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ABSTRACT

We show that the effect of tax advantages of municipal bonds on the market microstructure of municipal bond auctions 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%, consistent with a greater than-unity passthrough elasticity. Non-parametric evidence shows that strategic participation and bidding in imperfectly-competitive auctions generates this greater-than-unity passthrough. Using a structural auction model to evaluate the efficiency of Obama and Trump administration proposals, we find that the reduction in municipal borrowing costs is 2.8-times the revenue cost of the tax advantage.

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1 Introduction

State and local governments finance multi-year expenditures by issuing municipal bonds. In 2014 outstanding municipal debt totaled $3.8 trillion, and annual interest payments of $124 billion surpassed expenditures on other categories such as unemployment insurance, policing, and workers' compensation.[1] Clearly, municipal bonds represent a major fiscal obligation of state and local governments. To reduce the cost of such borrowing, municipal bonds are tax advantaged by the excludability of municipal interest income from federal and, in most cases, state taxation. These tax advantages aim to lower bondholders' required rate of return, and consequently, the interest rate paid by state and local governments. This market distortion thus links tax policy with the cost of public good provision, which motivates our first research question: do tax advantages lower municipal borrowing costs?

While higher personal income tax rates may lower the interest cost for a municipal bond issuer, they create a new tax *expenditure* for the federal and state governments. This tax expenditure is forecasted 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 who are the primary bondholders. Not surprisingly, the tax advantage of municipal bonds has been the subject of a controversial policy debate over whether public funds should be used to stimulate the municipal bond market, and whether these tax advantages are an effective means of reducing the borrowing costs of state and local governments. For instance, in every budget proposal from 2012-2016, the Obama administration proposed limiting the exemption of municipal bond income from federal taxation. However, despite over 120 initiatives to reduce or eliminate municipal bonds' tax advantaged status since 1918, the favored treatment by the U.S. tax code has remained largely unchanged.[2] Our second research question is whether tax advantages are an efficient way to lower borrowing rates.

This paper answers these two questions and shows that the interaction of tax advantages with the structure of the municipal bond issuance market plays a crucial role in determining the effect of tax advantages on borrowing rates, as well as on the efficiency of this subsidy. Answers to these questions have been hindered by the paucity of data on municipal bonds, by the lack of tax variation that may identify how tax changes are "passed-through" to borrowing rates, and by a lack of understanding of the interactions between tax advantages and imperfect competition. This paper contributes to this literature by focusing on new issuances of municipal bonds sold at auction.[3] We analyze a novel dataset on over 14,000 auctions of municipal bonds sold at auction between 2008 and 2015, we exploit identifying variation in state and federal taxes, and we develop an empirical auction model that determines borrowing rates for state and local governments that enables us to evaluate the effects counterfactual tax policies.

[1] See U.S. Securities and Exchange Commission (2012) for an SEC report on the state of the market for municipal bonds and U.S. Census Bureau (2017) for state and local government expenditures.

[2] See U.S. Department of the 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. Proposals by the new administration to lower the top income tax rate would also affect the value of the exemption (Anderson, 2017).

[3] Auctions make up an important part of the municipal bond issuance market. Roughly half the municipal bonds issued in any year will be 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 this 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.

Overall, this paper is the first to consider the interactions between imperfect competition and tax advantages in the market for municipal bonds. This results in a fundamental reassessment of the mechanism through which tax subsidies reduce borrowing costs, and we provide new evidence suggesting that tax subsidies may be more efficient at subsidizing local borrowing costs than previously thought. In particular, we evaluate recent proposals by the Obama and Trump administrations to limit the tax advantage of municipal bonds. We find that for every $1 reduction in the federal tax expenditure, municipal borrowing costs increase by $2.8, suggesting the tax advantage may be more efficient at lowering municipal borrowing costs than previously thought.

Our analysis proceeds in four steps. First, we exploit changes in state and federal tax policies to provide reduced-form evidence that a 1-percentage-point (pp.) increase in the tax subsidy, or what we term the "effective rate," leads to a decrease in borrowing costs of 6.5-7 basis points.[4] Given the mean borrowing rate is 2.14%, a 3-pp. increase in the effective rate would reduce borrowing costs by 9-10%.[5] Our results imply a passthrough elasticity of the borrowing rate to the tax advantage of 1.7-1.9.

In the second step of our analysis, we highlight the forces that may cause changes in tax advantages to have greater-than-unity passthrough on borrowing costs. In perfectly competitive auctions, where tax advantages do not influence auction competitiveness, we would expect to find a unit-passthrough elasticity. In imperfectly competitive auctions, a winning bidder may profit by increasing her bid while decreasing the likelihood she wins, just as a monopsonist increases its surplus by restricting quantity and lowering price. In such auctions, bidders may respond to an increase in the tax advantage by decreasing their bid. The equilibrium borrowing rate is further lowered as other participants respond to this incentive by lowering their bids, and as more participants enter the auction. We show that these forces work to generate greater-than-unity passthrough elasticities. We provide non-parametric evidence that winning bidders extract positive markups in equilibrium, and that tax advantages affect strategic participation and bidding; these effects are responsible for the large effects of the tax policy on borrowing rates.

In the third step of our analysis, we quantify the markups implied by imperfect competition in auctions by estimating an empirical auction model that accounts for the effect of the tax advantage on the distribution of bidder values, as well as their decision to participate in an auction. This model shows that, consistent with the reduced-form results, subsidies increase demand for the bonds. By analyzing the entire distribution of bids, the model also shows that subsidies lead to a decrease in the dispersion of values, which reduces market power, as any one bidder's information rents are dissipated. Model estimates imply markups of 11 basis points at the median, with an inter-quartile range of between 2.5% to 27% of borrowing costs.

Finally, in the fourth step, we use the estimates of the model to evaluate the effects of a range of policies that increase or decrease the size of the federal exemption, and we also consider the effects of eliminating

[4]The effective rate is determined by four policy variables: the federal income tax rate, the excludability of own-bond interest from state income taxation, the deductibility of federal income taxes from state taxes, and the state personal income tax rate. See Section 2 for details. This result is robust to controlling for bond maturity and quality ratings, political support at the state and federal level, other tax policies including sales, property, and corporate tax rates, local economic conditions including state GDP and unemployment, and measures of state spending including total state spending and intergovernmental grants. The result is also robust to using bidder fixed effects, issuer fixed effects, and to restricting the effects of taxes on bidder participation. 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 severely limits concerns that our results are driven by omitted factors that may be correlated with both tax changes and borrowing costs.

[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 50^{th} percentile to the 75^{th} percentile as shown in Table 1.

the state exemption altogether. We find that capping the excludability of municipal bond interest at 28%, as proposed by the Obama administration, would increase the average borrowing rate by 31%, and markups by 185%, and that states with fewer bidders and lower state taxes would be more affected by this policy. We find smaller effects from the Trump proposal to lower the top marginal tax rate to 35%, and very large effects from completely eliminating the exemption. Overall, we find that the increased borrowing costs from reducing tax advantages are 2.8-times as large as the reduction in the cost of the tax expenditure. This suggests that, while this tax advantage is mostly enjoyed by top-income individuals, the effect on the market structure makes it an efficient way to lower municipal borrowing rates.

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. (2017), Cassola et al. (2013), Hortaçsu and Kastl (2012), or 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 (Hortaçsu et al., 2017). Like these papers, 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, but additionally, and perhaps more importantly, its concentration on the interaction between tax policy and market structure,[6] including bidders' endogenous participation decisions.[7]

Second, we contribute to the extant 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.[8] While most of this literature focuses on arbitrage of existing issues of municipal bonds, our paper is more suited to studying the effects on government budgets.[9] Third, the tax advantages of municipal bond interest are a large tax expenditure from the point of view of federal and state governments, which is forecast to cost the federal government alone more than $500 billion in forgone revenue over the next 10 years (U.S. Department of the Treasury, 2016). 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

[6]Tang (2011) and Shneyerov (2006) study municipal bond auctions for the purposes of non-parametrically analyzing revenue implications of alternative mechanism designs. They do not study the tax incentives associated with such bonds.

[7]Recent work has shown the importance of allowing for endogenous participation in auctions for a variety of mechanism design and policy-related questions in both theoretical (e.g., Sogo et al. (2016)) and empirical (e.g., Li and Zheng (2009) and Roberts and Sweeting (2013)) settings, and this paper contributes further evidence to these findings.

[8]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. (Forthcoming) 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.

[9]For instance, Green (1993), Schultz (2012), Ang et al. (2010b), and Kueng (2014) compare traditional municipal bonds to other bonds and calculate implied tax rates. While previous papers address important interactions between tax advantages and the behavior of financial markets, our focus is the effects of tax advantages on borrowing costs. In particular, our results are not informative of the incidence of tax advantages in secondary markets. However, the existence of markups in our analysis is consistent with results in Green et al. (2007) that show that broker-dealers may be able to benefit from losses of uninformed investors.

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 at reducing borrowing costs,[10] which current conventional wisdom believes it is not.[11]

Third, we contribute to the literature focused on the importance of competition for auction outcomes. Despite the conventional wisdom in the literature that increasing competition is more important for maximizing sellers' revenues, or in this case minimizing borrowing costs, than many parameters of auction design,[12] there are few real-world examples of policies designed to promote more competition in auctions.[13] Our paper, on the other hand, analyzes a real-world policy that subsidizes the value of the auctioned good, which affects the set of all potential bidders, as well their entry and bidding decisions.

Finally, we contribute to both the Public Economics and Industrial Organization literatures by analyzing a realistic setting in a second-best world where imperfect competition, under-provision of public goods, and tax expenditures may interact. We build on recent work in public finance that has shown accounting for these interactions is important when measuring the effects and incidence of taxes in markets that are not perfectly competitive.[14] Our setting provides a very clear example where we provide non-parametric evidence of market power within auctions, and we show that such market power may lead to greater-than-unity passthrough.[15] 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. Section 4 shows that tax advantages may have greater-than-unity passthrough to borrowing rates, and provides non-parametric evidence that this mechanism is important in our setting. In Section 5, we develop an auction model for municipal debt with tax advantages. Section 6 estimates this model and conducts policy counterfactuals. Finally, Section 7 concludes.

[10] Some highlights of this literature are Poterba (1989, 1986), Cestau et al. (2013), Ang et al. (2010a), Schultz (2012), and Galper et al. (2014). Our paper is also related to a literature that models general equilibrium implications of removing this subsidy. For instance, Feenberg and Poterba (1991), Gordon and Metcalf (1991), Gordon and Slemrod (1983), Poterba and Verdugo (2011), and Galper et al. (2014) examine implications of removing the subsidy for different involved parties.

[11] See discussion of potential rents by high income individuals from the municipal bond exemption in Liu and Denison (2014).

[12] 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, if not more, important. 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.

[13] A key exception are bidder subsidy or 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), Krasnokutskaya and Seim (2011), and Marion (2007). However, these subsidies are generally targeted at small or minority-owned bidders, and as such the subsidies may be driven more by a desire to spread resources across a wide 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 their value.

[14] Several recent papers include Marion and Muehlegger (2011), Auerbach and Hines (2011), Fabinger and Weyl (2013), and Conlon and Rao (2015).

[15] In our study of the role that imperfect competition plays in dictating passthrough, we are also related to similar papers that have studied related questions in other settings like electricity markets (e.g., Fabra and Reguant (2014) who analyze how emission costs pass through to electricity prices) or import markets (e.g., Goldberg and Hellerstein (2008) who study exchange rate passthrough).

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

In the U.S., municipal bonds have been consistently issued by municipalities and local governments to fund various public projects including the construction of schools, highway repairs, and capital improvement of 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, its total outstanding debt surpassed $3.8 trillion as of 2016, with about $400 billion worth of bonds having been issued in 2015 alone (SIFMA, 2017). The secondary market for municipal bonds is characterized by low liquidity; typically, purchasers in this market do not trade the bonds again.

2.1 Issuance of Municipal Debt Through Auctions

There are three ways in which the bonds are issued: through negotiation, competitively through auctions, and via private placement; 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.[16] In practice, municipalities often sell series of bonds in a single batch, and potential underwriters compete for the whole series at the same time by placing total interest cost bids. These interest costs essentially correspond to the interest rate 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.[17]

2.2 Tax Advantages of Municipal Debt

In the U.S., interest income from most municipal debt is exempt from both federal corporate tax and federal personal income tax, as well as 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 controlled the use of municipal debt to fund non-municipal projects—so-called "private activity" bonds.[18]

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, and 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 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

[16] 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.

[17] In negotiated sales the issuer finds a willing underwriter and together they discuss conditions of the sale and design of the bonds. Private placement involves selling the bonds directly to the final consumer.

[18] 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 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.

curtail infrastructure projects or raise taxes on sales, property or income" (Ackerman, 2016). It remains to be seen whether the current administration or the Republican-dominated legislature will propose similar adjustments to the tax status of these bonds, but as they currently do support reductions in marginal rates, that alone would affect the tax advantage of these bonds. We discuss proposed reforms in more detail in Appendix G, and we simulate the effects of some of these proposals in Section 6.4.

Most states exempt interest earned from municipal bonds initiated within their borders and tax the 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. None of the states with a personal income tax exempt interest from municipal bonds sourced from other states. The federal personal income tax allows for the deduction of state income taxes paid in the last year, so the marginal federal income tax rate can be higher in states that do not have a personal income tax. Lastly, 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. The effective tax advantage in state s, at time t, is given by:[19]

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

The resulting variation in effective tax rates across states and over time is an important source of variation in the data that we use to identify the effect of tax treatment on municipal borrowing costs.

2.3 Data

We now introduce the data we use in our analysis. The primary data on bond auctions come from two sources. The first source is The Bond Buyer, the leading news resource of the industry where notices of upcoming sales as well as results of past sales are posted. From this data source we obtain all competitive sales of bonds, and all bids submitted in each auction. These data are supplemented with information from the SDC Platinum database from which we obtain more details about the characteristics of the bonds being sold, such as their refund status, funding source, and their rating, as some of the bonds are rated by the major rating agencies.

In our analysis, we focus on issuances of General Obligation bonds, which are not associated with a particular revenue source, that are larger than \$5 million, and that are issued between February 2008 and December 2015. Complete details of the sample construction are given in Appendix B. Our final sample of 14,631 auctions is summarized in Table 1. 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, and Panel (a) in Figure 1 plots the geographic distribution of bonds. While more than half of the bond issuances come from five states: Massachusetts, Minnesota, New

[19]This formula ignores issues related to alternative minimum taxes and to the potential for state deduction of federal taxes. Our empirical analysis incorporates the effects of these policies.

Jersey, New York, and Texas, the dollar value of the bonds is more spread out, with half coming from eight states: California, Florida, Maryland, Massachusetts, New Jersey, New York, Texas, and Washington. Panel (b) of Figure 1 shows the variation in the average winning bid by state, and shows considerable heterogeneity 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, we construct a measure of the set of potential bidders that potentially could have bid, but did not.[20] We define the number of potential bidders in a given auction to be the number of actual bidders in the auction plus the number of other bidders that 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 N_j is defined as follows:

$$N_j = n_j + \frac{\sum_{i \in G} \sum_{a \in i} \mathbb{1}(a \text{ not in } j) K(X_i - X_j)}{\sum_{i \in G} K(X_i - X_j)},$$

where i iterates over auctions in G, and a iterates over agents in auction i. The function $K(X_i - X_j)$ measures similarity between auctions i and j based on their observable characteristics. In practice, we use a triweight kernel for $K(\cdot)$, X includes the size and maturity of the bonds, and we round-up to the nearest integer. 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. While this measure of potential bidders is in line with the current literature, we also explore an alternative definition in Appendix C.[21]

The primary tax policy of interest in this study is the top marginal personal income tax rate. In order to measure state and federal personal income tax rates, we employ the NBER TAXSIM data on maximum state income tax rates (Feenberg and Coutts, 1993). These tax rates are simulated by the NBER from actual tax return data and take into account deductions and exemptions of individuals living in each state.[22] 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.

Table 1 describes the distributions of the marginal state and federal rates, as well as the effective marginal income rate that would be applicable for municipal bond income. The average rate in our period of analysis is 40.1%, and the difference between the 5th and the 95th percentile of the distribution is 12 pp. In 2008 for

[20]In the literature, there is typically no direct measure of the number of potential bidders and there is a variety of ways such measures are constructed. In procurement contexts, the set of potential bidders is often set to be those firms holding plans for the job being procured (e.g., Krasnokutskaya and Seim (2011), Li and Zheng (2009), or Bhattacharya et al. (2014)). In other contexts, the set of potential bidders are 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 are those bidders that bid in the auction, plus those bidders who bid in nearby auctions within a relatively short amount of time.

[21]Arguably, our definition of potential bidders represents an advance over other 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 are only indirectly controlled for by geographic proximity. Under our alternative approach, we view every underwriter participating in an auction as a potential bidder for all auctions held in the same state in the same month.

[22]The exact number computed by the NBER is the simulated marginal tax rate 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.

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. Panel (c) of Figure 1 describes the geographic distribution of the tax advantage for municipal bonds in 2015. This map shows considerable cross-sectional variation. Our period of study contains a significant number of policy changes that drive within-state variation in the tax advantage. Panel (d) of Figure 1 shows that between 2008-2015 most states experienced an increase in the effective rate, and that 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 provide an annual report detailing state level fiscal policies including balanced budget amendments and taxation and expenditure limitations (TELs) (National Association of State Budget Officers, 2008-2015). 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).

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

Our first set of analyses explores the reduced-form effects of changes in taxes 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, the log-value of the issuance, the 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. In particular, since state income taxes are deducted from federal income taxes, the sunsetting of the Bush tax cuts in 2012 led to an increase in the tax advantage that was disproportionately larger in states with lower, or no personal income taxes. Since the variation in the tax advantage is defined at the state-level, we allow for arbitrary correlation of ε_{ist} across auctions in a given state.

Column (1) in the first panel of Table 2 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 0.018. To gauge the magnitude of this effect, consider that at the mean borrowing rate of 2.14%, a 3 pp. increase in the effective rate would imply a reduction in borrowing costs of 9.1%. Since state and municipal governments spent \$124 billion on interest payments in 2014, this would imply a cost reduction of \$11.3 billion (U.S. Census Bureau, 2017). An additional way to appreciate the magnitude of this effects is through the passthrough elasticities of the net-of-tax rate (i.e.,

$1 - \tau$) on borrowing costs. Given a median effective tax of 40.8% and a median winning bid of 221 basis points, this estimate implies a passthrough elasticity of 1.7.

The exclusion restriction 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 election. Column (3) controls for tax base policies 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. We include new variables digitized from *State Tax Handbooks* (CCH, 2008-2015) including whether a state has an alternative minimum tax, whether a state allows for the deductibility of federal taxes, and whether own- or other-state municipal bond income is excluded from taxation.[23] Column (4) also controls for the state sales tax rate, while Column (5) also adds controls for business and property tax policies.[24] Our estimate of β is remarkably stable with a range of 6.3-7.0 basis points across these specifications, which suggests that the exclusion restriction is likely to hold. Relative to the mean borrowing cost, these estimates imply that a 3-pp. increase in effective tax rates reduces borrowing costs by 9-10%, and imply passthrough elasticities between 1.7-1.9.

Appendix C discusses additional robustness checks. In particular, Table A.4 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.[25] Our most demanding specification identifies β using repeated bond auctions by the same issuer (municipality) in time periods with different (federal and state) tax rates, which severely limits concerns that our results are driven by omitted factors that may be correlated with both tax changes and borrowing costs.

We now explore the interaction between tax policy and imperfect competition. First, we estimate an analogous specification to Equation 2 but where the dependent variable is the number of potential bidders. The second panel in Table 2 presents the result 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. These estimates are also stable across specifications, and Table A.5 shows that a similar increase is found when using an alternative definition of potential bidders.

As additional potential bidders are likely to lead to lower winning bids, we now explore the degree to which the results in the first panel are due to tax-driven changes in the competitiveness of a given auction. The third panel of Table 2 presents estimates of Equation 2 where we now partial out this mechanism

[23] 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.

[24] We use data from Suárez Serrato and Zidar (2016) and control for sales taxes, corporate income taxes, business tax apportionment rules, and a measure of the average property tax in the state.

[25] We formalize this evidence of coefficient stability by using the methods proposed by Altonji et al. (2005) and Oster (Forthcoming), which we present in Table A.8, and discuss in Appendix C.5.

by controlling for fixed effects in 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.[26] We compare the results from the first and third panels of Table 2 and report the fraction of the total effect that is due to changes in auction competitiveness. We find that this fraction ranges between between 23% and 28%, which suggest that the effect of taxes on bidders' participation decisions are an important determinant of borrowing costs.[27] Finally, we note that removing the indirect effect of taxes on auction competition results in a smaller passthrough elasticity in the range 1.2-1.4.[28]

These reduced-form results 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. An economic model of the effects of tax advantages on borrowing costs must therefore reconcile these reduced-form facts by showing how taxes affect entry into the auction, how the strategic participation of bidders affects the residual supply for individual bidders, and how these changes affect the ability of bidders to extract information rents by shading their bids relative to their valuations.

4 Tax Incidence in Auctions: Intuition and Non-Parametric Evidence

This section builds on the reduced-form results of Section 3 in two ways. First, we identify conditions under which changes in tax advantages may have greater-than-unity passthrough in imperfectly competitive auctions. These conditions suggest that the reduced-form results may be consistent with two features of the auctions we analyze: (1) that winning bidders enjoy markups over their valuation of the bonds, and (2) that bidder selection and markups are highly responsive to changes in taxes. Second, we provide non-parametric evidence that these forces are at play in our data. In contrast to the reduced-form results that only rely on the winning bid, the non-parametric analysis uses the full distribution of bids to demonstrate the existence of markups, and to show how these are affected by changes in tax advantages.

4.1 Incidence

To build intuition, we work with a simple model of competition among bidders in a first-price sealed low-bid auction with independent private values. Each bidder i knows her valuation and the distribution of the valuations of the other N bidders. In Section 5, when we present the structural auction model that we will take to the data, we enrich the simple model presented here in a number of ways, including allowing for

[26] Figure A.2 reports the coefficients on the number of bidders fixed effects 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 bonds have less than 8 bidders, there is substantial scope for lowering municipal borrowing costs by increasing competition in auctions.

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

[28] In Appendix C.3 we find that there is not a meaningful response in the supply of issuances to changes in τ.

endogenous bidder participation decisions and unobserved (to the econometrician) heterogeneity in bonds that can lead to correlation in bidder values even conditional on observable bond characteristics.

