0.33	0.16	0.19

(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)	3.19%	20.35%	11.03%	-4.76%	-1.31%
Full	5.92%	49.58%	24.99%	-7.00%	-1.85%
Markups					
Partial (No Potential Entry)	7.82%	66.33%	31.74%	-9.91%	-2.46%
Full	15.34%	143.39%	69.10%	-15.65%	-3.98%

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 deductino is repealed and the exemption is limited to 96% of its current level. 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 results presented in Tables A.27 to A.30.

Table A.28: Average Effects from Counterfactual Policy Reform: Model with Alternative Definition of Potential Bidders N S2.

(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	1.96	2.21	2.07	1.84	1.89
Full	1.91	1.99	2.70	2.26	1.81	1.89
Markups						
Partial (No Potential Entry)	0.19	0.20	0.30	0.24	0.17	0.18
Full	0.19	0.21	0.41	0.28	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)	2.64%	15.60%	8.32%	-3.92%	-0.99%
Full	4.20%	40.98%	18.13%	-5.24%	-1.20%
Markups					
Partial (No Potential Entry)	7.47%	62.87%	28.76%	-9.08%	-1.92%
Full	11.44%	123.57%	52.90%	-12.49%	-2.37%

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. 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 results presented in Tables A.27 to A.30.

Table A.29: Average Effects from Counterfactual Policy Reform: Model with Parameterized Bids S3.

(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	1.96	2.27	2.10	1.83	1.88
Full	1.91	2.00	2.50	2.21	1.79	1.86
Markups						
Partial (No Potential Entry)	0.18	0.19	0.26	0.22	0.17	0.18
Full	0.18	0.22	0.52	0.35	0.15	0.17

(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)	2.56%	18.56%	9.61%	-4.57%	-1.81%
Full	4.32%	30.65%	15.76%	-6.36%	-2.54%
Markups					
Partial (No Potential Entry)	4.65%	40.67%	21.30%	-8.07%	-3.50%
Full	20.34%	185.28%	92.00%	-20.47%	-9.49%

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. 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 results presented in Tables A.27 to A.30.

Table A.30: Average Effects from Counterfactual Policy Reform: Model with Heterogeneous Bidders S4.

(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	2.28	2.10	1.83	1.89
Full	1.91	2.02	2.78	2.39	1.79	1.88
Markups						
Partial (No Potential Entry)	0.17	0.18	0.23	0.20	0.16	0.17
Full	0.17	0.19	0.28	0.22	0.14	0.16

(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)	2.84%	19.44%	10.00%	-4.14%	-1.05%
Full	5.60%	45.08%	24.77%	-6.39%	-1.77%
Markups					
Partial (No Potential Entry)	4.61%	34.82%	18.31%	-6.27%	-1.88%
Full	10.29%	66.21%	27.82%	-15.65%	-3.33%

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. 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 results presented in Tables A.27 to A.30.