In order to maximize her payoff, a bidder solves:

$$\max_b (b - v)\mathbb{P}r[b < b_{-i}|N, X, v]$$

where $\mathbb{P}r[b < b_{-i}|N, X, v]$ is the probability an agent with value v for a bond with characteristics X wins the auction when she bids b, while the other $N - 1$ bidders bid b_{-i}. For ease of notation, let $\mathbb{P}r \equiv \mathbb{P}r[b < b_{-i}|N, X, v]$. A given bidder in an auction faces a tradeoff between lowering the probability of winning, and obtaining a larger surplus conditional on winning. This tradeoff is formalized by the solution to the bidders' problem:

$$b = v + \underbrace{\frac{\mathbb{P}r}{-\frac{\partial}{\partial b}\mathbb{P}r}}_{\text{Markup}}.$$

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 that bids above her valuation is zero, 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.[29] 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. While these mechanisms are well-understood in the auction literature, we make a point to stress their empirical importance in our setting, since the role of imperfect competition has not been analyzed in the municipal bond literature.

Consider now the effects of an increase in the tax advantage of municipal bonds, where the effective rate increases from τ_0 to τ_1. Taking the difference in the winning bid between time periods 0 and 1, we have:

$$b_1 - b_0 = v_1 - v_0 + \left(\frac{\mathbb{P}r_1}{-\mathbb{P}r'_1} - \frac{\mathbb{P}r_0}{-\mathbb{P}r'_0}\right).$$

We can decompose this change into three effects: tax advantage, selection of bidders, and changes in markups. Defining the markup rate, $m = \frac{b_0 - v_0}{b_0}$, we can write:[30]

$$\varepsilon^b_{1-\tau} \quad = \quad (1 - m) + (1 - m)\varepsilon^{\text{Selection}}_{1-\tau} + m\varepsilon^{\text{Markup}}_{1-\tau}, \tag{3}$$

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

[30] This follows from letting $\tilde{v}_t$ be the pre-tax value of the bond and adding and subtracting $(1 - \tau_1)\tilde{v}_0$:

$$b_1 - b_0 \quad = \quad [(1 - \tau_1) - (1 - \tau_0)]\tilde{v}_0 + (1 - \tau_1)(\tilde{v}_1 - \tilde{v}_0) + \left(\frac{\mathbb{P}r_1}{-\mathbb{P}r'_1} - \frac{\mathbb{P}r_0}{-\mathbb{P}r'_0}\right).$$

Dividing by the initial bid b_0 and using ΔX to denote the percentage change in a given variable, we obtain:

$$\Delta b \quad = \quad (1 - m)\Delta(1 - \tau) + (1 - m)\frac{(1 - \tau_1)}{(1 - \tau_0)}\Delta\tilde{v} + m\Delta\text{Markup}.$$

Equation 3 results from dividing by $\Delta(1 - \tau)$, and noting that for small tax changes $\frac{(1-\tau_1)}{(1-\tau_0)} \approx 1$. In the setting described above with exogenous and fixed participation, $\Delta\tilde{v} = 0$ and there is no selection effect. The selection effect arises when changes in taxes interact with endogenous participation decisions, which we allow for in Section 5. When taxes change, the set of potential bidders can change, the set of actual bidders can change, and thus the identity of the winning bidder can change, so that $\Delta\tilde{v}$ may not be zero.

where we introduce the tax advantage elasticities of borrowing costs, $\varepsilon^{b}_{1-\tau}$, selection, $\varepsilon^{\text{Selection}}_{1-\tau}$, and markups, $\varepsilon^{\text{Markup}}_{1-\tau}$.[31] The term $(1-m)$ captures the direct effect of the change in the tax advantage conditional on the same bidder winning the auction in both periods. The term $\varepsilon^{\text{Selection}}_{1-\tau}$ captures the possibility that as changes in tax advantages affect the participation decision of bidders, the winning bidder may have an idiosyncratically larger valuation for the bond. Finally, $\varepsilon^{\text{Markup}}_{1-\tau}$ captures the fact that changes in the tax advantage may affect the degree to which bidders are able to shade their bids and extract information rents.

Equation 3 shows that in perfectly competitive auctions, where $m=0$ and $\varepsilon^{\text{Selection}}_{1-\tau}=0$, we would expect a unit passthrough elasticity. In imperfectly competitive auctions, $\varepsilon^{b}_{1-\tau}$ may be greater or smaller than one, depending on the effects of taxes on selection and markups. In particular, the effects of changes in the tax advantage on selection and markups may have countervailing effects on borrowing costs. If a larger tax advantage, i.e. smaller $(1-\tau)$, leads to a less dispersed distribution of bidder values, it will be harder for bidders to shade their bids and markups may decrease, *i.e.*, $\varepsilon^{\text{Markup}}_{1-\tau}<0$. At the same time, a less dispersed distribution of bidder values decreases the chance that a bidder will have an idiosyncratically high value for the bond, which increases borrowing costs, *i.e.*, $\varepsilon^{\text{Selection}}_{1-\tau}>0$. Without a selection effect, this equation also implies that if $\varepsilon^{b}_{1-\tau}>1$, it must also be the case that $\varepsilon^{\text{Markup}}_{1-\tau}>1$.

Our reduced-form results may be consistent with the case where markups are non-zero, where markups have a greater-than-unity elasticity with respect to the tax advantage, and where the countervailing effect on selection does not overwhelm the effect on markups. One of the main contributions of this paper is to reassess the role of tax advantages for municipal bonds by pointing to this interaction between imperfect competition and tax policy as the source for large passthrough elasticities.

In order to illustrate the relation to the data, we further decompose the effect of taxes on markups:

$$\varepsilon^{b}_{1-\tau}=(1-m)+(1-m)\varepsilon^{\text{Selection}}_{1-\tau}+m\times\left(\underbrace{\varepsilon^{\mathbb{P}r}_{1-\tau}}_{\text{change in own market share}}+\underbrace{\varepsilon^{-1/\frac{\partial}{\partial b}\mathbb{P}r}_{1-\tau}}_{\text{change in inverse supply slope}}\right),\tag{4}$$

where the last two terms decompose $\varepsilon^{\text{Markup}}_{1-\tau}$.[32] An increase in the tax advantage may decrease the 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, which is consistent with a less dispersed distribution of values in our model.

[31] This equation focuses on the within-auction effects of tax changes. Our empirical analysis controls for the size of the issuance, and in Appendix C.3 we show that there are no supply responses on the extensive margin.

[32] This follows from:

$$b_1-b_0=\underbrace{v_1-v_0}_{\text{direct effect}}+\underbrace{(\mathbb{P}r_1-\mathbb{P}r_0)}_{\text{change in own market share}}\underbrace{\frac{1}{-\frac{\partial}{\partial b}\mathbb{P}r_0}}_{\text{inverse supply slope}}+\underbrace{(\mathbb{P}r_1)}_{\text{new market share}}\underbrace{\left[\frac{1}{-\frac{\partial}{\partial b}\mathbb{P}r_1}-\frac{1}{-\frac{\partial}{\partial b}\mathbb{P}r_0}\right]}_{\text{change in inverse supply slope}}$$

Rearranging as in Equation 3 we obtain: $\Delta b=(1-m)\Delta(1-\tau)+(1-m)\frac{(1-\tau_1)}{(1-\tau_0)}\Delta\tilde{v}+m\Delta\mathbb{P}r+m\frac{\mathbb{P}r_1}{\mathbb{P}r_0}\Delta\left(\frac{1}{-\frac{\partial}{\partial b}\mathbb{P}r}\right)$. Noting that for small changes we have $\frac{\mathbb{P}r_1}{\mathbb{P}r_0}=1$, and dividing by $\Delta(1-\tau)$ we obtain Equation 4.

4.2 Non-Parametric Evidence

We now use standard tools in the auction literature (e.g., Li et al. (2000)) to provide non-parametric evidence that bidders may be able to exploit limited competition in auctions to extract markups from the auction, and to show how changes in tax advantages may limit the scope for this behavior.

We begin by estimating the probability of winning an auction using the kernel estimator:

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

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 X_j. We use triweight kernels with bandwidth $h_X = c \cdot std(X) \cdot (J)^{-1/5}$, where J denotes the number of auctions, $std(X)$ measures the standard deviation of X, and $c \approx 3$ is the kernel-specific constant. We condition on the number of potential bidders N, on the effective tax rate τ, and on maturity between 2 and 17 years, which corresponds to the middle tercile of the length distribution.

Figure 2 plots this estimated probability for different values of N and τ. As discussed above, 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 blue solid lines correspond to estimated probabilities of winning for the mean value of $\tau = 0.35$ and for $N = 4, 6, 8, 10$.[33] These lines show that auctions for municipal bonds are far from the ideal of perfect competition as the finite slope allows for 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 add intuition to the incidence of taxes on the winning bid. For each value of N, the red line plots the estimated probability of winning with a higher $\tau = 0.39$. These plots show that auctions with larger tax advantages reduce the 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 in Section 3, higher effective rates also lead to increases in N. In particular, a reform that increased 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. These graphs show that the scope for markups is further reduced by the indirect effect of the tax advantage on the level of competition.

We now relate the changes in the probability of winning in Figure 2 to passthrough estimates. We decompose the effect of tax changes on borrowing costs into three mechanisms: the change in value, the change in competitive bidding behavior, and the change arising from increasing the number of potential bidders. For a given hypothetical valuation (we set the value equal to the median bid), we solve for the optimal bid under four conditions:

1. <u>b_0: Baseline condition; $v_0 =$ Median b, $\tau_0 = 0.35$, and N_0.</u> The optimal bid is given by:

$$b_0 = \arg\max_b \, (b - v_0) \mathbb{P}r[b < \widehat{b_{-i}|}N_0, X_0].$$

[33]Here N refers to the measure of potential bidders in the data, although in this model there is no distinction between potential and actual bidders. That distinction will be introduced in Section 5.

Table 3 shows the initial values, v_0, and the optimal bids, b_0, for different values of N_0. The third column of this table lists the borrowing cost that would be implied by a unit passthrough elasticity.

2. b'_1: Change in own-value; $v_1 = \frac{(1-\tau_1)}{1-\tau_0} v_0$, $\tau_0 = 0.35$, $\tau_1 = 0.39$, and N_0. This hypothetical bid results from only changing the value of one bidder and holding constant the values of all other bidders, and is given by:

$$b'_1 = \arg\max_b \, (b - v_1)\mathbb{P}r[b < \widehat{b_{-i}|N_0}, X_0].$$

Column (4) in Table 3 shows the optimal bids are lower than b_0, and, in some cases are close to the bid implied in the case of perfect passthrough. Column (2) in Table 4 displays the implied passthrough elasticities and shows that even when the probability of winning remains unchanged, the change in a given bidder's valuation results in substantial passthrough elasticities.

3. b''_1: Change in values for all bidders; v_1 as above, $\tau_1 = 0.39$, and N_0. In this case, bidders further lower their bids because the increase in other bidders' valuations affects the probability of winning.

$$b''_1 = \arg\max_b \, (b - v_1)\mathbb{P}r[b < \widehat{b_{-i}|N_0}, X_1].$$

Table 3 shows that the optimal bid is lowered even further and Table 4 shows that the implied passthrough elasticity is greater than one in most cases.

4. b_1: Total effect including additional entry; v_1 as above, $\tau = 0.39$, and $N_1 = N_0 + 2$. This case comprises the total effect, where we now adjust N to include the indirect effect of taxes on bidding through its effect on the number of potential bidders. The optimal bid is now given by:

$$b_1 = \arg\max_b \, (b - v_1)\mathbb{P}r[b < \widehat{b_{-i}|N_1}, X_1].$$

Tables 3 and 4 show how the indirect effect on the number of potential bidders further lowers the optimal bid and increases the passthrough elasticity in most cases.

These results are illustrative of how tax-driven changes in the probability of winning affect bidder behavior and, in particular, how this may limit the scope for bidders to extract information rents leading to greater-than-unity passthrough. As discussed above, cases with greater-than-unity passthrough to borrowing costs require large effects of tax changes on markups. In Appendix D, we discuss the implementation of the methods of Li et al. (2000) to estimate the distribution of values and implied equilibrium markups for every auction. Table 5 shows the estimated markups, m_0, in actual auctions with $\tau = 0.35$. The second column shows the markups that would result if τ increases to 0.39, while holding the number of potential bidders fixed. The third column shows the markups in auctions with $\tau = 0.39$, and where we allow the number of potential bidders to increase with the tax advantage. The fourth and fifth columns show estimates of $\varepsilon^{\text{Markup}}_{1-\tau}$, and show that these elasticities are much greater than unity, consistent with the decomposition in Equation 3. Column (5) shows that the increase in the number of potential bidders generally results in larger markup elasticities.

While the results of the non-parametric analysis provide transparent evidence that bidders in imperfectly competitive auctions may obtain markups in equilibrium, and that changes in the tax advantage lead to greater-than-unity passthrough through changes on markups, this analysis is limited in several dimensions.

First, while we observe that the distribution of bids is compressed when the tax advantage is larger, we are not able to quantify this effect without a specific model. Second, the kinds of reforms that are proposed by policymakers are often beyond the range of variation in the data, and it is not possible to evaluate the effects of these policies on the equilibrium borrowing costs of municipal governments without a specific model. Third, the curse of dimensionality prevents us from conducting non-parametric analyses that control for many observable features of auctions. Fourth, both the reduced-form results and non-parametric analyses show that the indirect effect of tax advantages on the number of potential bidders is a significant component of the total effect on borrowing costs. However, these methods do not allow us to quantify how potential bidders decide to enter into auctions, and how tax advantages affect this choice. The following section proposes an empirical auction model that overcomes these limitations, and that allows us to further analyze the mechanisms driving the effects of tax advantages on auctions for municipal bonds.

5 Model of Participation and Bidding in Municipal Bond Auctions

In this section we present a model of participation and bidding in municipal bond auctions, which we will estimate in order to perform counterfactual changes to tax policy in Section 6.[34] Consider the 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 that submits the lowest bid b. Each bidder i has a private value v_i for the bond, which is drawn 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 a 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 $\left[\underline{d}, \overline{d}\right]$. 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.

The informational assumptions of the model are as follows. At the entry stage, each of the N potential bidders knows his own entry cost d_i, the number of potential bidders N, 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. We assume conditionally independent private values, similar to other recent work on auctions for financial products (*e.g.*, Hortaçsu et al. (2017)).[35]

[34] Similar entry and bidding models are used elsewhere in the literature, e.g. Krasnokutskaya and Seim (2011) or Li and Zheng (2009). As we will assume that bidders do not know the number of competing bidders, our modeling approach is closest to that of Li and Zheng (2009). Appendix E provides additional details behind the model derivation.

[35] When a bank or other broker-dealer wins an auction to be the underwriter of a municipal bond issue, they can hold some of the debt themselves and sell the rest of the bond package to other institutional and individual investors. The bidder's value depends 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 differing levels of information, so that 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 geographically or otherwise, their 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

As in Li and Zheng (2009), the model can be altered to incorporate reserve prices, but like them we will focus on auctions without reserve prices to be consistent with the data. We follow Li and Zheng (2009) in assuming that each potential bidder holds the belief that if they are 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. This allows us to rationalize instances in our data where there is one participating bidder that 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 unknown number of competitors. This is due to the fact that, since there is always a chance that an entrant faces no competition, there is always an incentive to bid infinity.

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 its expected profits by choosing its 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 she will face:

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

Here $Pr^*(\cdot)$ is the equilibrium probability that k bidders participate in the auction, and is given by:

$$Pr^*\left[n=k\right] = C_{N-1}^{k-1}(p^*)^{k-1}(1-p^*)^{N-k}, \tag{5}$$

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.

The first order condition of the above maximization problem is:

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

The equilibrium bidding function $\beta(\cdot)$ is characterized by the solution to this first order condition, subject to the upper boundary condition $\beta(\overline{v}) = \overline{v}$, and is given by:

$$\beta(v) = v + \frac{\sum_{k=1}^{N} Pr^*\left[n=k\right]\int_{v}^{\overline{v}}\left(1-F(q)\right)^{\max(k-1,1)}dq}{\sum_{k=1}^{N} Pr^*\left[n=k\right]\left(1-F(v)\right)^{\max(k-1,1)}}.$$

It will be helpful for us to define a mapping between bids and values which does not depend on the distribution of values directly. To that end, let $G(b)$ and $g(b)$ be the cumulative distribution and density functions of a randomly chosen participant's bid, and note that

$$f\left(\beta^{-1}(b)\right)\frac{\partial\beta^{-1}(b)}{\partial b} = g(b),$$

the bidders. Interestingly, Tang (2011) shows that making incorrect assumptions about bidder values has negligible impacts on expected revenue.

which allows us to rewrite the first order condition for bidding as:

$$\frac{1}{b_i - v_i} = \frac{\sum_{k=1}^{N} Pr^* [n = k] (k-1) g(b_i) (1 - G(b_i))^{\max(k-2,0)}}{\sum_{k=1}^{N} Pr^* [n = k] (1 - G(b_i))^{\max(k-1,1)}}. \tag{6}$$

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 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 value. The equilibrium cutoff is determined by a zero profit condition for the potential entrant for whom $d_i = d^*$:

$$E\pi(v_i | p^*(d^*)) = d^*, \tag{7}$$

where the dependence of p^* on d^* is explicitly denoted.

6 Estimation and Policy Counterfactuals

We now outline the estimation of the model, discuss estimation results, and analyze the effects of counterfactual policy reforms that have recently been proposed. This allows us to evaluate the efficiency of subsidizing municipal borrowing costs through tax advantages.

To take the model in Section 5 to the data, we allow for bidders' bond valuations to depend on bond-specific characteristics that may or may not be observable to the econometrician. Consider an auction for municipal bond j with characteristics X_j and Z_j, which are observable to the econometrician as well as the bidders. Bidder i's value for this bond is given by $v_{ij} = \tilde{v}_{ij} + u_j$, where u_j represents heterogeneity across bonds that are observable to the bidders but not the econometrician, and $\tilde{v}_{ij}$ are i.i.d. for each bidder i.[36] The additive structure of the bidders' idiosyncratic values for bond j and the unobservable heterogeneity component imply that bidder i's bid $b_{ij} = \tilde{b}_{ij} + u_j$, where $\tilde{b}_{ij}$ can be interpreted as the bidder-specific bid component. At the entry stage, each of the N_j potential bidders observe X_j and u_j, realize their idiosyncratic private information entry costs d_{ij}, and decide whether to enter based on their expected profits from participating in the auction.

6.1 Estimation

We estimate this empirical model using a two-step estimation approach. In the first step we estimate parameters of the bid ($\theta_{\tilde{b}}$), entry cost (θ_d), and unobservable heterogeneity distributions (θ_U), and in the second step we back out the distribution of bidder values following the arguments of Guerre et al. (2000).[37]

[36] 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. However, as we will assume that both X_j and u_j will be observable to bidders before they take their entry decisions, it need not be independent of the actual number of entrants, n_j.

[37] A similar approach is used elsewhere in the literature (e.g., Krasnokutskaya and Seim (2011) and Athey et al. (2011)). Compared to the alternative approach of parameterizing the values, this method enables us to lessen the computational burden of the estimation procedure and include a richer set of controls.

We parametrize the model as follows:

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

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,[38] $ln\mathcal{N}(c,d)$ 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.

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:

$$\mathcal{L}(\theta) = \prod_{j=1}^{J} C_{N_j}^{n_j} \hat{p}_j(\theta)^{n_j}(1-\hat{p}_j(\theta))^{N_j-n_j} g(b_1,\ldots,b_{n_j};\theta), \tag{8}$$

where $g(b_1,\ldots,b_{n_j};\theta)$ is the joint density of bids in auction j, and $\hat{p}_j(\theta)$ the equilibrium entry probability associated with parameters θ. We compute these entry probabilities as follows. First, following Equation 6, define the expected profits of submitting bid $\tilde{b}$ for any given probability of entry p as

$$E\pi(\tilde{b}|p) = \frac{1}{g(\tilde{b};\theta_{\tilde{b}})} \sum_{k=1}^{N} \left[Pr^*\left[n=k\right] \left(1-G(\tilde{b};\theta_{\tilde{b}})\right)^{\max(k-1,1)} \right],$$

with $Pr^*\left[n=k\right]$ defined in Equation 5. The entry probability $\hat{p}_j$ is given by the probability that the entry cost d_{ij} is below the entry cost implied by the zero profit condition in Equation 7.[39] After maximizing Equation 8 to recover estimates $\widehat{\theta}$, we back out the implied value v_{ij} corresponding to each bid b_{ij} using Equation 6.

We note that our model is nested within the framework of Gentry and Li (2014), who study non-parametric identification in auction models where potential bidders can observe a noisy, and potentially independent, signal of their value prior to entry. They show that with sufficient exogenous variation in signal thresholds, which could stem from variation in the number of potential bidders, the model is non-parametrically point identified even in the presence of unobserved auction-level heterogeneity. In order 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 believe it is important to include an extensive set of covariates in the model, and so we adopt a parametric estimation approach.

[38] 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 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.

[39] To determine the unique solution to Equation 7 we evaluate the left-hand-side of the zero profit condition with

$$E\pi(p^*) = \int_{\underline{\tilde{b}}}^{\infty} E\pi(\tilde{b}|p^*, u=0) g(\tilde{b};\theta_{\tilde{b}}) d\tilde{b}.$$

Note here that we leverage the fact that bids and values are linear functions of the unobservable, which imply that bidder's profits are independent of u, and it is enough to compute them just for $u=0$. This is in contrast to Athey et al. (2011), where profits of bidders are proportional to a function of unobservable u, and Krasnokutskaya and Seim (2011), where profits are proportional to u.

6.2 Estimation Results

The baseline model parametrizes the mean of the distribution of bids as a linear function of the number of potential bidders, the maturity of the bond, and the effective rate. For unobservables, we allow for the mean of the distribution to have different values for every state and every year. The mean of the distribution is also allowed to vary linearly with a number of the controls used in Section 3.[40] The standard deviation and the lower threshold of the distribution of bids are parametrized as linear functions of the number of potential bidders, the maturity of the bond, and the effective rate.

Estimation results for the baseline model are reported in Table 6. The estimate for the effect of τ on the mean of the parametrized distribution of bids, $\hat{\beta}$, has a similar sign and magnitude as in the reduced-form estimates of Table 2 that condition on entry: a 1 pp. increase in τ leads to a 4.2 basis point decrease in bids, on average.[41] We also find that τ has a negative effect on the standard deviation of the parametrized distribution of bids, $\hat{\gamma}$. This implies that the dispersion in bids decreases as the tax advantage increases. As discussed in Section 4, this may imply a tradeoff between markup and selection effects, which we explore below.

We now evaluate the fit of the model. Table 7 presents summary statistics of actual and simulated bids and shows that the model fits the patterns of the data very well. This is further confirmed by Figure 3, which plots kernel densities of the bids in the data along with the simulated bids from the model.[42] Table 7 also reports patterns of auction entry in the form of the ratio of actual to potential bidders, n/N. The model predicts that, on average, 73% of the potential auction participants enter the auction, which fits the actual mean of 70%.

We use the model estimates to simulate entry costs and bidder markups, which we report in Table 7. We find that the median threshold entry cost in our data d^* is 0.35%. At the median bond size offering, this translates to an entry cost of about \$35,000, which may be reasonably commensurate wth the costs of engaging in pre-sale marketing activities, as well as performing due diligence on the particular bond offering. In terms of markups, we estimate that the median markup in the data is 11 basis points. We find considerable heterogeneity in markups, m_1, ranging between 7 to 20 basis points across the interquartile range.[43] Relative to the winning bid, m_1/b_1, the median markup rate is 5.4%, and the interquartile range is 2.5%-27%. This suggests that there is substantial scope for lowering municipalities' borrowing costs by targeting auctions with high markup rates.

Figure 4 gives a more complete illustration of markup rates and how they vary with the effective rate and the number of potential bidders. Our model predicts rich patterns of heterogeneity in markups. As expected, we find larger markups in auctions with low numbers of potential bidders, and we find that

[40] These include sales, corporate, and property tax rates, political party measurements for senate, president, and governor support, and, finally, major party index. Note that we exclude auctions in the state of Nebraska (18 auctions) from the estimation due to missing data. Table A.4 confirms that our reduced-form results are robust to using this set of controls.

[41] Since τ affects the lower threshold for the distribution of bids, the effect on the distribution mean may not directly reflect the effect from a shift in τ on the average bid. However, we find that the threshold is sufficiently far from the mean for typical values of observables in the data, which reduces the concern of this bias.

[42] The bi-modal distribution of winning bids 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.

[43] The markups we find are in line with estimates of *ex-post* surplus for winners calculated in Hortaçsu et al. (2017) 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.

markups decrease fairly rapidly in the number of potential bidders. We also find markups are larger when the tax advantage is smaller, and that this pattern is most pronounced in auctions with low numbers of potential bidders. Table 7 calculates the dollar value of the markup for a given year, $m_1 s$, with a median value of \$14,232, and over the life of the bond, $m_1 st$, with a median value of \$112,282.

We explore the robustness of these results to alternative models that allow for flexible effects of covariates, alternative definitions of potential bidders, and that limit the role of the effective rate on the dispersion of bids and on the truncation of the distribution. Appendix F discusses these models, and Tables A.9-A.13 show that we obtain similar estimated markups across these specifications.

6.3 Incidence

We now evaluate the implications of the model for the passthrough of tax advantages to borrowing costs. For a given a tax advantage, τ, and number of potential bidders, N, our model implies a winning bid $b_1(N,\tau)$. We use these model predictions to compute passthrough elasticities. We first compute a partial elasticity, $\varepsilon_{1-\tau}^{b,\text{Partial}}$, which focuses on the direct effect of τ on bidding and ignores the effect of τ on the number of potential bidders. Table 7 reports this elasticity, which has a mean value of 1.83. We then compute a full elasticity, $\varepsilon_{1-\tau}^{b,\text{Full}}$, that incorporates the fact that, as the effective rate changes, so does the number of potential bidders. Table 7 reports a larger mean elasticity of 2.62, and median elasticity of 1.3. Figure A.11 explores the heterogeneity in passthrough elasticities by N and τ. While these results display considerable heterogeneity, they are broadly in line with the reduced-form elasticities reported in Table 2, and with the non-parametric elasticities in Table 4.

We now explore the degree to which the decline in borrowing costs that arises from an increase in τ is due to decreased markups. To this end, we use the model estimates to compute the changes of bids and markups in both τ and N. We then use these values to compute:

$$S_m(N, N+\Delta N) = \frac{m_1(N+\Delta N, \tau+\Delta\tau) - m_1(N,\tau)}{b_1(N+\Delta N, \tau+\Delta\tau) - b_1(N,\tau)} \cdot 100\%,$$

which represents the share of the change in winners' bids due to the change in markups as τ increases. As in the case of the passthrough elasticities, we compute this share with and without the effect of τ on N, i.e., ΔN. Figure 5 plots this share as a function of N and τ. Overall, we find that a significant fraction of the change in the winning bid is due to the change in the markup, which is consistent with the intuition presented in Section 4. We find that the effect of τ on N increases this fraction significantly and that this fraction is decreasing in both τ and N.

We now present a second decomposition that uses our model to explore the underlying fundamentals of the effects of τ on winning bids. When τ increases, there are three effects that serve to depress bids. First, for a given set of bidders, values decline, and so do bids. As the effective rate increases, there is an increase in the number of potential bidders, which introduces two additional pressures on winning bids. The first is due to the chance that the new potential entrants will have an even lower value for the bond and will participate in the auction. The second effect is that, with increased competition from new entry, bidders will respond by reducing their markups for fear of losing the auction.

The *effective rate share* of the change in the winning bid is given by:

$$ers(\tau, N) = \frac{\Delta b(\Delta\tau, 0)}{\Delta b(\Delta\tau, \Delta N)}$$

where $b(\Delta\tau, \Delta N) = b(\tau + \Delta\tau, N + \Delta N) - b(\tau, N)$. We can think of this effect as representing the direct effect of changing τ on the existing set of bidders' values. The dashed curve in Figure 6 shows that this share is increasing in the number of potential bidders.

We now compute the *competitive share* of changes in bids due to changes in τ, which highlights the role of increasing potential competition for the bond. We quantify this effect as:

$$cs(\tau, N) = 1 - \frac{b_1'(\tau + \Delta\tau, N + \Delta N) - b_1(\tau, N)}{b_1(\tau + \Delta\tau, N + \Delta N) - b_1(\tau, N)},$$

where b' is the winning bid *had the agents bid as if there were N rather than $N + \Delta N$ participants*. Thus, while the private value drawn in simulations is the smallest among $N + \Delta N$ draws, bidding happens according to the strategy corresponding to $(\tau + \Delta\tau, N)$. The solid curve in Figure 6 shows that this share is decreasing in the number of potential bidders. Intuitively, as the number of bidders increases, markups are smaller and the effect of reducing markups to avoid losing the auction also declines.

Finally, we consider the impact of the change in the market structure from increasing τ, which leads bidders to lower their markups. This impact is given by $1 - cs(\tau, N) - ers(\tau, N)$, which is represented by the dotted line in Figure 6. While the share of the number of potential bidders is relatively flat, it is worth noting that the total effect is decreasing in N.

6.4 Counterfactual Policy Analysis

The tax advantages enjoyed by municipal bonds are the subject of intense debate. Several federal reforms have been proposed that directly or indirectly deal with the growing tax expenditure of the exemption of municipal interest. We provide a survey of 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. Three examples of reforms include repeated proposals by the Obama administration to limit the exemption to 28%, the Trump administration proposal to lower the top income rate to 35%, as well as other proposals that completely eliminate the exemption. We fit these three reforms into a general approach that evaluates the consequences of a change in federal tax rates, by parametrizing the effective tax rate as follows:[44]

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

Relative to the average federal rate from 2013 to 2015, eliminating the federal exemption corresponds to $\alpha = 0$; the Obama proposal corresponds to $\alpha = 0.73 \approx 0.28/0.384$; and the Trump tax plan would set $\alpha = 0.91 \approx 0.35/0.384$. We can also consider the effect of a *super exemption* of municipal bond interest by evaluating reforms that set $\alpha > 1$.

For the purposes of this section, 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 7. In this graph, values of $\alpha < 1$ correspond to decreases in the tax advantage, while values of $\alpha > 1$ increase the tax advantage through increases in the tax rate, or through a form of super

[44]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.

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 the full reform that allows for changes in N. While the effects on the winning bid are close to being linear in α, the full effects on markups (dashed green line) are strongly concave in α.

Table 8 presents average effects of specific policies. Recall that the proposal of the Obama administration is equivalent to reducing α to 0.73. The total effect of this reform would increase the average borrowing cost by 30.6%, which would imply an additional \$38 billion in interest payments by state and local governments. Without further behavioral responses, the reduction in the tax expenditure over the next decade would be close to \$135 billion ($\approx (1 - 0.73) \times \$500$ billion). On a yearly basis, this subsidy represents a gain of \$2.8 ($\approx \frac{38}{13.5}$) 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 2.8-times greater than the marginal value of providing public goods from municipal bonds.[45] Moving to a full repeal of the exemption would result in significantly larger borrowing rates with an average of 3.64%, of which 43% ($\approx \frac{1.584\%}{3.643\%}$) would correspond to markups.[46]

We now explore how these proposals would affect different states. Figure 8 plots the effects of setting $\alpha = 0.73$. Panel (a) plots the observed average winning bids by state, and Panel (b) presents the simulated average winning bid by state after capping the excludability, but without allowing for the additional potential entry. The effects vary across states depending on a number of factors.[47] 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 Texas, Florida, Nevada, and Wyoming. Second, the effects of this reform would depend on the distribution of bond characteristics across states, such as the average length of the bond. Panel (c) simulates the effects of the reform allowing for the effect of the reform on potential entry. Overall, we see larger increases in borrowing costs. In particular, states that have low number of potential bidders may be most affected by this channel. Panel (d) shows that the increase in winning bids ranges from 48-68 basis points. States with borrowing cost increases greater than 60 basis points include Texas, New York, New Jersey, Michigan, and Georgia. Figure 9 performs a similar analysis for the markups across states. While average markups are about 17 basis points, the reform leads to substantial increases, particularly due to the entry margin.

We perform two additional analyses that we report in the appendix. Figures A.12-A.13, report the effects of completely eliminating the excludability of municipal bond interest, that is, setting $\alpha = 0$.

[45] This calculation assumes that the increase in borrowing costs does not also increase the federal tax expenditure and ignores the externality on state governments who would also see an increased tax expenditure. Further, the federal government is not likely to recoup the full reduction in the tax expenditure because of behavioral substitution away from municipal bonds to other investment instruments described by Poterba and Verdugo (2011), so \$135 million is an upper bound on the revenue cost of the tax expenditure. These forces imply that the efficiency ratio of 2.8 is a lower bound. We also assume the total value of issuances to be fixed. A full welfare calculation that allows for changes in borrowing behavior would also have to account for the effect of changes in public good provision on social welfare, which is beyond the scope of this paper. This is also a conservative calculation relative to a linear extrapolation of the results of Table 2, where the implied decrease in τ for $\alpha = 0.73$ of $33.39\% - 43.76\% = -10.37\%$ would imply a percentage decrease in borrowing costs of 35.33% $\left(\approx \frac{10.37\% \times 6.519}{1.913}\right)$ and imply a ratio of 3.23 $\left(\approx \frac{35.33\% \times 124}{13.5}\right)$.

[46] Tables A.14-A.18 show the robustness of these results. In particular, we explore the robustness of our results to a model parametrization that eliminates the effect of τ on the standard deviation of bids. We find very similar quantitative results. For example, the increase in bids when $\alpha = 0.73$ is now 30.8%, instead of 30.6%, which is a result of the tradeoff between selection and markups effects and shows that this result does not depend solely on the effect of τ on the dispersion on bids.

[47] Note that Montana and Nebraska have no auctions from 2013 to 2015 and are excluded from the simulations.

While this policy represents a level of variation that is outside of our sample, our results suggest large and heterogeneous effects from this potential policy. Finally, Figures A.14-A.15 analyze the role of state exemption from taxation by eliminating state taxes from the tax advantage formula. While eliminating state taxes 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 state tax rates see a larger increase in borrowing costs.

7 Conclusions

The excludability of municipal interest 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, who use these funds to finance public goods, service, and infrastructure. Critics of this policy argue that top-income individuals are the largest beneficiaries of the policy, 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 a dataset of municipal bond auctions, and by pointing to the role of imperfect competition in determining the effects of tax subsidies on borrowing costs. Contrary to critics of the policy, we find that changes to tax policy have large effects on the borrowing costs of governments, which are summarized by an average passthrough elasticity that is greater than unity. We provide non-parametric evidence that these substantial effects are driven by the interaction between tax policy and imperfect competition, and, in particular, by the effects of taxes on markups. We estimate an empirical auction model that shows considerable heterogeneity in passthrough rates that depend on the number of potential auction participants.

We simulate the effects of actual policy proposals from both the Obama and Trump administrations, and evaluate heterogeneous effects on borrowing costs and markups across the U.S. We find that reductions in the tax advantage for municipal bonds translate to substantial increases in both borrowing rates and markups. The Obama administration's proposal of capping the exclusion at 28% would lead to an increase in markups of about 185%, and in borrowing rates of 31%. We find that states with lower state income tax rates, with fewer bidders, and with larger reliance on auctions are disproportionately more affected by this policy. Compared to the reduction in the federal tax expenditure, the increase in borrowing costs is 2.8-times as large, suggesting that the tax advantage for municipal bonds is an efficient mechanism to subsidize public good provision at the local level.

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 the auction, and stimulate more competitive bidding by existing bidders, which both serve 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 in auctions.

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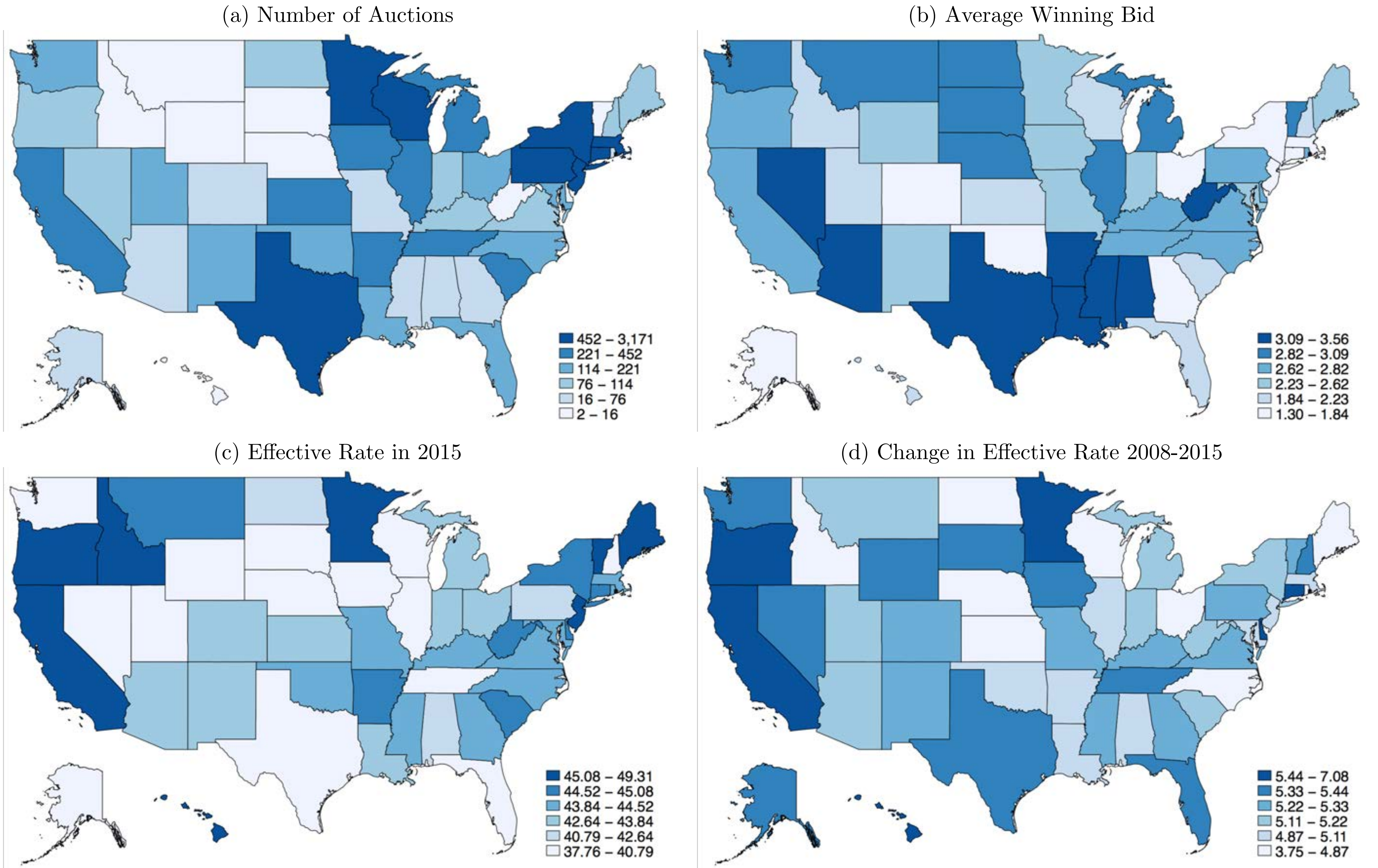
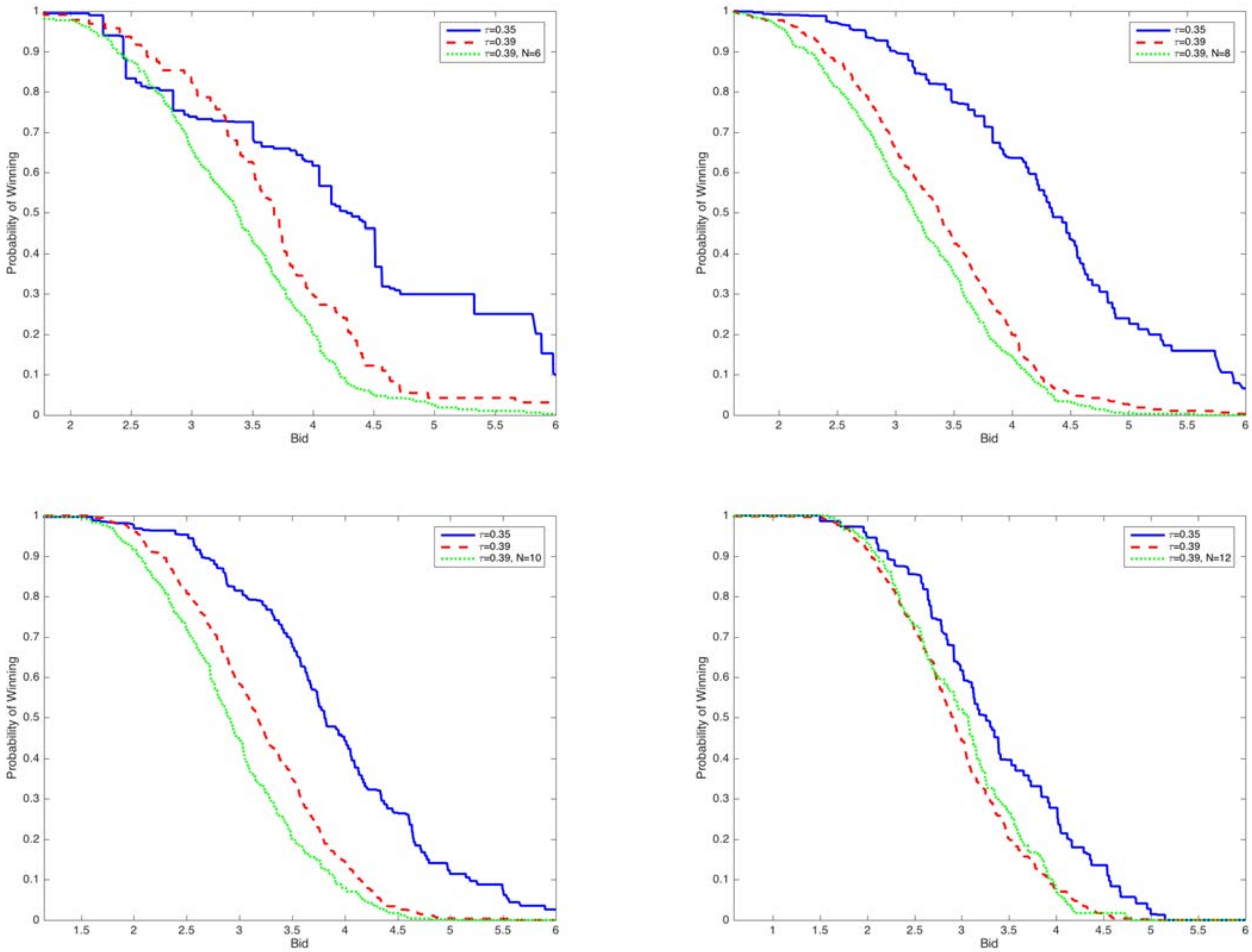
Figure 1: Maps of Summary Statistics



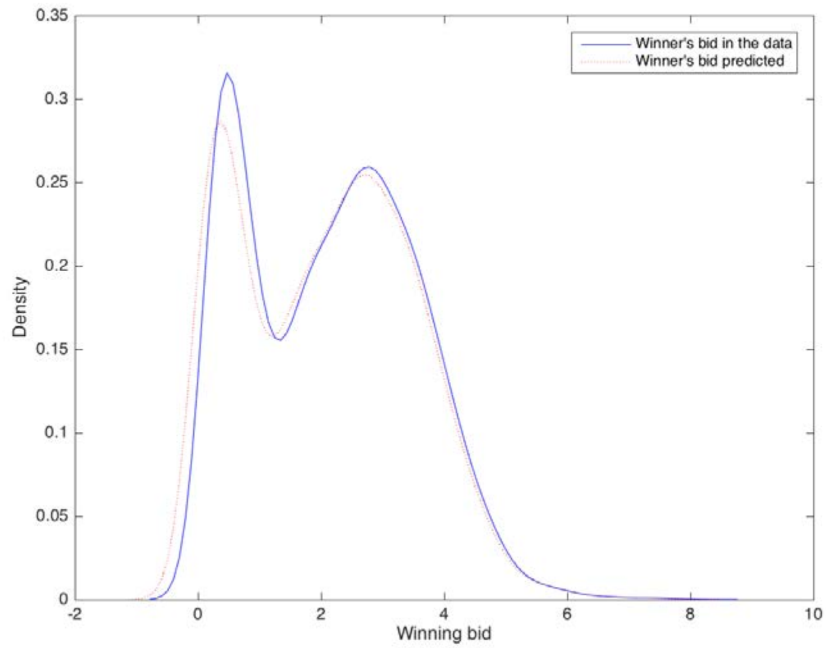
Notes: These maps show the spatial distribution of several important variables. Panel (a) shows the number of auctions in the estimation sample from each state and panel (b) shows the average winning bid or interest rate paid by the locality. Panels (c) and (d) show the distribution of effective tax rates 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 1.

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



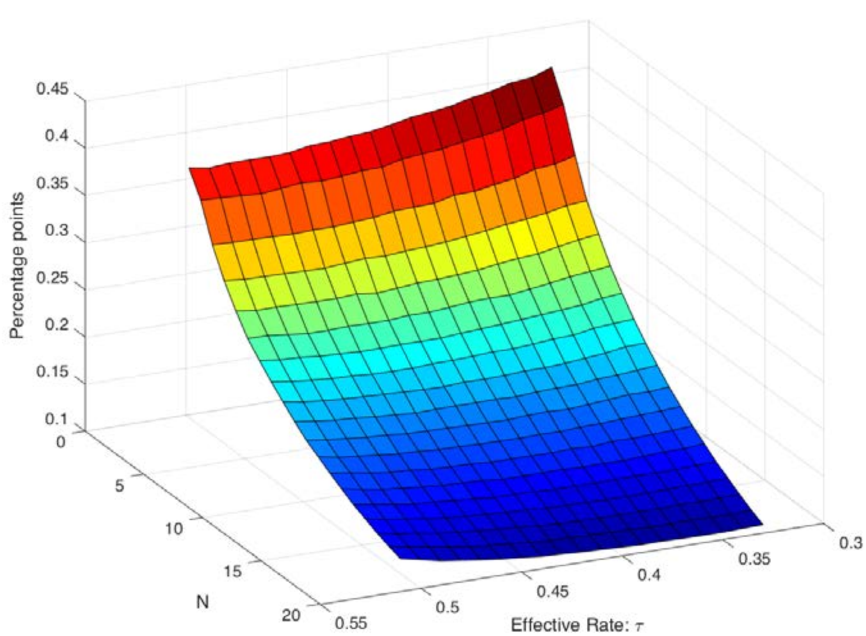
Notes: These figures show the non-parametric estimates of winning probability for a given bid conditional on maturity between 2 and 17 years, which is the middle third of the maturities. The non-parametric estimates here are also used to estimate optimal bids and elasticities for a given value. Optimal bids are shown in Table 3 and elasticities are shown in Table 4. See Section 4.2 for more information about these estimates.

Figure 3: Simulated and Observed Winner's 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 5 for the discussion of the model and Table 6 for the associated parameter estimates.

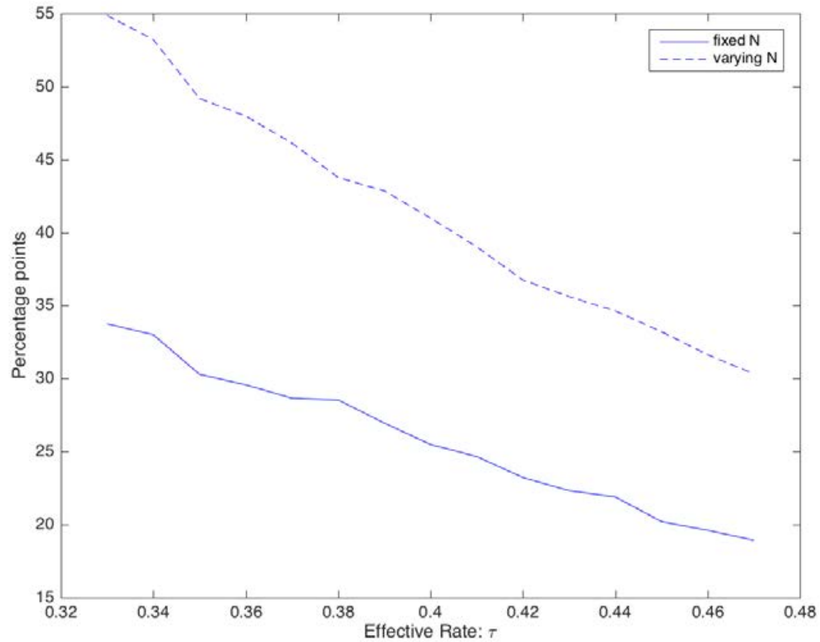
Figure 4: The Ratio of Winner's Markup to Bid



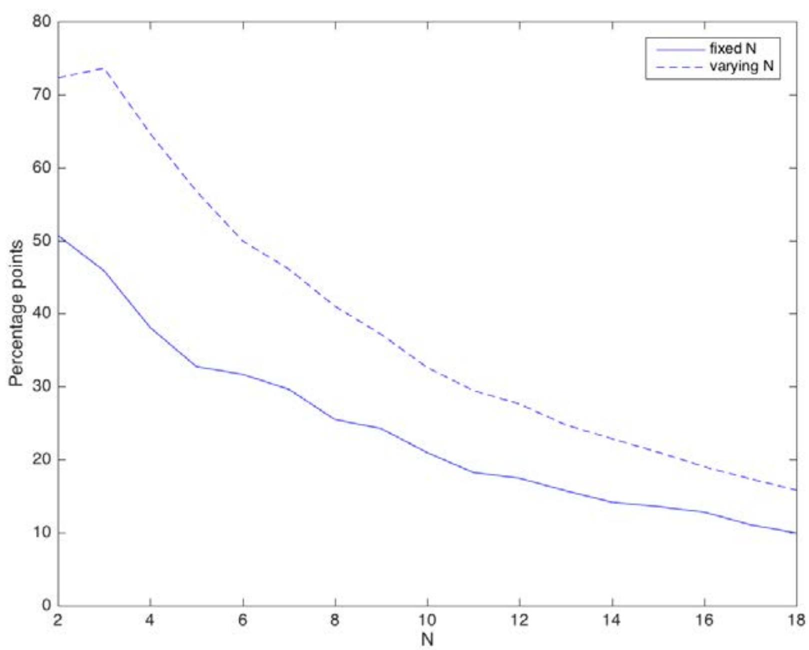
Notes: This figure shows the percent of the winner's bid that is attributable to the markup for different values of potential bidders (N) and effective tax rates (τ) in the baseline model. See Section 5 for additional discussion and Table 6 for the associated parameter estimates.

Figure 5: Share of Change in Bids Due to Change in Markups, $\Delta N = 2, \Delta\tau = 0.04$

(a) By Effective Rate

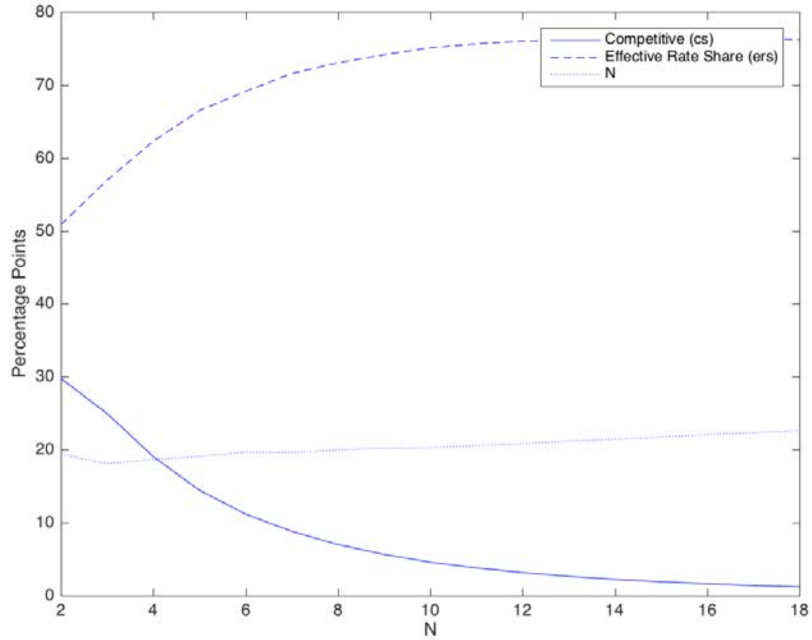


(b) By Number of Potential Bidders



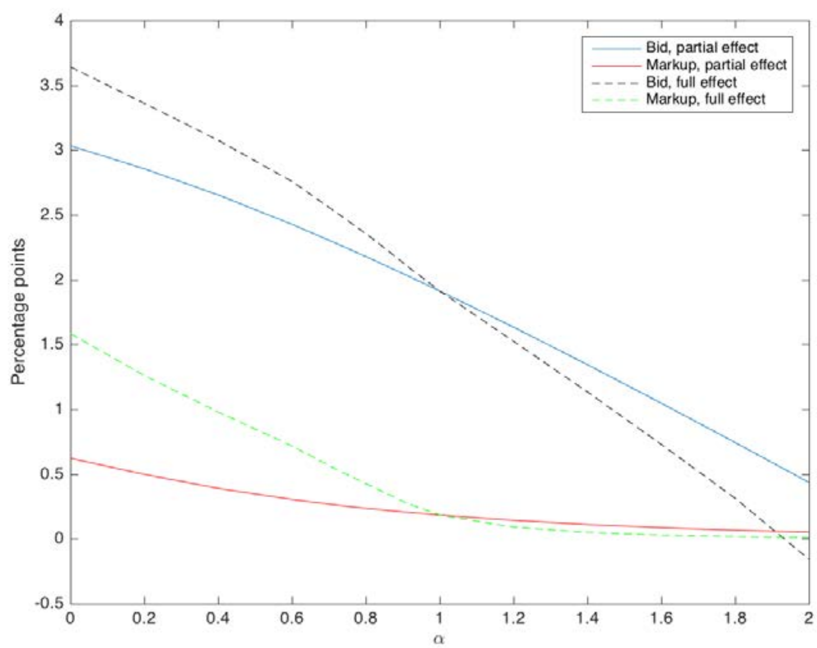
Notes: This figure shows the percent of a change in bid that is attributable to a change in markups. The change in bids results from a 4% tax change and a 2 unit increase in potential bidders. See Section 5 for additional discussion and Table 6 for the associated parameter estimates.

Figure 6: Decomposition of Full Change in Bids: τ Effect ers, Competitive Effect cs, Extra Draws



Notes: This figure decomposes a change in bid into a change in values associated with the tax (dashed), a change in bidding behavior (solid), and additional N (dotted). The change in bids results from a 4% tax change and a 2 unit increase in potential bidders. See Section 5 for additional discussion and Table 6 for the associated parameter estimates.

Figure 7: α-Policy Outcomes for Borrowing Rates and Markups

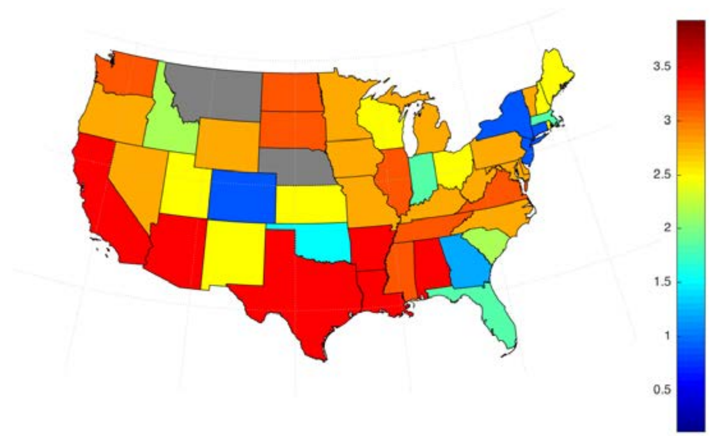


Notes: This figure shows counterfactual bids for different ratios of the current federal exemption. $\alpha = 0$ is equivalent to eliminating the exemption and $\alpha = 2$ would be doubling the exemption by subsidizing municipal bond interest income by an amount equal to the federal tax rate in addition to the exemption. See Section 6.4 for additional discussion and Figures 8 and 9 for the spatial distribution of counterfactual changes associated with $\alpha = 0.7$.

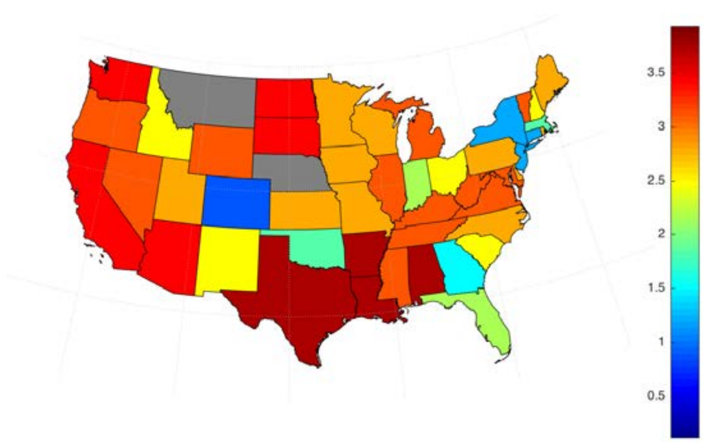
Figure 8: Effect of Capping Federal Excludability at 28% on Winning Bids

(a) Actual Average Winning Bid

(b) Simulated Average Bid Capping Excludability
(No Entry Margin)



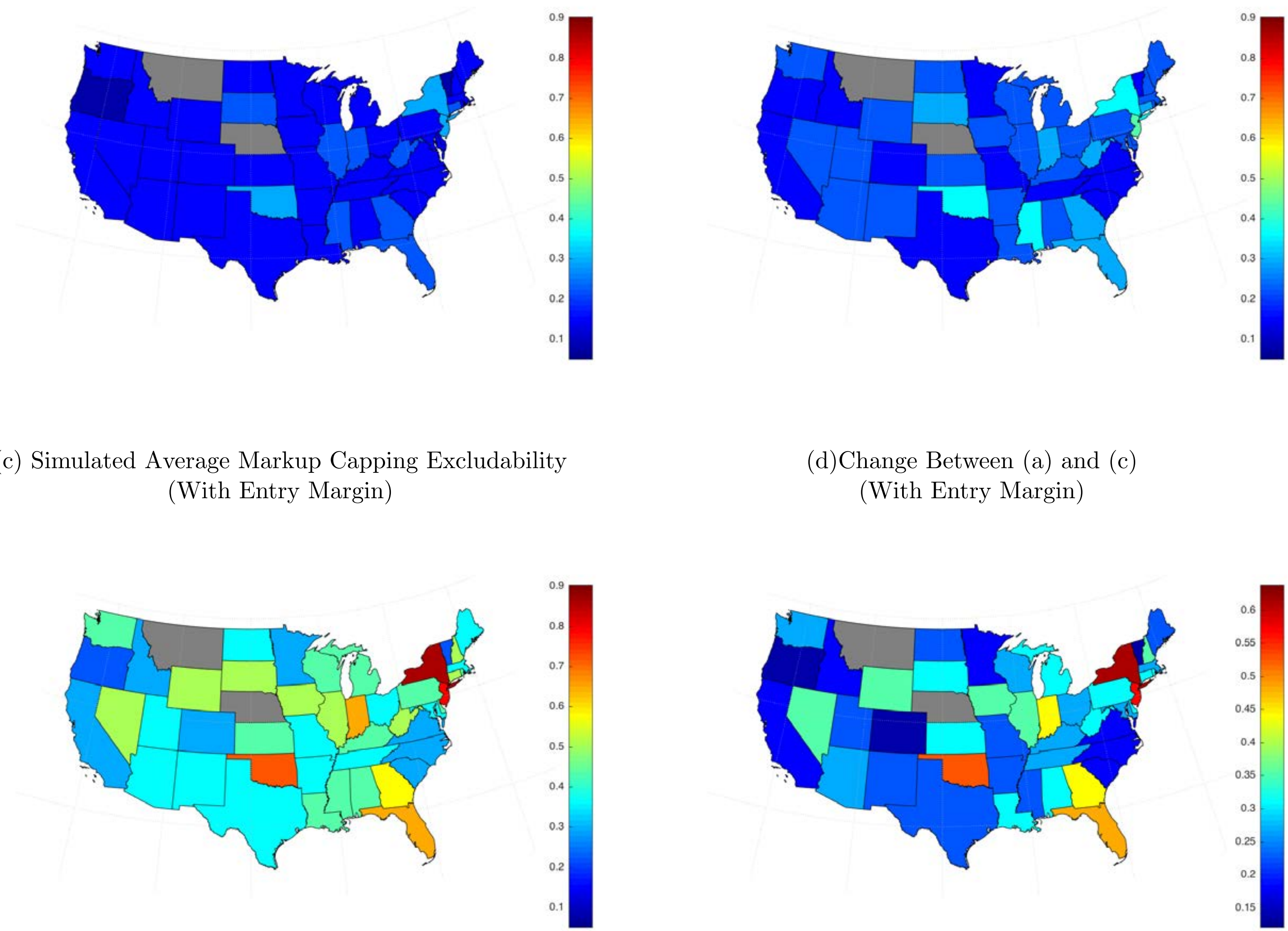
(c) Simulated Average Bid Capping Excludability
(With Entry Margin)



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

Notes: This figure shows spatial heterogeneity in counterfactual estimates of winning bids if the federal exclusion were capped at 28%. See Section 6.4 for additional discussion about the counterfactual analysis and Figure 9 for the corresponding markups. The comparable estimates of winning bids when eliminating the federal exemption or state exemption are shown in Figures A.12 and A.14, respectively. The average effects from the policy reforms are shown in Table 8, the parameter estimates are displayed in Table 6, and α-policy outcomes for borrowing rates and markups are shown in Figure 7.

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



(a) Average Markup

(b) Simulated Average Markup Capping Excludability (No Entry Margin)

(c) Simulated Average Markup Capping Excludability (With Entry Margin)

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

Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the federal exclusion were capped at 28%. See Section 6.4 for additional discussion about the counterfactual analysis and Figure 8 for the corresponding bids. The comparable estimates of markups when eliminating the federal exemption or state exemption are shown in Figures A.13 and A.15, respectively. The average effects from the policy reforms are shown in Table 8, the parameter estimates are displayed in Table 6, and α-policy outcomes for borrowing rates and markups are shown in Figure 7.

Table 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	220.11	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 2: Reduced-Form Effects of the Effective Rate on Winning Bid and the Number of Potential Bidders

	(1)	(2)	(3)	(4)	(5)
Unconditional Effect of Effective Rate on Bid					
Effective Rate	-6.519	-6.983	-6.316	-6.332	-6.806
	(2.655)	(2.401)	(2.636)	(2.722)	(2.879)
	0.018	0.005	0.020	0.024	0.022
Effect of Effective Rate on *N*					
Effective Rate	0.561	0.554	0.542	0.550	0.547
	(0.128)	(0.133)	(0.148)	(0.149)	(0.128)
	0.000	0.000	0.001	0.001	0.000
Conditional Effect of Effective Rate on Bid					
Conditional Effective Rate	-4.673	-5.211	-4.615	-4.571	-5.222
	(2.614)	(2.366)	(2.519)	(2.613)	(2.836)
	0.080	0.032	0.073	0.087	0.072
Observations	14,631	14,631	14,631	14,631	14,631
Median Bid	221.200	221.200	221.200	221.200	221.200
Median Effective Tax	40.790	40.790	40.790	40.790	40.790
Percentage Due to Competition	28.313	25.380	26.926	27.822	23.278
	(15.293)	(12.868)	(14.720)	(16.013)	(13.489)
	0.064	0.049	0.067	0.082	0.084
Unconditional Elasticity at the Median	1.745	1.869	1.691	1.695	1.822
	(0.711)	(0.643)	(0.706)	(0.729)	(0.771)
	0.014	0.004	0.017	0.020	0.018
Conditional Elasticity at the Median	1.251	1.395	1.235	1.223	1.398
	(0.700)	(0.633)	(0.674)	(0.699)	(0.759)
	0.074	0.028	0.067	0.080	0.066
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: Standard errors clustered at the state level are shown in parentheses and p-values for each estimate are displayed below standard errors. This table reports regression estimates of the effect of effective marginal tax rates on the winning bids 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 A.4. The first row showcases estimates of effective marginal tax rates on the winning bid without controlling for the effect of competition. The second row 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 row. All specifications include fixed effects for the state and year as well as controls for maturity, credit rating, refund status, and size. 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 Income Tax Base Controls include indicators for alternative minimum taxes, exemption of instate and out-of-state federally tax-exempt debt, and deductibility of federal income taxes. Sales Tax Controls controls for the state sales tax rates. Business and Property Tax Controls includes corporate tax rates, property tax rates, and sales apportionment rules.

Table 3: Expected Payoff Maximizing Bids (Tax from 35% to 39%)

	(1) v_0	(2) b_0	(3) Perfect Passthrough	(4) b_1'	(5) b_1''	(6) b_1
***N*=4**	3.565	5.544	5.203	5.518	4.146	3.962
***N*=6**	3.351	4.454	4.180	4.369	3.833	3.796
***N*=8**	3.161	4.252	3.990	4.079	3.665	3.638
***N*=10**	2.842	3.885	3.646	3.803	3.405	3.429

Notes: Column (1) shows the assumed value equal to the median bid conditional on N. The bid that maximizes expected payoff conditional on N, v_0, and $\tau = 35\%$ is shown in column (2). Column (3) shows the bid that would represent perfect passthrough after a 4% tax increase. Column (4) shows optimal bids derived from updating the value $v_1 = \frac{(1-\tau_1)}{1-\tau_0} v_0$, which does not affect the empirical CDF. Column (5) updates the probability of winning to the empirical CDF at $\tau = 39\%$ conditional on the original N. Estimates in column (6) are the new optimal bids after accounting for the change in potential bidders associated with the 4% tax increase. These estimates correspond with Figure 2 as described in Section 4.2. Elasticities implied by these estimates are displayed in Table 4.

Table 4: Implied Elasticity of Bid with Respect to Take Home Rate (Tax from 35% to 39%)

	(1) Perfect Passthrough	(2) $\frac{b_1'-b_0}{b_0}\frac{1-\tau_0}{\tau_0-\tau_1}$	(3) $\frac{b_1''-b_0}{b_0}\frac{1-\tau_0}{\tau_0-\tau_1}$	(4) $\frac{b_1-b_0}{b_0}\frac{1-\tau_0}{\tau_0-\tau_1}$
***N*=4**	1.000	0.075	4.098	4.637
***N*=6**	1.000	0.310	2.266	2.402
***N*=8**	1.000	0.663	2.245	2.348
***N*=10**	1.000	0.341	2.007	1.906

Notes: This table shows the elasticities implied by the estimates in Table 3. Column (1) shows the implied elasticity with perfect passthrough. Column (2) displays elasticities if the value updates proportionally but the probability of winning does not change. Column (3) shows the elasticity of bids when updating the bidding behavior but holding N to be constant. Column (4) shows the total elasticity of optimal bid with respect to take-home rate after accounting for the change in N and the chance of winning. See Section 4.2 and Figure 2 for more information.

Table 5: Implied Elasticity of Winner's Markup with Respect to Take Home Rate (Tax from 35% to 39%)

	(1) m_0	(2) m_1''	(3) m_1	(4) $\frac{m_1''-m_0}{m_0}\frac{1-\tau_0}{\tau_0-\tau_1}$	(5) $\frac{m_1-m_0}{m_0}\frac{1-\tau_0}{\tau_0-\tau_1}$
***N*=4**	1.211	0.930	0.593	3.773	8.300
***N*=6**	0.719	0.593	0.503	2.851	4.886
***N*=8**	0.606	0.503	0.425	2.778	4.869
***N*=10**	0.498	0.425	0.476	2.401	0.736

Notes: This table shows the elasticities of winner's markups with respect to a 4% increase in the effective tax rate from 35% to 39% computed from in-sample implied markups for auctions with maturity between 2 and 17 years. Columns (1) to (3) are stated in percentage points. The value of m_0 is computed in Column (1) as in-sample average markup conditional on N, $\tau = 0.35$; in Column (2) m_1'' is the in-sample average markup computed conditional on N, $\tau = 0.39$; in Column (3) m_1 is the in-sample average markup computed conditional on $N + 2$, $\tau = 0.39$. Columns (4) and (5) show the elasticities of winner's markups for moving from m_0 to m_1'' and from m_0 to m_1 respectively. See Section 4.2 for more information and Tables 3 and 4 for corresponding nonparametric bids and bid elasticities, respectively.

Table 6: MLE Coefficients for the Distributions of Bids $\tilde{b}$, Entry Costs, and Unobservable Heterogeneity

	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: Standard errors are in parentheses and the additional controls are the same as in Column (3) of Table 2. This table presents estimates from the baseline model as described in Section 6.

Table 7: Model Fit and Simulation Results

Statistic	Mean	StDev	25^{th}	50^{th}	75^{th}
Model Fit					
Winning Bid in Data: b_1	2.151	1.364	0.790	2.210	3.190
Simulated Winning Bid: b_1	2.071	1.394	0.714	2.133	3.138
Entry Probability in Data: n/N	0.701	0.180	0.600	0.714	0.833
Simulated Entry Probability: n/N	0.728	0.010	0.721	0.728	0.733
Simulation Results					
Markups					
Markup: m_1	0.169	0.195	0.067	0.111	0.196
Markup Rate: m_1/b_1	0.196	0.332	0.025	0.054	0.267
Yearly Value of Markup: $m_1 s$	33.235	95.848	7.661	14.232	30.886
Total Value of Markup: $m_1 st$	405.632	1599.878	49.009	112.282	283.580
Entry Costs					
Entry Cost Threshold: d^*	0.352	0.206	0.229	0.314	0.408
Passthrough Elasticities					
$\varepsilon_{1-\tau}^{b,Partial}$	1.831	1.899	0.683	0.951	2.357
$\varepsilon_{1-\tau}^{b,Full}$	2.624	2.735	0.959	1.328	3.470

Notes: s is bond issue size, t is bond issue maturity, $\varepsilon_{1-\tau}^{b,Partial}$ is elasticity of borrowing cost in $1-\tau$ at b_1, and $\varepsilon_{1-\tau}^{b,Full}$ full is the same elasticity which accounts for change in N. Measurement units: b_1, m_1, and d are in percentage points, $m_1 s$ is in thousands of USD, t is in years. Robustness checks in five additional specifications are discussed in Appendix F with results presented in Tables A.9 to A.13. The model is discussed at length in Section 5.

Table 8: Average Effects from Counterfactual Policy Reform

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

	(1) $\alpha = 1$	(2) $\alpha = 0.91$	(3) $\alpha = 0.73$	(4) $\alpha = 0$	(5) No state excludability
Winning Bid					
Partial (No Potential Entry)	1.913	2.034	2.268	3.034	2.337
Full	1.913	2.109	2.499	3.643	2.460
Markups					
Partial (No Potential Entry)	0.183	0.205	0.257	0.622	0.249
Full	0.183	0.276	0.521	1.584	0.395

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

	(1) $\alpha = 0.91$	(2) $\alpha = 0.73$	(3) $\alpha = 0$	(4) No state excludability
Winning Bid				
Partial (No Potential Entry)	6.350%	18.558%	58.592%	22.186%
Full	10.260%	30.646%	90.419%	28.595%
Markups				
Partial (No Potential Entry)	12.045%	40.672%	240.205%	36.440%
Full	50.827%	185.280%	766.711%	116.031%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 70% and 91% of its current level. Section 5 discusses the setup of the model while Section 6.4 discusses the counterfactual simulations. Robustness checks for five additional specifications are discussed in Appendix F with results presented in Tables A.14 to A.18.

Online Appendix: Not For Publication

This appendix includes several sections of supplemental information. First, 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 to the primary reduced-form results are presented in Appendix C, while additional non-parametric results are described in Appendix D. The derivation of the full model is shown in Appendix E, and robustness checks for alternative model specifications are presented in Appendix F. Appendix G lists several potential policy reforms that motivate our counterfactual simulations.

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 from 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 1 and 2.

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 that is 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 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 2 and A.4 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 calculated by Caesar and Saldin (2006). The data are updated through 2010 and imputed for future years. MPI is not used in Table 2 but is part of the structural model controls used in Table A.4.

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 federal taxes paid being deductible 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 from within the 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 from 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.4.

2. Gross domestic product (GDP). The total economic activity in each state-year with data from Bureau of Economic Analysis (2017). The first difference of the log of GDP is included in Table A.4.

3. State government spending. Total annual expenditures by the state government. Data from Census Bureau (2007-2014) with 2015 entries imputed.

4. State intergovernmental transfers. Total annual transfers from state to local governments. Data from Census Bureau (2007-2014) with 2015 entries imputed.

A.2 Effective Rate Calculations

From TAXSIM, we get variables for top marginal state and federal personal income tax rates, $\tilde{t}_s$ and $\tilde{t}_f$ respectively. Each of these variables are already defined such that After Tax Income (ATI) can be describe 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 let 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, $t_f = \tilde{t}_f$. Secondly, 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 rate can be calculated directly from t_s and t_f. If a state does not exempt interest on their 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 Construction

The combined Bond Buyer and SDC data represent 41,918 competitive auctions issued between February 2008 and December 2015 worth a total $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 thousand to $950 million with a median value of $4.05 million. 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 we analyze by dropping: RV bonds, bonds for which we lack important information (like maturity or size), bonds with total size less than $5 million, taxable municipal bonds, and Build America Bonds (BABs).[48] The step-by-step outcomes of our sample construction are shown in Tables A.1 and A.2.

After merging the SDC Platinum and Bond Buyer data, we are left with 15,354 auctions. Of those, 433 are dropped for being issued in 2016 for which we don't have corresponding TAXSIM data and 290 are dropped for missing the winning bid. The final analysis sample is made up of 14,631 auctions from 2008 to 2015.

C Robustness of Reduced-Form Results

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

Table A.4 builds on the main specifications presented in Table 2 with additional controls. Column (1) is the same across tables for comparison where base controls include 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, presidential, gubernatorial, and senate voting records, and major party index. 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 6.2. Columns (3) and (4) 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. These specifications, in particular, showcase the rich detail in our data and push the identification of β to be driven by variation in winning bids across repeated auctions of the same municipality, but in years with different levels of the effective rate. Columns (5) to (8) individually test additional state economic and spending controls: unemployment rate, state GDP, government spending, and intergovernmental transfers. Column (9) includes every control used in the robustness table, while Column (10) uses every control in the robustness table plus every control in Table 2. The estimated coefficients are very stable between 6.3 and 6.75 basis points across all specifications without controls for number of actual or potential bidders. With controls for actual and potential bidders shown in the third panel, estimates still only vary from 4.5 to 5.5 basis points.

C.2 Effect of Taxes on Potential and Actual Bidders

Panel B in Table 2 shows that our preferred definition of potential bidders is responsive to changes in the tax advantage. We explore whether this result also holds for the number of actual bidders as well as for alternative definition of the number of potential bidders. Table A.5 shows similar results for the actual

[48] 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 will not be directly influenced by tax policy.

number of bidders, as well as our alternative definition of potential bidders. The effects on these panels are stable across specifications and are statistically significant in most 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.3 Effect of Taxes on Supply of Municipal Debt

We explore whether changes in the effective rate affect the supply for municipal bonds. Adelino et al. (Forthcoming) find that supply of municipal debt increases at the local level when the cost of debt decreases. Since we control for the size of the bond, we are primarily concerned with any supply response on the extensive margin. Table A.6 shows that the supply of municipal debt is not responsive to changes in effective tax rates.

C.4 Heterogeneous Effects by Bond Length

The main reduced-form results in Table 2 assume 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 length. Figure A.4 shows the empirical distribution of bond length. If the effect of the tax advantage varies by bond length, the estimates in Table 2 may be biased. Figure A.5 shows estimated coefficients of the effective rate on winning bid by length of bond. This specification controls for all our main controls including bidder fixed effects and corresponds to Column (4) of Table 2. This figure shows there is some variance on effects with larger effects in the first two years and more variable effects in later years. Table A.7 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.5 vary a lot, the interactions between the length 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, 23%, versus 28% in the FE. These results suggest that the assumption of homogeneous coefficients is not biasing our main results.

C.5 Coefficient Stability Robustness Tests

In Tables 2 and A.4 we provide evidence of coefficient stability across several specifications with different, sequentially-added controls. However, Altonji et al. (2005) and Oster (Forthcoming) have pointed out that coefficient stability is not sufficient to show that omitted variable bias, or selection on unobservables, has been negated. 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 estimated coefficients when more regressors are added can be used to correct for omitted variable bias. Changes in R^2 should be used to scale changes in estimates of β when additional regressors are being added sequentially. In order to test the validity of our coefficient stability as a signal of mitigated omitted variable bias, we implement one of the estimators from Oster (Forthcoming). 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 main control of interest explainable by unobservables.
- R_{max}. The maximum R^2 attainable with perfect controls.

Parameters δ and R_{max} are not observable, so we assume that both are equal to one following the guidance of Oster (Forthcoming). There are two primary ways to implement the estimator: 1) estimate β^* for a given δ and R_{max}, 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. The latter is interpreted as the 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 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.8. We set $R_{max} = 1$ for all specifications.

For columns (1) and (2), the estimates of δ are negative 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. In column (3), the estimate attenuates toward zero slightly while R^2 increases with additional controls. The estimate of δ is 113.9, which is much larger than the cutoff threshold of 1 suggested in Oster (Forthcoming). 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. The results of this test highlight that selection on unobservables would need to be very large to negate the results presented in Tables 2 and A.4.

D Additional Non-Parametric Results

In this section we discuss the implementation of the methods of Li et al. (2000) to estimate the distribution of values and markups for every auction. In our model, the relationship between bids and values can be expressed as

$$b_i - v_i = \frac{Pr[b_{-i} > b_i | N, X, u]}{-\frac{\partial}{\partial b_i} Pr[b_{-i} > b_i | N, X, u]}$$

Under the assumption of additive separability for the unobservable, the results of Li et al. (2000) allow us to non-parametrically recover values from bids. This recovery is based on constructing non-parametric estimators for the right-hand side of the equation above. Concretely, we have

$$\hat{Pr}[b_{-i} > b|N, X, u] = \frac{\sum_j \frac{1}{n} \sum_{l=1}^{n_j} \mathbb{1}(b_{-l,j} > b) k\left(\frac{b_{l,j}-b}{h_b}\right) K\left(\frac{X_j - X}{h_X}\right)}{\sum_j \sum_{l=1}^{n_j} K\left(\frac{X_j - X}{h_X}\right) k\left(\frac{b_{l,j}-b}{h_b}\right)}$$

where $\sum_j$ goes over all auctions with N potential bidders and $b_{-l,j}$ indicates the lowest bid in auction j other than $b_{l,j}$. Similarly, an estimator for the density can be represented as

$$\widehat{-\frac{\partial}{\partial b} Pr}[b_{-i} > b|N, X, u] = \frac{\sum_j \frac{1}{n} \sum_{l=1}^{n_j} \frac{1}{h_b} k\left(\frac{b_{-l,j}-b}{h_b}\right) k\left(\frac{b_{l,j}-b}{h_b}\right) K\left(\frac{X_j - X}{h_X}\right)}{\sum_j \sum_{l=1}^{n_j} K\left(\frac{X_j - X}{h_X}\right) k\left(\frac{b_{l,j}-b}{h_b}\right)}$$

with $k(\cdot)$ being another kernel function used for bids rather than observables. For the estimation purposes, we utilize the same triweight kernel function as in the paper. For controls X, we use maturities, effective rates, and sizes of bonds.

As we have seen from the shapes for empirical CDFs of raw bids, larger effective rates are associated with lower bidding. It is not immediately clear whether the same is true for the bidders' values. However, when we plot similar CDFs for the values recovered using the procedure below, we find that values do in fact go down—see Figure A.6. Figure A.7 reports the empirical CDF of markups for $N = 8$ and various values of τ, and Figure A.8 plots the distribution of these markups relative to the winning bid. Figure A.9 shows how the estimated markup-to-bid ratios vary in response to changes in τ from 0.34 to 0.39, including the indirect effect of taxes on the number of bidders.

Because of data limitations, this procedure does not allow us to reliably control for binary observables such as state and year indicators. Thus, it is important to build a model of auction participation where agent's bids are parameterized. In addition to more controls, the model allows us to study in more detail effects from competition and effective rate changes as well as simulate various policy consequences.

E 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 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 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 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 she had value v', while all other agents bid according to the strategy $\beta(\cdot)$. In

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 lack of a border condition which would allow us to solve the equation. We pick a specific equilibrium in which the participant with the highest valuation bids precisely her 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 represent the unique monotone smooth equilibrium bidding strategy under our assumption $\beta(\overline{v}) = \overline{v}$.[49] 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 entry-bidding game in the form of

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

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

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

F Robustness of Structural Estimates

We now show that our implications for passthrough elasticities, markups, and counterfactual policies are robust to different model specifications. We estimate the following models:

S1 This is our baseline model, but where the mean is a flexible piecewise-linear function of N and maturities, as opposed to the linear case in the baseline model.

In particular, if $\mu_b = X\beta$ is the representation of the mean parameter for bids in the baseline model, in the piecewise-linear mean model we have

$$\mu_b = \widetilde{X\beta} + \sum_{i=1}^{k} \left(\mathbb{1}(N_{i-1} \leq N < N_i) \left[\beta_{N,i}(N - N_{i-1}) + \sum_{j=1}^{i-1} \beta_{N,j}(N_j - N_{j-1}) \right] \right)$$

where $\widetilde{X\beta}$ represents the portion of the mean which does not include N as a dependent variable, and points N_i partition the support of N in the sample so that $0 = N_0 < N_1 < \ldots < N_k$. Coefficients $\beta_{N,i}$ are simply slopes of μ_b in N when N lies in $[N_{i-1}, N_i)$. In practice, we have $k = 4$, and the intermediary N_i are chosen as quartiles of the distribution of N in our data sample. An equivalent construction is used for maturities.

The model fit and simulated passthrough elasticities are presented in Table A.9, and the policy simulations are presented in Table A.14. This approach allows us to see if the best fit is non-linear in N and maturities. The estimated passthrough elasticities, markups, and policy implications are very similar to our baseline model.

S2 Baseline model, but where N is defined as the number of unique bidders across all auctions within a given state in a given month. The model fit and simulated passthrough elasticities are presented in Table A.10, and the policy simulations are presented in Table A.15. These tables present similar results to our baseline model. This definition of potential bidders mechanically implies lower entry on average, and our model matches this pattern quite closely.

S3 Baseline model, but we restrict the threshold parameter to 0 for all auctions. The model fit and simulated passthrough elasticities are presented in Table A.11, and policy simulations are presented in Table A.16. These tables present evidence that our results are not sensitive to issues that may arise when the support of the variables depends on the estimated parameters.

S4 Baseline model, but where the effect of Effective Rate τ on standard deviation of bids set to 0. The model fit and simulated passthrough elasticities are presented in Table A.12, and the policy simulations are presented in Table A.17. These tables show that our results are not solely dependent on the effect of the tax advantage on the dispersion of bids. As discussed in the paper, the effect of the tax advantage on the dispersion of bids may have countervailing implications for the markup and selection effects which, in this case, result in similar effects for our counterfactual policies.

S5 Baseline model, but where we truncate the distribution of bids at the entry stage. One potential concern is that the inclusion of the full support of distribution of bids in the calculations for expected profits at the entry stage may artificially generate high entry costs, which may bias our results. As a robustness check, we re-estimate the baseline mode by excluding 0.1% of bid support from its left tail. Precisely, we assume that

$$E\pi(p) = \int_{q_b(0.001)}^{\infty} g(b)\pi(b|p)db \tag{9}$$

where p denote the probability of entry and $q_b(0.001)$ is the 0.001-quantile for the distribution of b. We obtain similar simulated passthrough elasticities, presented in Table A.13, and policy implications, which are presented in Table A.18.

G Proposed Reforms

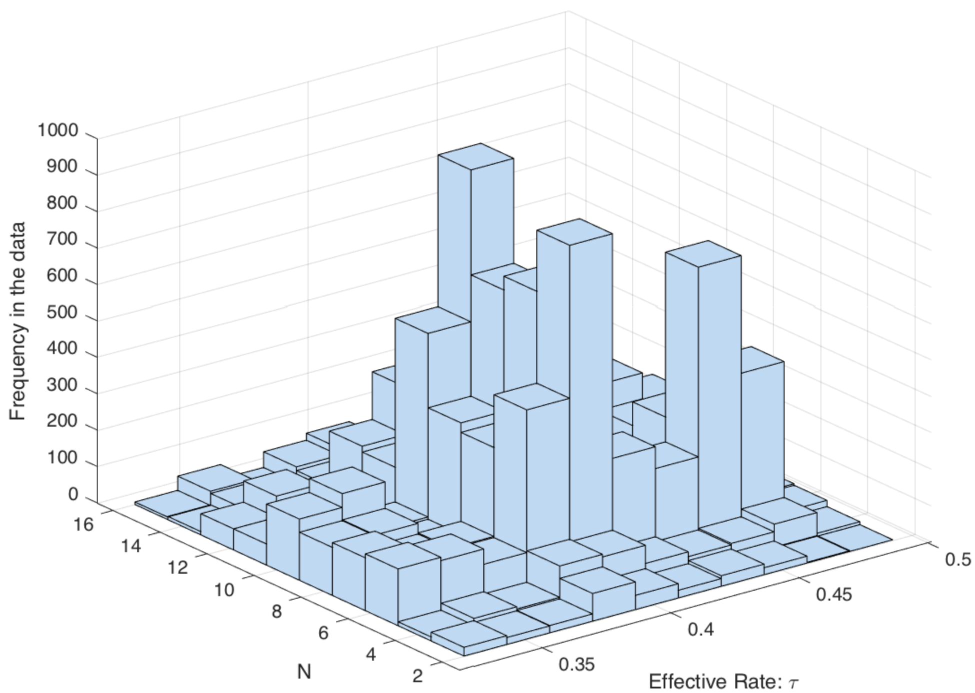
There are several recent and current tax reform proposals at the federal level that would change the borrowing cost of municipalities and demand for municipal debt. Broadly speaking, proposed reforms fit into 3 categories: changing the federal tax rate of the exemption, permanently introducing other 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 reforms that have been proposed.

Both Democrats and Republicans have proposed plans in recent years that will decrease the size of the tax exemption received by municipal bonds. In April 2017, President Trump suggested cutting the top marginal rate from 39.6% down to 35% (Rubin, 2017). 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 first proposed a cap in the municipal bond exemption at 28% in the American Jobs Act of 2011 and then in budget proposals in the 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 $\alpha = \frac{0.28}{0.384} \approx 0.73$ and $\alpha = \frac{0.35}{0.384} \approx 0.91$ where 0.384 is the average top marginal rate in the subsample for years 2013-2015.

Other reforms to the supply of municipal bonds to extend the availability of Build America Bond subsidies or to tighten tax-exempt eligibility are discussed among scholars and think-tanks but have not been formally proposed to our knowledge. Puentes et al. (2013) suggests that BABs are superior to traditional municipal bonds on several margins, which 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 that kept many bond issues from qualifying for tax exemption.

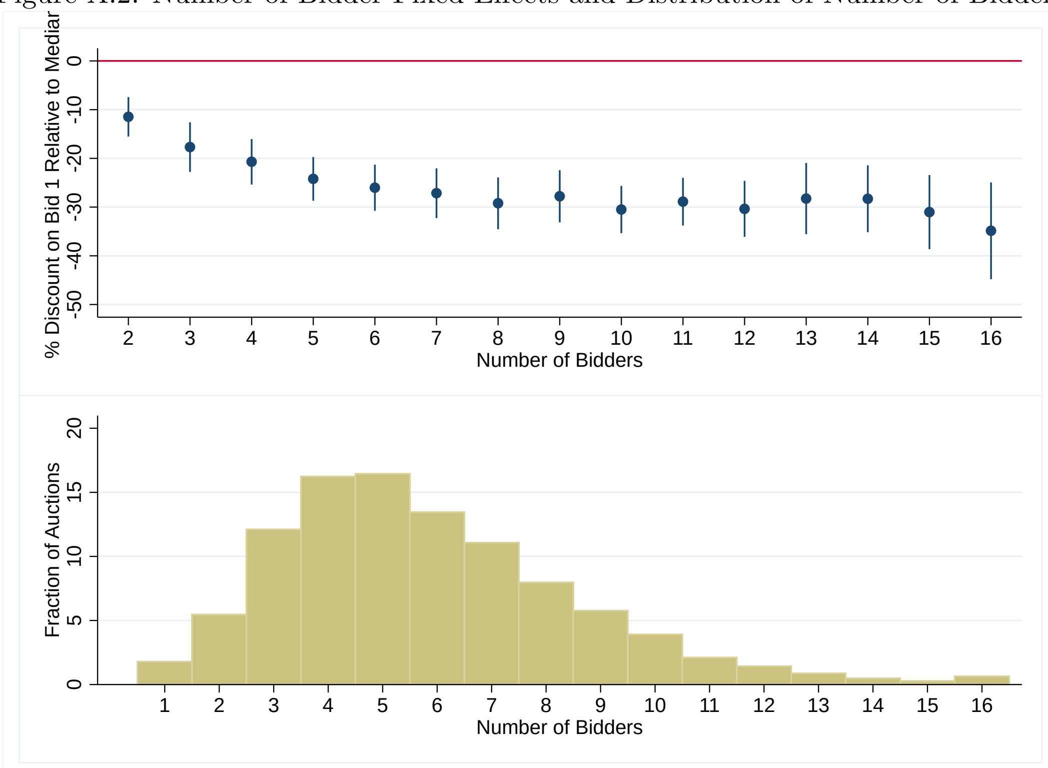
Appendix Graphs

Figure A.1: Frequency of Auctions by (N, τ) Pairs



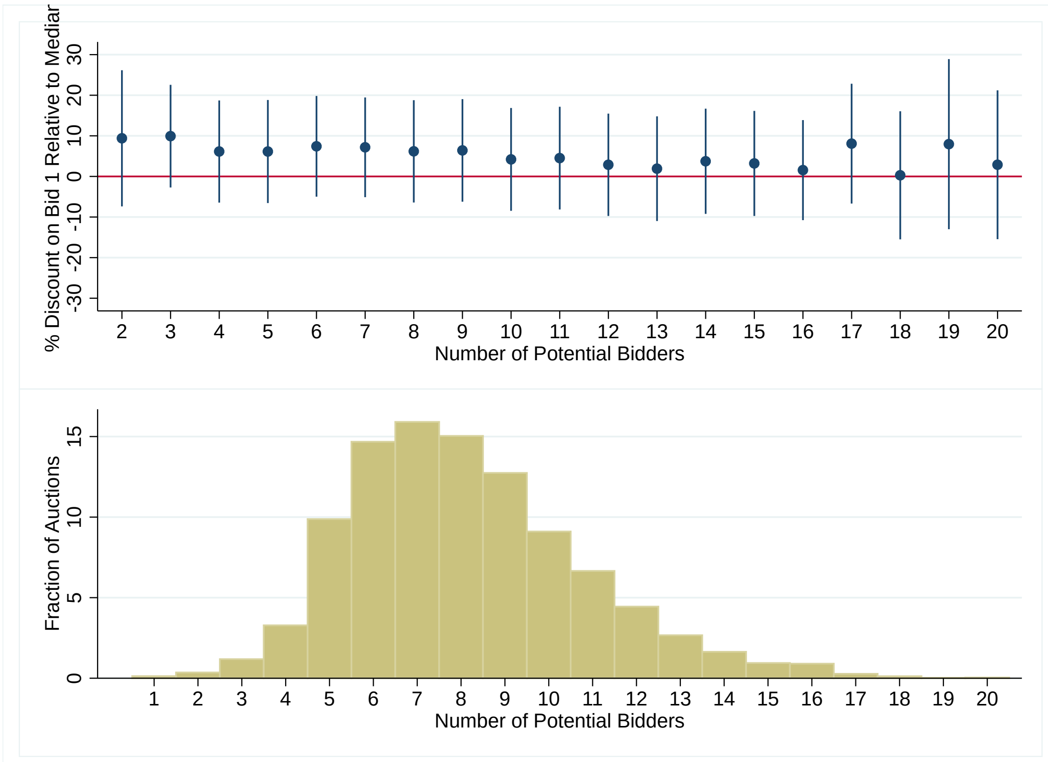
Notes: This figure shows the frequency of observations by number of potential bidders (N) and bins of effective tax rate. See Section 2 for more information about the data and variables.

Figure A.2: Number of Bidder Fixed Effects and Distribution of Number of Bidders



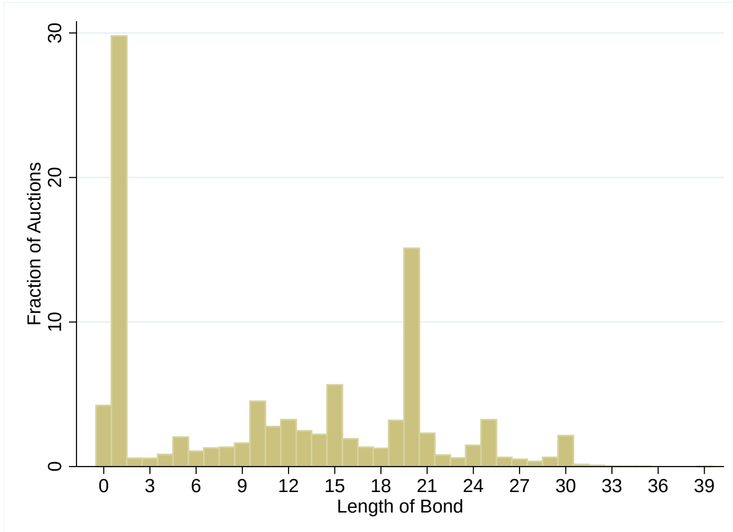
Notes: This figure shows the number of bidder fixed effect estimates from specification (4) of Table 2 normalized to the median bid in addition to the empirical distribution of the number of bidders in our sample. The reduced-form analysis is discussed in Section 3 and robustness checks are presented in Appendix C.

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



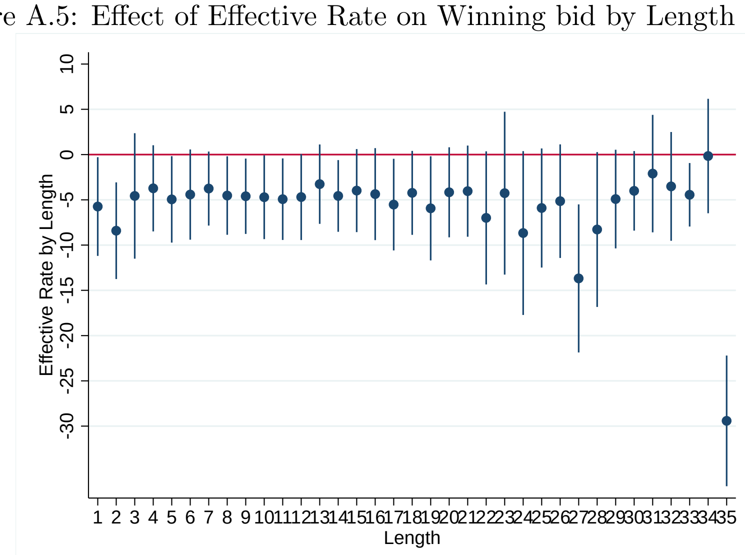
Notes: This figure shows the frequency of observations by number of potential bidders (N) and the associated fixed effect estimates from Table 2, column (4). See Section 3 for discussion of the reduced-form model.

Figure A.4: Empirical Distribution of Bond Lengths



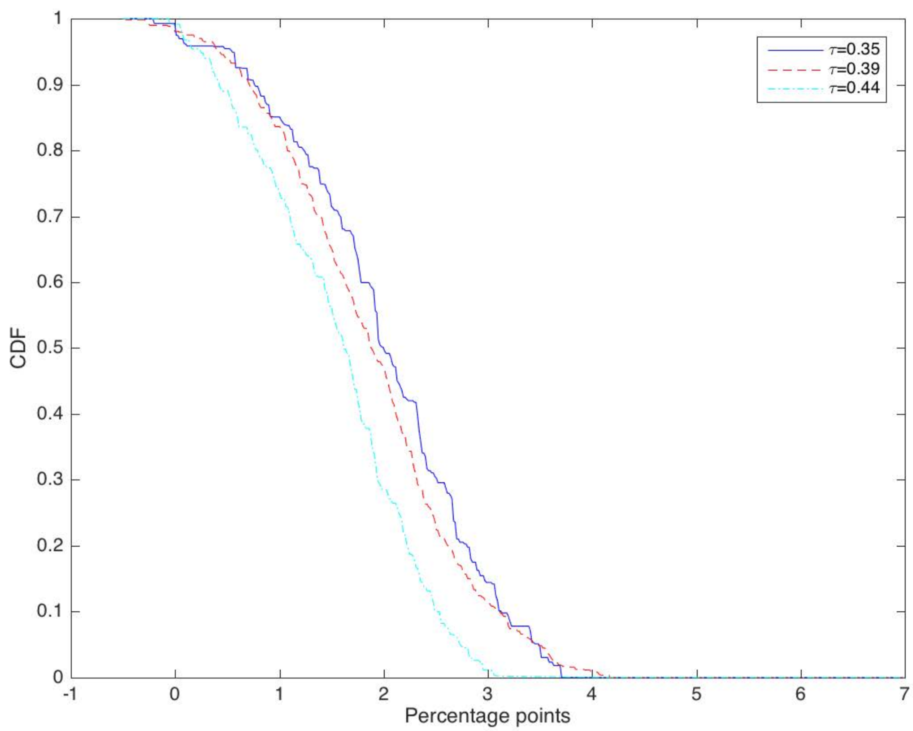
Notes: This figure shows the frequency of observations by length of bond. We test for heterogeneity of effect by length of bond in the reduced-form model in Appendix C.

Figure A.5: Effect of Effective Rate on Winning bid by Length of Bond



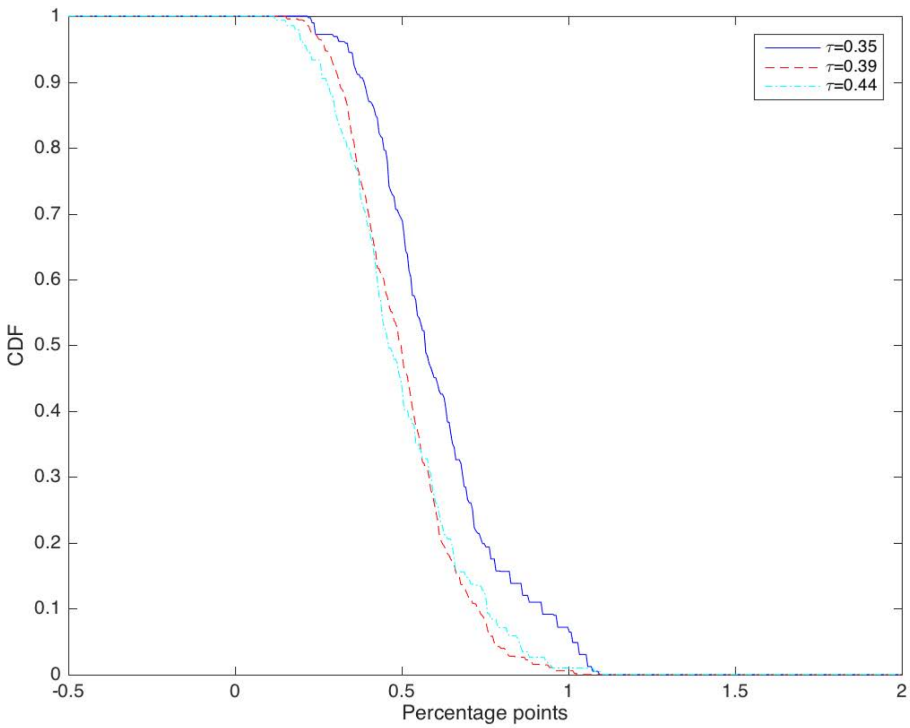
Notes: This figure shows the estimated coefficients of effect of effective rate on winning bid. See Appendix C form more information and Table A.7 for the associated statistical tests.

Figure A.6: Winners' Values at Different τ, Maturities Restricted to the Range of $[2, 17)$ Years



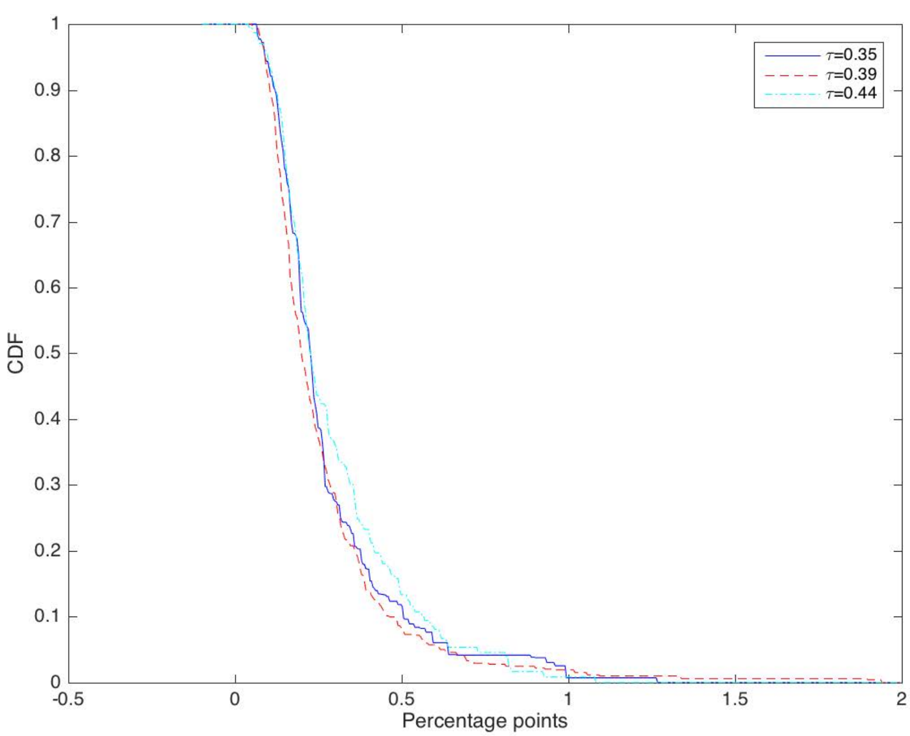
Notes: See Appendix D for more information about estimating the density of values from bids.

Figure A.7: Winners' Markups at Different τ, Maturities Restricted to the Range of $[2, 17)$ Years



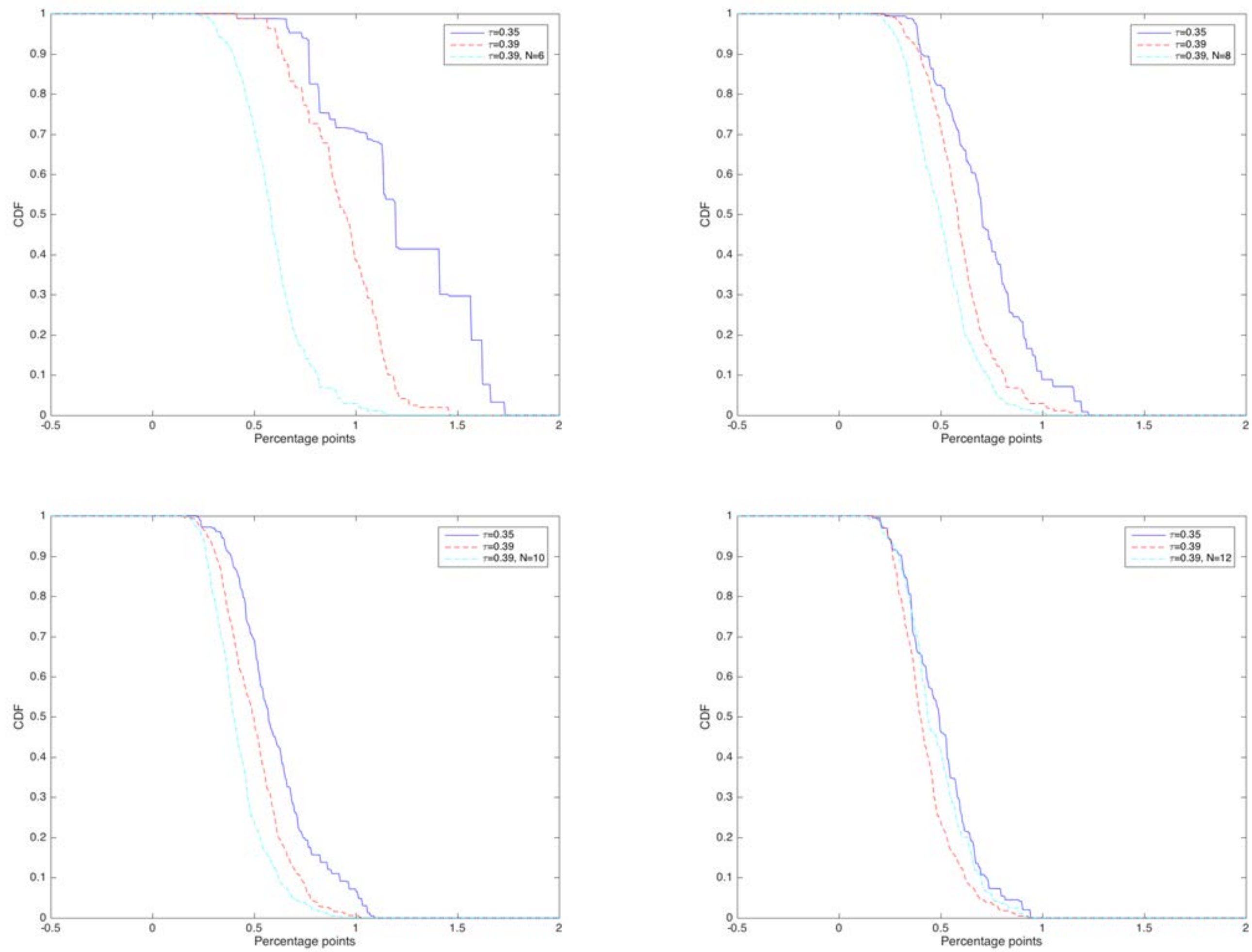
Notes: See Appendix D for more information about estimating the density of values and markups from bids.

Figure A.8: Winners' Markups/Bids at Different τ, Maturities Restricted to the Range of $[2, 17)$ Years



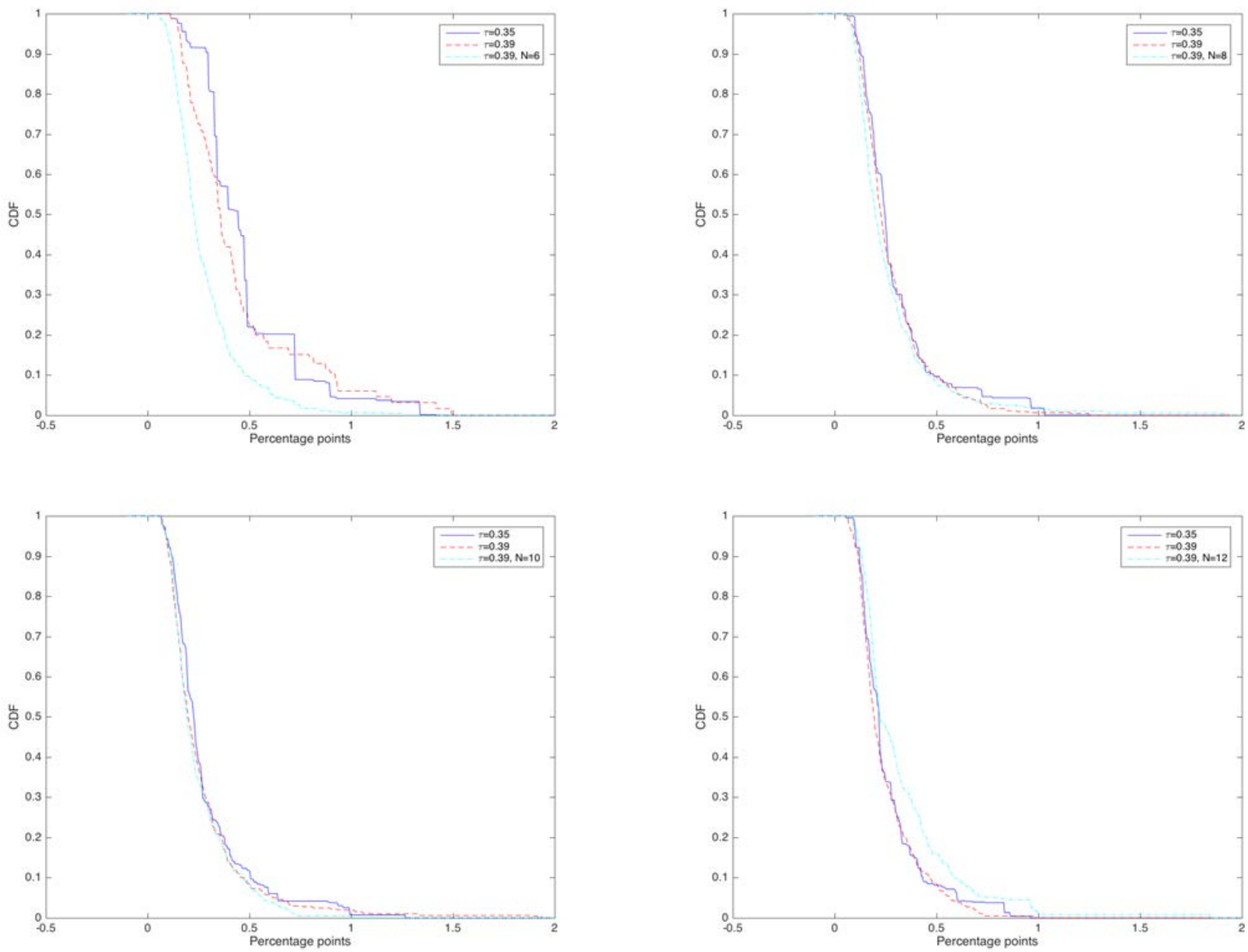
Notes: See Appendix D for more information about estimating the density of values and markups from bids.

Figure A.9: Winners' Markups at Different τ, Maturities Restricted to the Range of $[2, 17)$ Years



Notes: See Appendix D for more information about estimating the density of values and markups from bids.

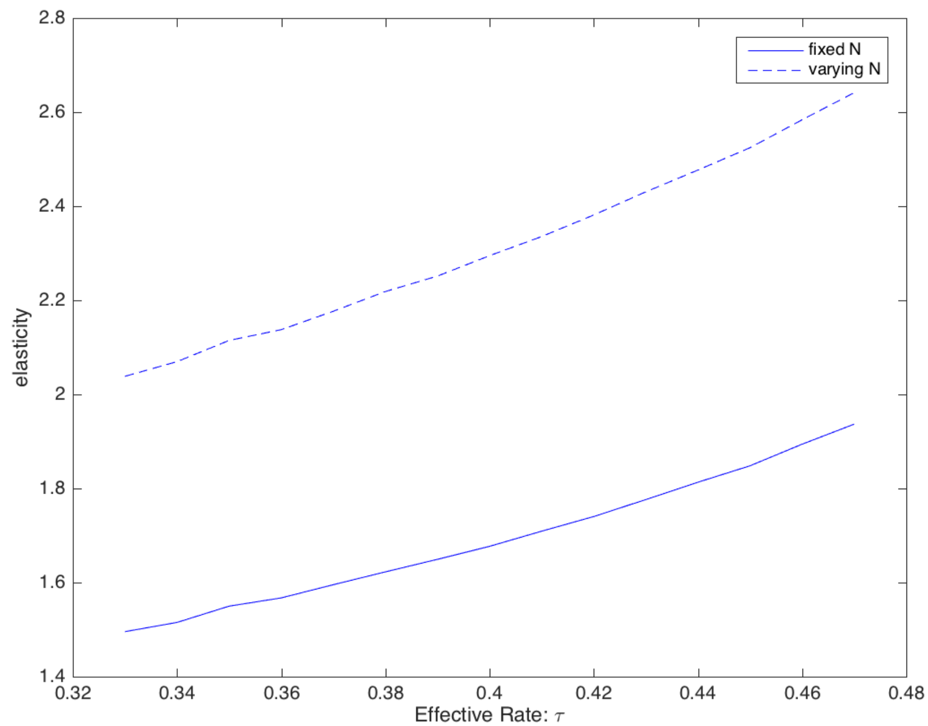
Figure A.10: Winners' Markups/Bids at Different τ, Maturities Restricted to the Range of $[2, 17)$ Years



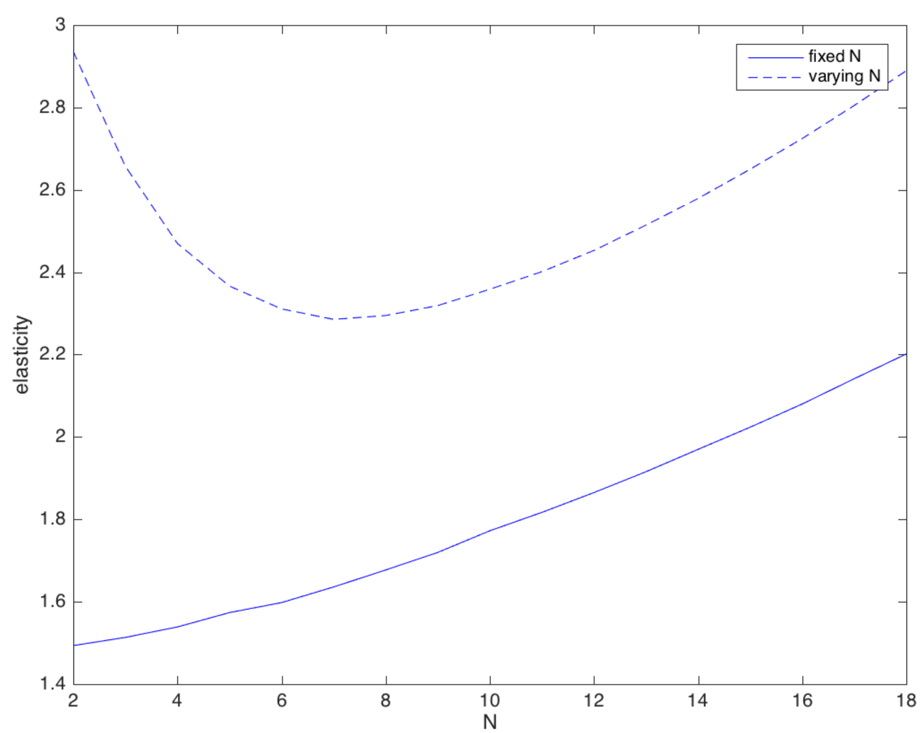
Notes: This figure shows the empirical CDF of markups as a percent of bids. See Appendix D for more information about estimating the density of values and markups from bids.

Figure A.11: Elasticities of the Winning bid in the "Take-Home Rate" $(1 - \tau)$

(a) By Effective Rate



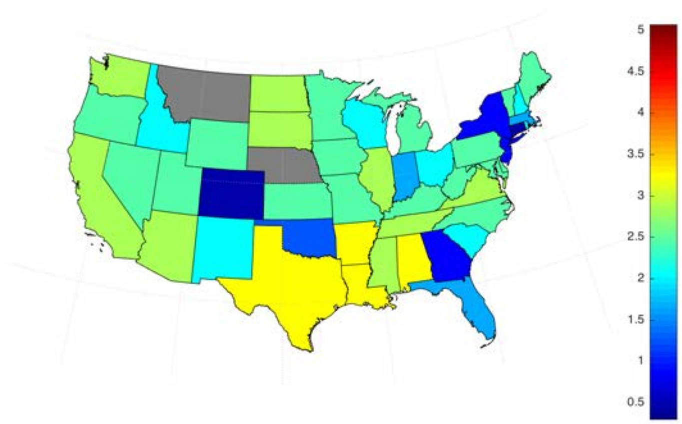
(b) By Number of Potential Bidders



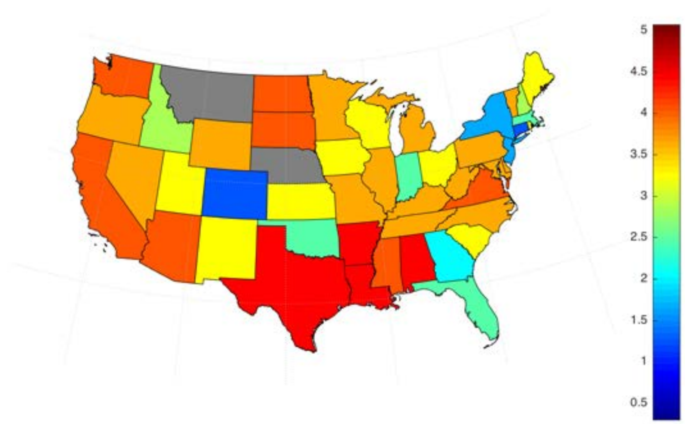
Notes: This figure shows elasticities implied by the structural model. See Section 6 for more information.

Figure A.12: Effect of Removing Federal Excludability on Winning Bids

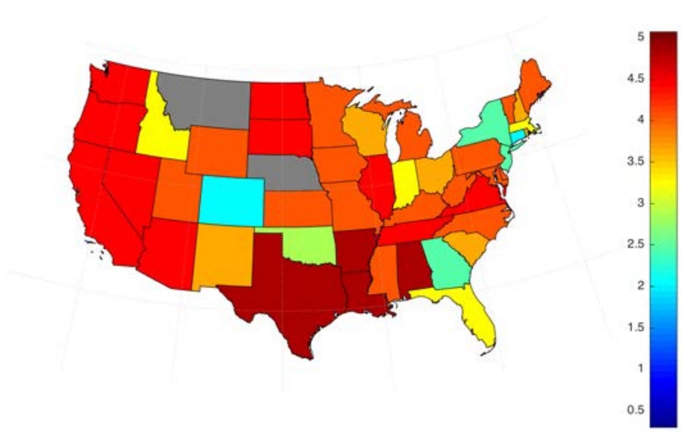
(a) Actual Average Winning Bid



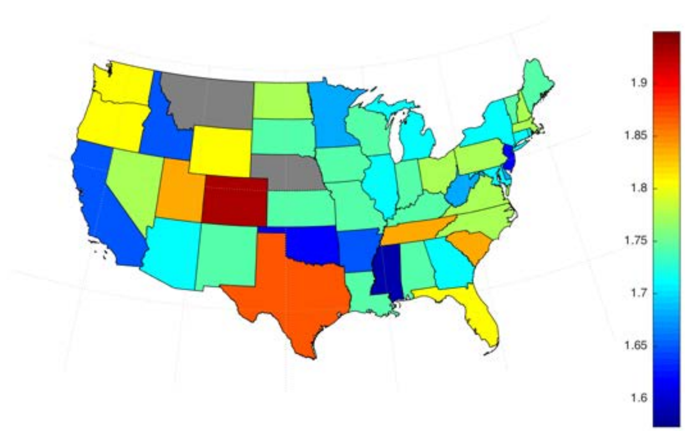
(b) Simulated Average Bid Removing Excludability
(No Entry Margin)



(c) Simulated Average Bid Removing Excludability
(With Entry Margin)



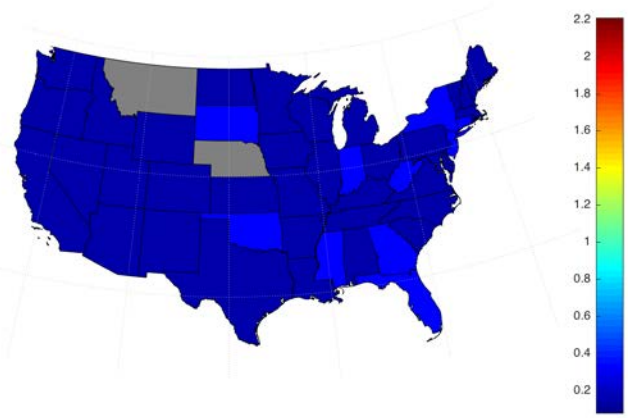
(d) Change Between (a) and (c)
(With Entry Margin)



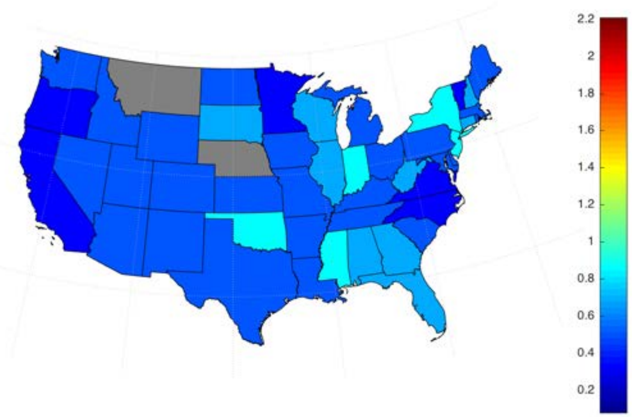
Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the federal exclusion was removed. See Section 6.4 for additional discussion and Figure A.13 for the corresponding markups. The comparable estimates of winning bids when capping the federal exemption at 28% is shown in Figure 8. The average effects from the policy reforms are shown in Table 8, the parameter estimates are displayed in Table 6, and federal α-policy outcomes for borrowing rates and markups are shown in Figure 7.

Figure A.13: Effect of Removing Federal Excludability on Markups

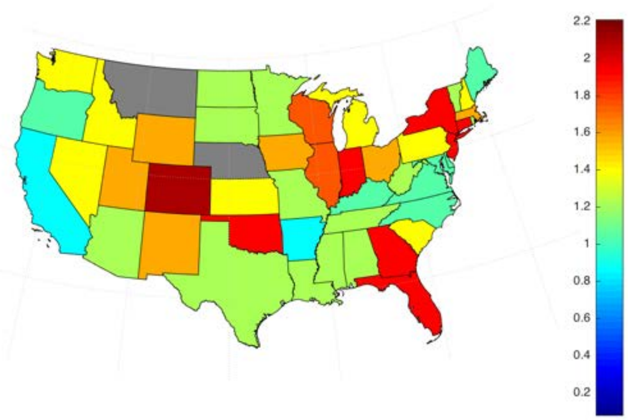
(a) Average Markup



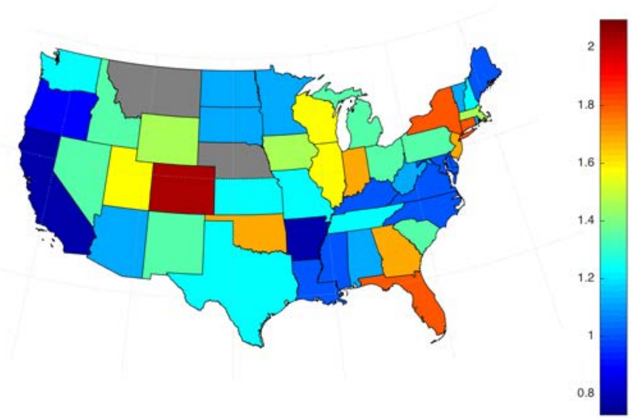
(b) Simulated Average Markup Removing Excludability (No Entry Margin)



(c) Simulated Average Bid Removing Excludability (With Entry Margin)



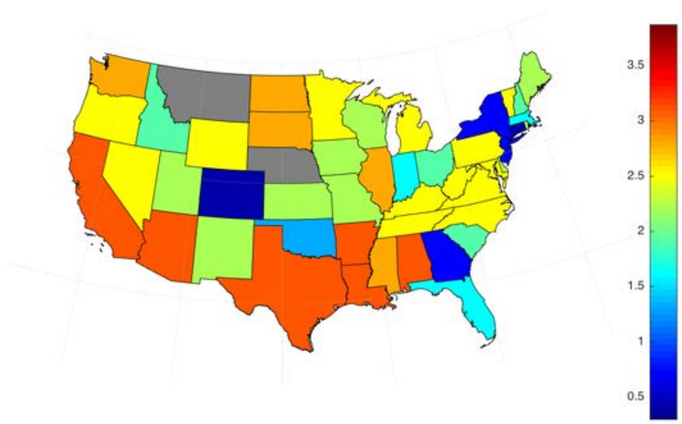
(d) Change Between (a) and (c) (With Entry Margin)



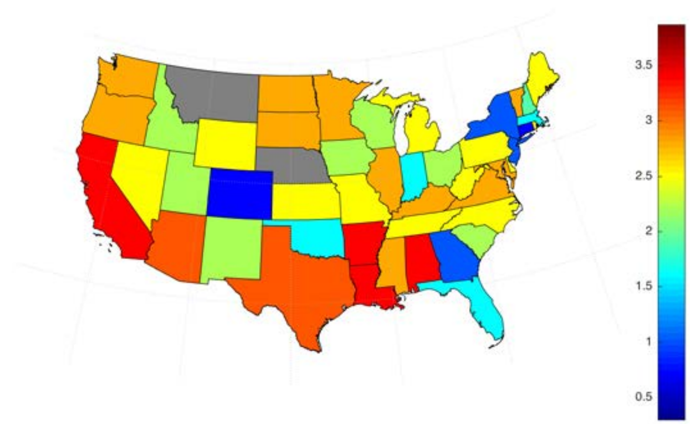
Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the federal exclusion was removed. See Section 6.4 for additional discussion and Figure A.12 for the corresponding bids. The comparable estimates of markups when capping the federal exemption at 28% is shown in Figure 9. The average effects from the policy reforms are shown in Table 8, the parameter estimates are displayed in Table 6, and federal α-policy outcomes for borrowing rates and markups are shown in Figure 7.

Figure A.14: Effect of Removing State Excludability on Winning Bids

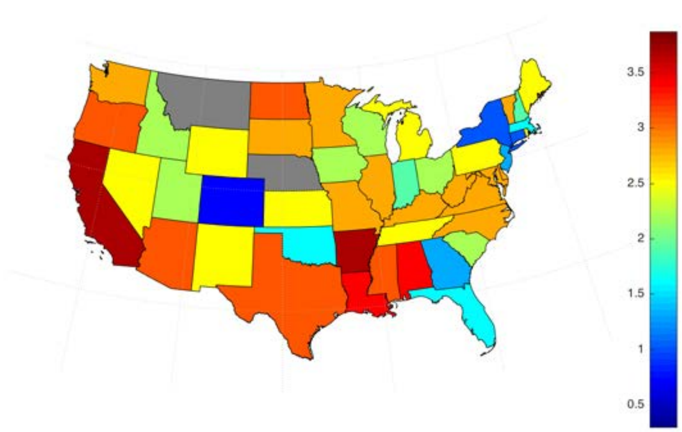
(a) Actual Average Winning Bid



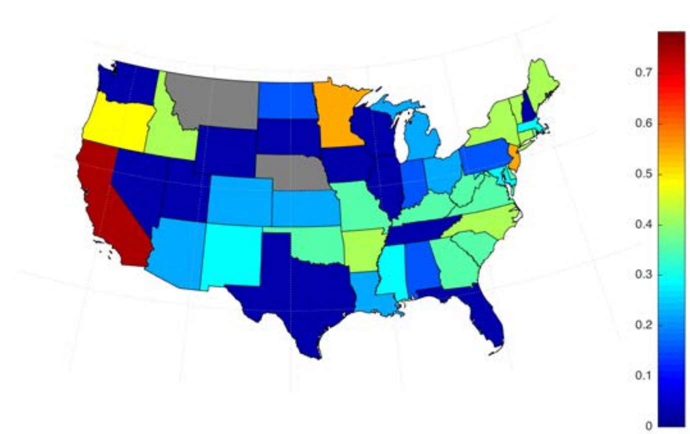
(b) Simulated Average Bid Removing Excludability
(No Entry Margin)



(c) Simulated Average Bid Removing Excludability
(With Entry Margin)



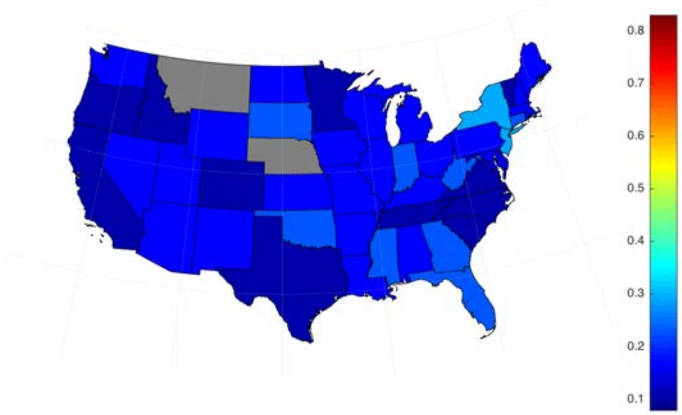
(d) Change Between (a) and (c)
(With Entry Margin)



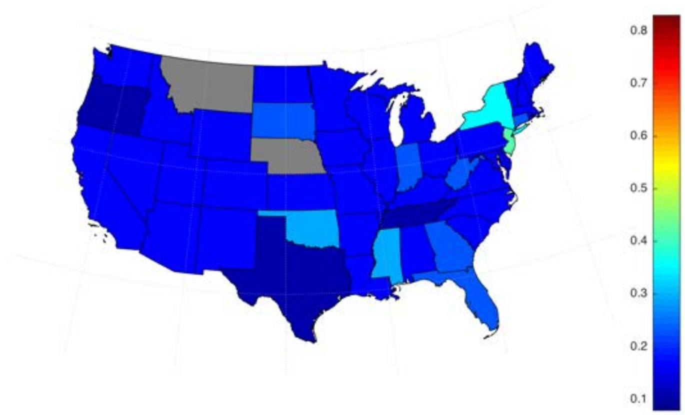
Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the state exclusion was removed. See Section 6.4 for additional discussion and Figure A.15 for the corresponding markups. The comparable estimates of winning bids when capping the federal exemption at 28% is shown in Figure 8. The average effects from the policy reforms are shown in Table 8 and the parameter estimates are displayed in Table 6.

Figure A.15: Effect of Removing State Excludability on Markups

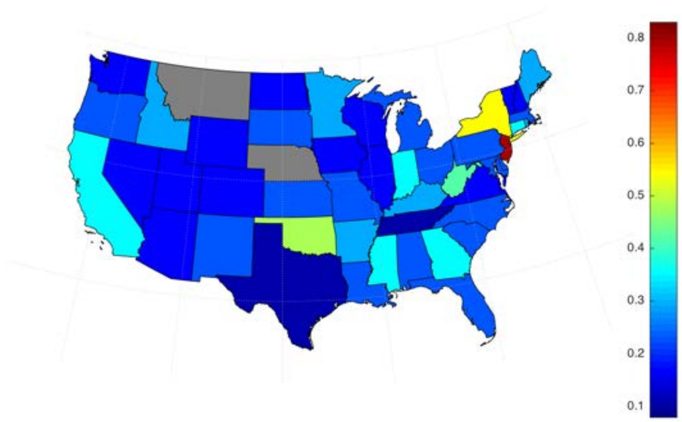
(a) Average Markup



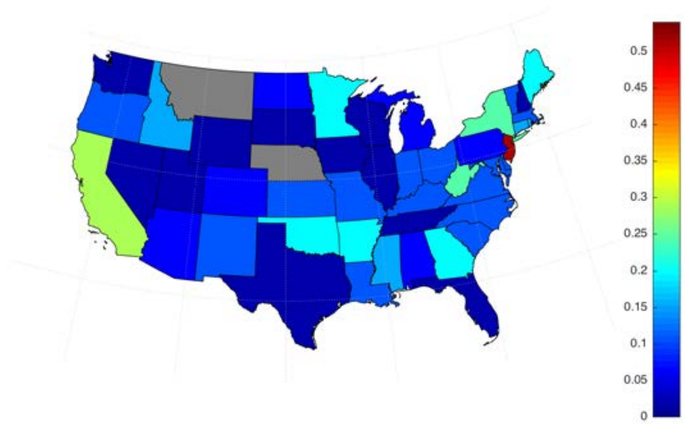
(b) Simulated Average Markup Removing Excludability
(No Entry Margin)



(c) Simulated Average Markup Removing Excludability
(With Entry Margin)



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



Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the federal exclusion was removed. See Section 6.4 for additional discussion and Figure A.14 for the corresponding bids. The comparable estimates of markups when capping the federal exemption at 28% is shown in Figure 9. The average effects from the policy reforms are shown in Table 8 and the parameter estimates are displayed in Table 6.

Appendix Tables

Table A.1: 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 information about the data cleaning process.

Table A.2: 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 information about the data cleaning process.

Table A.3: Waterfall 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 SDC Platinum and Bond Buyer data. See Appendix B for information about the data cleaning process.

Table A.4: Reduced-Form Effects of the Effective Rate on Winning Bid and the Number of Potential Bidders: Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Unconditional Effect of Effective Rate on Bid										
Effective Rate	-6.519	-6.659	-6.687	-6.215	-6.559	-6.698	-6.695	-6.517	-6.655	-6.738
	(2.655)	(2.885)	(2.595)	(3.505)	(2.749)	(2.920)	(2.710)	(2.723)	(2.918)	(3.224)
	0.018	0.025	0.013	0.082	0.021	0.026	0.017	0.021	0.027	0.042
Effect of Effective Rate on N										
Effective Rate	0.561	0.523	0.547	0.636	0.561	0.554	0.563	0.544	0.563	0.519
	(0.128)	(0.130)	(0.116)	(0.180)	(0.129)	(0.094)	(0.129)	(0.083)	(0.084)	(0.099)
	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid										
Conditional Effective Rate	-4.673	-4.704	-4.886	-4.505	-4.699	-4.838	-4.812	-4.734	-5.111	-5.475
	(2.614)	(2.895)	(2.533)	(3.242)	(2.732)	(2.843)	(2.669)	(2.822)	(3.142)	(3.410)
	0.080	0.111	0.060	0.171	0.092	0.095	0.078	0.100	0.110	0.115
Observations	14,631	14,613	14,631	14,631	14,631	14,631	14,631	14,631	14,613	14,613
Median Bid	221.200	221.010	221.200	221.200	221.200	221.200	221.200	221.200	221.010	221.010
Median Effective Tax	40.790	40.790	40.790	40.790	40.790	40.790	40.790	40.790	40.790	40.790
Percentage Due to Competition	28.313	29.351	26.928	27.516	28.349	27.767	28.131	27.369	23.207	18.744
	(15.293)	(18.553)	(13.653)	(13.473)	(15.991)	(15.882)	(15.300)	(18.079)	(15.869)	(13.648)
	0.064	0.114	0.049	0.041	0.076	0.080	0.066	0.130	0.144	0.170
Unconditional Elasticity at the Median	1.745	1.784	1.790	1.664	1.756	1.793	1.792	1.745	1.783	1.805
	(0.711)	(0.773)	(0.695)	(0.938)	(0.736)	(0.782)	(0.725)	(0.729)	(0.782)	(0.864)
	0.014	0.021	0.010	0.076	0.017	0.022	0.014	0.017	0.023	0.037
Conditional Elasticity at the Median	1.251	1.260	1.308	1.206	1.258	1.295	1.288	1.267	1.369	1.467
	(0.700)	(0.775)	(0.678)	(0.868)	(0.731)	(0.761)	(0.715)	(0.755)	(0.842)	(0.914)
	0.074	0.104	0.054	0.165	0.085	0.089	0.071	0.093	0.104	0.108
Base Controls	Y		Y	Y	Y	Y	Y	Y	Y	Y
Structural Model Controls		Y							Y	Y
Bidder Fixed Effects			Y						Y	Y
Issuer Fixed Effects				Y					Y	Y
Unemployment Rate					Y				Y	Y
Gross Domestic Product (log)						Y			Y	Y
State Government Spending (log)							Y		Y	Y
State Intergov Spending (log)								Y	Y	Y
Political Party Controls										Y
Personal Income Tax Base Controls										Y
Sales Tax Controls										Y
Business and Property Tax Controls										Y

Notes: Standard errors clustered at the state level are shown in parentheses and p-values for each estimate are displayed below standard errors. This table presents more estimates corresponding to Table 2. See Appendix C for details and Appendix A for variable definitions.

Table A.5: Robustness of Regression of Number of Potential Bidders on 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
	(0.094)	(0.099)	(0.109)	(0.111)	(0.098)
	0.000	0.001	0.003	0.004	0.002
Effect of Effective Rate on N (Definition 1)					
Effective Rate	0.561	0.554	0.542	0.550	0.547
	(0.128)	(0.133)	(0.148)	(0.149)	(0.128)
	0.000	0.000	0.001	0.001	0.000
Effect of Effective Rate on N (Definition 2)					
Effective Rate	1.373	1.413	1.411	1.467	1.345
	(0.416)	(0.403)	(0.420)	(0.403)	(0.366)
	0.002	0.001	0.002	0.001	0.001
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: Standard errors clustered at the state level are in parentheses and p-values are listed below standard errors. 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 F.

Table A.6: Effect of Effective Rate on Supply of Bond Auctions

	Frequency		ln(Frequency)	
	(1)	(2)	(3)	(4)
Effective Rate	1.853	1.816	0.001	0.005
	(10.136)	(10.020)	(0.087)	(0.088)
	0.856	0.857	0.989	0.957
Observations	400	400	382	382
R^2	0.984	0.984	0.958	0.958
Dependent Var. Mean	101.885	101.885	3.338	3.338
Effective Rate Mean	39.962	39.962	39.884	39.884
Elasticity of Supply at Mean	1.092	1.070	0.047	0.187
	(5.973)	(5.904)	(3.481)	(3.499)
	0.855	0.856	0.989	0.957
Year Fixed Effects	Y	Y	Y	Y
State Fixed Effects	Y	Y	Y	Y
State Policy Controls		Y		Y

Notes: Standard errors clustered at the state level are shown in parentheses with p-values listed below standard errors. This table shows regressions of the supply of municipal debt as measured by the number of bond offerings in our sample on effective tax rates. Columns (1) and (2) use the raw number of auctions at the state-year level as the dependent variable. Columns (3) and (4) use the log of the number of auctions as the dependent variable. Columns (1) and (3) only include state and year fixed effects while columns (2) and (4) also include controls for federal deductibility of income, alternative minimum taxes, and the exclusion of municipal bond income. See Section 3 and Appendix C for more information.

Table A.7: Effect of Effective Rate on Winning Bid: APE and FE

	(1) No Controls for Number of Bidders	(2) Controls for Number of Bidders
Average Partial Effect		
Effective Rate	-6.462	-4.970
	(2.675)	(2.746)
	0.016	0.070
Fixed Effect Estimate		
Effective Rate	-6.519	-4.673
	(2.644)	(2.601)
	0.014	0.072
Observations	14,631	14,631
Score p-value (Interactions)	0.519	1.000
Hausman p-value (APE=FE)	0.948	0.649
Percentage diff (APE-FE)/FE	0.009	-0.064
	(0.133)	(0.141)
	0.948	0.651
Percentage Due to Competition (APE)		0.231
Percentage Due to Competition (FE)		0.283

Notes: Standard errors are shown in parentheses with p-values below standard errors. See Appendix C for information about testing for heterogeneous effects in length. This table presents the estimates that correspond to Figure A.5 and shows the Hausman test p-value for the difference between the average partial effect and fixed effect estimates, which is insignificant at conventional levels.

Table A.8: Oster Coefficient Stability Tests

	(1)	(2)	(3)
	Table 2, (1)	Table 2, (1)	Table 2, (5)
Effective Rate	-6.519	-6.519	-6.806
	(2.655)	(2.655)	(2.879)
	0.018	0.018	0.022
R^2	0.898	0.898	0.899
	Table 2, (5)	Table 12, (10)	Table 12, (10)
Effective Rate	-6.806	-6.738	-6.738
	(2.879)	(3.224)	(3.224)
	0.022	0.042	0.042
R^2	0.899	0.953	0.953
Observations	14,631	14,613	14,613
δ such that $\beta^* = 0$	$[< 0]$	$[< 0]$	113.843
Corrected β^*	-42.590	-6.926	-6.679

Notes: Standard errors clustered at the state level are shown in parentheses and p-values are below standard errors. This table uses an estimator from Oster (Forthcoming) to test how much selection on unobservables is needed to to negate the results in Tables 2 and A.4. Each cell represents the results of a previously estimated model. Under some assumptions discussed in Oster (Forthcoming), columns (1) and (2) show that no amount of unobserved heterogeneity will negate the observe coefficients. The δ shown in column (3) implies that selection on unobservables would need to be 113.9 times more important than selection on observables for our results to be negated. For more information see Appendix C.5.

Table A.9: Simulations on In-Sample Observables S1: Robustness to Flexible Controls

Statistic	Mean	StDev	25^{th}	50^{th}	75^{th}
Model Fit					
Winning Bid in Data: b_1	2.151	1.364	0.790	2.210	3.190
Simulated Winning Bid: b_1	2.073	1.394	0.714	2.137	3.144
Entry Probability in Data: n/N	0.701	0.180	0.600	0.714	0.833
Simulated Entry Probability: n/N	0.720	0.009	0.714	0.720	0.724
Simulation Results					
Markups					
Markup: m_1	0.170	0.195	0.068	0.113	0.198
Markup Rate: m_1/b_1	0.197	0.334	0.026	0.056	0.266
Yearly Value of Markup: $m_1 s$	33.637	99.765	7.791	14.327	31.174
Total Value of Markup: $m_1 st$	411.139	1651.927	49.334	114.400	290.685
Entry Costs					
Entry Cost Threshold: d^*	0.487	0.262	0.326	0.443	0.549
Passthrough Elasticities					
$\varepsilon_{1-\tau}^{b,Partial}$	1.318	1.346	0.508	0.700	1.681
$\varepsilon_{1-\tau}^{b,Full}$	2.543	2.696	0.912	1.271	3.392

Notes: This table shows model fit and simulation results for in-sample observations from a variant of the baseline model where the bid mean is a piecewise-linear function of N and maturities (S1). The simulation results from the baseline model are displayed in Table 7. The model fit is still very similar to the baseline specification and markups are almost identical. The mean full passthrough elasticity shrinks from 2.624 in the baseline to 2.543 in this specification. Section 5 discusses the setup of the model while Appendix F contains information about specification S1 and other robustness checks.

Table A.10: Simulations on In-Sample Observables S2: Robustness to Alternative Definition of N

Statistic	Mean	StDev	25^{th}	50^{th}	75^{th}
Model Fit					
Winning Bid in Data: b_1	2.151	1.364	0.790	2.210	3.190
Simulated Winning Bid: b_1	2.097	1.376	0.774	2.157	3.147
Entry Probability in Data: n/N	0.338	0.211	0.182	0.280	0.444
Simulated Entry Probability: n/N	0.324	0.148	0.217	0.298	0.398
Simulation Results					
Markups					
Markup: m_1	0.181	0.273	0.069	0.115	0.182
Markup Rate: m_1/b_1	0.228	0.465	0.024	0.056	0.303
Yearly Value of Markup: $m_1 s$	35.980	116.056	7.712	14.398	33.073
Total Value of Markup: $m_1 st$	382.086	2099.698	56.285	113.654	284.115
Entry Costs					
Entry Cost Threshold: d^*	0.426	0.241	0.287	0.369	0.482
Passthrough Elasticities					
$\varepsilon_{1-\tau}^{b,Partial}$	1.480	1.564	0.532	0.747	1.933
$\varepsilon_{1-\tau}^{b,Full}$	2.062	2.069	0.802	1.114	2.631

Notes: This table shows model fit and simulation results for in-sample observations from a variant of the baseline model with N defined as the number of unique bidders across all auctions within a given state in a given month (S2). The simulation results from the baseline model are displayed in Table 7. The model fit with the different definition of potential bidders is similar to the baseline. Markups are estimated to be 18.1 basis points instead of 16.9 basis points in the baseline while mean full passthrough elasticity is about 2.1 in this specification. Section 5 discusses the setup of the model while Appendix F contains information about specification S2 and other robustness checks.

Table A.11: Simulations on In-Sample Observables S3: Robustness to Limiting Effect of τ on Truncation δ

Statistic	Mean	StDev	25^{th}	50^{th}	75^{th}
Model Fit					
Winning Bid in Data: b_1	2.151	1.364	0.790	2.210	3.190
Simulated Winning Bid: b_1	2.075	1.391	0.723	2.139	3.141
Entry Probability in Data: n/N	0.701	0.180	0.600	0.714	0.833
Simulated Entry Probability: n/N	0.717	0.010	0.711	0.717	0.723
Simulation Results					
Markups					
Markup: m_1	0.173	0.204	0.067	0.113	0.200
Markup Rate: m_1/b_1	0.202	0.345	0.025	0.055	0.273
Yearly Value of Markup: $m_1 s$	33.946	98.804	7.766	14.492	31.562
Total Value of Markup: $m_1 st$	410.321	1632.440	50.067	113.892	287.767
Entry Costs					
Entry Cost Threshold: d^*	0.742	0.490	0.451	0.627	0.885
Passthrough Elasticities					
$\varepsilon_{1-\tau}^{b,Partial}$	1.255	1.278	0.486	0.668	1.600
$\varepsilon_{1-\tau}^{b,Full}$	2.082	2.158	0.771	1.057	2.765

Notes: This table shows model fit and simulation results for in-sample observations from a variant of the baseline model with N defined as the number of unique bidders across all auctions within a given state in a given month (S3). The simulation results from the baseline model are displayed in Table 7. The model fit of this robustness check is similar to that of the baseline model. The simulated markups are very close to those in the baseline model while the mean full passthrough elasticity shrinks from 2.624 in the baseline to 2.082 in this specification. Section 5 discusses the setup of the model while Appendix F contains information about specification S3 and other robustness checks.

Table A.12: Simulations on In-Sample Observables S4: Robustness to Limiting Effect of τ on Bid Dispersion γ

Statistic	Mean	StDev	25^{th}	50^{th}	75^{th}
Model Fit					
Winning Bid in Data: b_1	2.151	1.364	0.790	2.210	3.190
Simulated Winning Bid: b_1	2.066	1.401	0.711	2.135	3.135
Entry Probability in Data: n/N	0.701	0.180	0.600	0.714	0.833
Simulated Entry Probability: n/N	0.764	0.009	0.757	0.763	0.769
Simulation Results					
Markups					
Markup: m_1	0.163	0.199	0.062	0.104	0.190
Markup Rate: m_1/b_1	0.192	0.330	0.023	0.050	0.258
Yearly Value of Markup: $m_1 s$	31.391	75.459	7.118	13.543	29.499
Total Value of Markup: $m_1 st$	376.190	1255.688	46.927	104.921	268.154
Entry Costs					
Entry Cost Threshold: d^*	0.625	0.430	0.373	0.521	0.740
Passthrough Elasticities					
$\varepsilon_{1-\tau}^{b,Partial}$	1.966	2.132	0.664	0.966	2.617
$\varepsilon_{1-\tau}^{b,Full}$	2.794	3.009	0.945	1.347	3.782

Notes: This table shows model fit and simulation results for in-sample observations from a variant of the baseline model with threshold parameter set to 0 for all auctions (S4). The simulation results from the baseline model are displayed in Table 7. Here the mean full passthrough elasticity of 2.794 is close to that in the baseline model 2.624. Section 5 discusses the setup of the model while Appendix F contains information about specification S4 and other robustness checks.

Table A.13: Simulations on In-Sample Observables S5: Robustness to Computation of Profits at Entry Stage

Statistic	Mean	StDev	25^{th}	50^{th}	75^{th}
Model Fit					
Winning Bid in Data: b_1	2.151	1.364	0.790	2.210	3.190
Simulated Winning Bid: b_1	2.078	1.392	0.724	2.141	3.145
Entry Probability in Data: n/N	0.701	0.180	0.600	0.714	0.833
Simulated Entry Probability: n/N	0.694	0.017	0.681	0.694	0.706
Simulation Results					
Markups					
Markup: m_1	0.177	0.208	0.071	0.117	0.203
Markup Rate: m_1/b_1	0.204	0.346	0.027	0.057	0.277
Yearly Value of Markup: $m_1 s$	35.090	101.976	8.131	14.987	32.404
Total Value of Markup: $m_1 st$	432.903	1717.132	51.589	119.184	303.138
Entry Costs					
Entry Cost Threshold: d^*	0.098	0.094	0.041	0.072	0.127
Passthrough Elasticities					
$\varepsilon_{1-\tau}^{b,Partial}$	1.874	1.944	0.698	0.972	2.413
$\varepsilon_{1-\tau}^{b,Full}$	2.581	2.687	0.947	1.309	3.409

Notes: This table shows model fit and simulation results for in-sample observations from a variant of the baseline model where we truncate the distribution of bids at the entry stage (S5). The simulation results from the baseline model are displayed in Table 7. The model fit of this robustness check is similar to that of the baseline model. The mean simulated markup is slightly larger at 17.7 basis points instead of 16.9 basis point in this specification while the mean full passthrough elasticity is still very close to 2.6. Section 5 discusses the setup of the model while Appendix F contains information about specification S5 and other robustness checks.

Table A.14: Average Effects from Counterfactual Policy Reform S1: Robustness to Flexible Controls

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

	(1) $\alpha = 1$	(2) $\alpha = 0.91$	(3) $\alpha = 0.73$	(4) $\alpha = 0$	(5) No state excludability
Winning Bid					
Partial (No Potential Entry)	1.913	2.002	2.171	2.670	2.285
Full	1.913	2.111	2.481	3.376	2.452
Markups					
Partial (No Potential Entry)	0.182	0.204	0.256	0.631	0.248
Full	0.182	0.276	0.520	1.596	0.394

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

	(1) $\alpha = 0.91$	(2) $\alpha = 0.73$	(3) $\alpha = 0$	(4) No state excludability
Winning Bid				
Partial (No Potential Entry)	4.657%	13.490%	39.564%	19.462%
Full	10.331%	29.683%	76.486%	28.165%
Markups				
Partial (No Potential Entry)	12.025%	40.597%	246.174%	36.343%
Full	51.194%	185.360%	775.565%	116.186%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 91% of its current level–for a variant of the baseline model where the bid mean is a piecewise-linear function of N and maturities (S1). Table 8 displays the corresponding counterfactuals for the baseline model. Relative to the baseline model, the counterfactual percentage change in winning bid is unchanged at all levels except for $\alpha = 0$ where there is a 76.5% increase instead of a 90.4% increase. The markups still show a tremendous increase with a decrease in the tax rate of the same order of magnitude as the baseline. Section 5 discusses the setup of the model while Section 6.4 discusses the counterfactual simulations. Appendix F contains information about specification S1 and other robustness checks.

Table A.15: Average Effects from Counterfactual Policy Reform S2: Robustness to Alternative Definition of N

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

	(1) $\alpha = 1$	(2) $\alpha = 0.91$	(3) $\alpha = 0.73$	(4) $\alpha = 0$	(5) No state excludability
Winning Bid					
Partial (No Potential Entry)	1.913	2.009	2.197	2.880	2.302
Full	1.913	2.055	2.361	3.326	2.385
Markups					
Partial (No Potential Entry)	0.154	0.170	0.205	0.432	0.202
Full	0.154	0.177	0.267	0.943	0.228

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

	(1) $\alpha = 0.91$	(2) $\alpha = 0.73$	(3) $\alpha = 0$	(4) No state excludability
Winning Bid				
Partial (No Potential Entry)	5.044%	14.845%	50.527%	20.346%
Full	7.422%	23.406%	73.872%	24.656%
Markups				
Partial (No Potential Entry)	10.092%	33.357%	180.400%	31.289%
Full	14.791%	73.419%	512.181%	47.756%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 91% of its current level–for a variant of the baseline model with N defined as the number of unique bidders across all auctions within a given state in a given month (S2). Table 8 displays the corresponding counterfactuals for the baseline model. Relative to the baseline model, the counterfactual percentage change in winning bid is unchanged at all levels except for $\alpha = 0$ where there is slightly less change. The markups still experience large increases with a decrease in the tax rate, although the magnitude is lower for all levels of α. Section 5 discusses the setup of the model while Section 6.4 discusses the counterfactual simulations. Appendix F contains information about specification S2 and other robustness checks.

Table A.16: Average Effects from Counterfactual Policy Reform S3: Robustness to Limiting Effect of τ on Truncation δ

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

	(1) $\alpha = 1$	(2) $\alpha = 0.91$	(3) $\alpha = 0.73$	(4) $\alpha = 0$	(5) No state excludability
Winning Bid					
Partial (No Potential Entry)	1.913	1.998	2.159	2.615	2.279
Full	1.913	2.075	2.395	3.211	2.404
Markups					
Partial (No Potential Entry)	0.182	0.204	0.256	0.641	0.248
Full	0.182	0.274	0.515	1.611	0.391

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

	(1) $\alpha = 0.91$	(2) $\alpha = 0.73$	(3) $\alpha = 0$	(4) No state excludability
Winning Bid				
Partial (No Potential Entry)	4.447%	12.858%	36.696%	19.124%
Full	8.476%	25.186%	67.870%	25.681%
Markups				
Partial (No Potential Entry)	12.009%	40.537%	252.133%	36.291%
Full	50.737%	182.855%	785.244%	114.942%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 91% of its current level–for a variant of the baseline model with N defined as the number of unique bidders across all auctions within a given state in a given month (S3). Table 8 displays the corresponding counterfactuals for the baseline model. Relative to the baseline model, the counterfactual percentage change in winning bid is similar at all levels with slightly diminished magnitudes relative to the baseline. The markups still experience large increases with a decrease in the tax rate for all levels of α. Section 5 discusses the setup of the model while Section 6.4 discusses the counterfactual simulations. Appendix F contains information about specification S3 and other robustness checks.

Table A.17: Average Effects from Counterfactual Policy Reform S4: Robustness to Limiting Effect of τ on Bid Dispersion γ

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

	(1) $\alpha = 1$	(2) $\alpha = 0.91$	(3) $\alpha = 0.73$	(4) $\alpha = 0$	(5) No state excludability
Winning Bid					
Partial (No Potential Entry)	1.913	2.036	2.283	3.285	2.350
Full	1.913	2.114	2.501	3.606	2.467
Markups					
Partial (No Potential Entry)	0.201	0.201	0.201	0.200	0.203
Full	0.201	0.269	0.407	0.513	0.319

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

	(1) $\alpha = 0.91$	(2) $\alpha = 0.73$	(3) $\alpha = 0$	(4) No state excludability
Winning Bid				
Partial (No Potential Entry)	6.453%	19.360%	71.704%	22.859%
Full	10.489%	30.759%	88.511%	28.981%
Markups				
Partial (No Potential Entry)	-0.006%	-0.018%	-0.062%	1.076%
Full	34.286%	103.103%	155.738%	58.933%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 91% of its current level–for a variant of the baseline model with threshold parameter set to 0 for all auctions (S4). Table 8 displays the corresponding counterfactuals for the baseline model. Relative to the baseline model, the counterfactual percentage change in winning bid is similar at all levels. The markups show large increases with a decrease in the tax rate for all levels of α although the magnitudes are much smaller than the baseline. The markups are 1.5 to 3 times more responsive to the tax changes than the winning bids. Section 5 discusses the setup of the model while Section 6.4 discusses the counterfactual simulations. Appendix F contains information about specification S4 and other robustness checks.

Table A.18: Average Effects from Counterfactual Policy Reform S5: Robustness to Computation of Profits at Entry Stage

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

	(1) $\alpha = 1$	(2) $\alpha = 0.91$	(3) $\alpha = 0.73$	(4) $\alpha = 0$	(5) No state excludability
Winning Bid					
Partial (No Potential Entry)	1.913	2.037	2.276	3.052	2.341
Full	1.913	2.106	2.491	3.647	2.455
Markups					
Partial (No Potential Entry)	0.183	0.205	0.258	0.632	0.250
Full	0.183	0.275	0.519	1.606	0.394

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

	(1) $\alpha = 0.91$	(2) $\alpha = 0.73$	(3) $\alpha = 0$	(4) No state excludability
Winning Bid				
Partial (No Potential Entry)	6.491%	18.961%	59.519%	22.398%
Full	10.068%	30.219%	90.625%	28.347%
Markups				
Partial (No Potential Entry)	12.221%	41.330%	246.186%	36.953%
Full	50.827%	184.513%	779.405%	115.929%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 91% of its current level–for a variant of the baseline model where we truncate the distribution of bids at the entry stage (S5). Table 8 displays the corresponding counterfactuals for the baseline model. Relative to the baseline model, the counterfactual percentage change in winning bid is very stable at all levels relative to the baseline. The markups show large increases with a decrease in the tax rate for all levels of α with magnitudes that are in-line with the baseline model. Section 5 discusses the setup of the model while Section 6.4 discusses the counterfactual simulations. Appendix F contains information about specification S5 and other robustness checks.