Hutchins Center Working Paper #49

November 2018

Tax Advantages and Imperfect Competition in Auctions for Municipal Bonds

Daniel Garrett
Duke University

James W. Roberts
Duke University & NBER

Andrey Ordin
Duke University

Juan Carlos Suárez Serrato
Duke University & NBER

ABSTRACT

We study the interaction between tax advantages for municipal bonds and the market structure of auctions for these bonds. We show this interaction can limit the ability of bidders to extract information rents and is a crucial determinant of state and local governments' borrowing costs. Reduced-form estimates show that increasing the tax advantage by 3 pp. lowers mean borrowing costs by 9-10%, consistent with a greater-than-unity passthrough elasticity. We estimate a structural auction model to measure markups, and to illustrate and quantify how the interaction between tax policy and bidder strategic behavior leads to large passthrough elasticities. We use the estimated model to evaluate the efficiency of Obama and Trump administration policies that limit the tax advantage for municipal bonds. We find that the resulting increase in municipal borrowing costs is 2.8 times as large as the tax savings induced by these policies.

A version of this paper was presented as part of the 7th annual Municipal Finance Conference, held July 16-17, 2018 at Brookings. The authors are grateful for comments from Manuel Adelino, Pat Bayer, Vivek Bhattacharya, Javier Donna, Josh Gottlieb, Ali Horta¸csu, Kei Kawai, Lorenz Kueng, Tong Li, Matt Panhans, Jim Poterba, Mar Reguant, Stephen Ryan, Xun Tang, Owen Zidar and numerous seminar participants. Suárez Serrato is grateful for funding from the Kauffman Foundation. All errors remain their own.

The authors did not receive financial support from any firm or person with a financial or political interest in this article. None is currently an officer, director, or board member of any organization with an interest in this article.

Hutchins Center on Fiscal & Monetary Policy at BROOKINGS

THIS PAPER IS ONLINE AT
https://www.brookings.edu/research/tax-advantages-and-imperfect-competition-in-auctions-for-municipal-bonds

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] To reduce the borrowing costs of state and local governments, municipal bond income is excluded from federal and, in most cases, state taxation. This tax advantage creates a tax *expenditure* for the federal and state governments, which is forecast to cost the federal government alone more than $500 billion over the coming decade, has been rising over time, and is mainly enjoyed by top-income individuals. Not surprisingly, the tax advantage of municipal bonds has been the subject of a controversial policy debate. However, in spite of the more than 120 proposals to eliminate or limit this tax advantage since 1918, including every budget proposal by the Obama administration from 2012-2016, this favored treatment by the U.S. tax code has remained largely unchanged.[2]

We contribute to this debate by showing that the interaction of the tax advantages with the market 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. Specifically, we analyze a novel dataset on over 14,000 new issuances of municipal bonds sold at auction between 2008 and 2015.[3] We exploit within-state changes in taxes over time to show that tax advantages have large effects on the borrowing costs of state and local governments. We then develop an empirical auction model that clarifies the economic mechanisms in this market. In particular, we use our structural auction model to illuminate and quantify the importance of the interaction between tax advantages and strategic bidding behavior in generating this effect. Finally, we use the estimated model to evaluate recent proposals by the Obama and Trump administrations, as well as parts of the Tax Cuts and Jobs Act of 2017 (TCJA17) that affect the tax advantages of municipal bonds. By highlighting the interactions between taxes and imperfect competition, our results suggest a fundamental reassessment of the mechanism through which tax subsidies reduce borrowing costs, and provide new evidence suggesting that tax subsidies may be more efficient at subsidizing local borrowing costs than previously thought.

We begin our analysis by providing reduced-form evidence that a 1 percentage-point (pp.) increase in the tax subsidy, or what we term the "effective rate," leads to a decrease in borrowing costs of 6.5-7 basis

. . .

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.

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.

points. Given the mean borrowing rate is 2.14%, a 3 pp. increase in the effective rate would reduce borrowing costs by 9-10%. Our results imply a passthrough elasticity of the borrowing rate to the tax advantage of 1.7-1.9.[4] This causal interpretation relies on the identifying assumption that changes in the effective rate are not driven by other factors that may spuriously correlate with borrowing costs. This assumption is supported by several facts. First, variation in the effective rate is driven by both federal and state tax changes, as well as by their interaction due to the federal deduction of state and local taxes (SALT). Second, the vast majority of the auctions are held by sub-state municipalities that have no influence over the effective rate. Finally, we show that this result is robust to controlling for a number of potential confounders including determinants of borrowing rates and economic conditions of the municipal bond market. Our most demanding specification identifies this effect using repeated bond auctions by the same issuer (municipality) in time periods with different (federal and state) tax rates, which severely limits concerns that our results are driven by omitted factors that may be correlated with both tax changes and borrowing costs.[5]

In order to better understand the economic mechanisms behind this reduced-form result, we estimate an empirical auction model in the spirit of Li and Zheng (2009) that accounts for the effect of the tax advantage on the distribution of bidder values, as well as their decision to participate in an auction. We use this model for three reasons. First, the model recovers the latent distribution of bidders' willingness to pay for these bonds. This allows us to quantify the information rents enjoyed by bidders. Our model implies that the average markup is 17 basis points and that state issuers enjoy smaller markups than do cities, counties, and school districts.

Second, the model helps us understand the relationship between bidder markups and the tax advantage. In particular, the model shows that, in imperfectly competitive auctions, changes in taxes can have greater-than-unity passthrough if tax changes have large effects on equilibrium markups. 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. An increase in the tax advantage will lead bidders to decrease their bid, and will further lower the equilibrium borrowing rate as other participants respond to this incentive by lowering their bids, and as more participants enter the auction. We show that these forces have large effects on equilibrium markups leading to greater-than-unity passthrough elasticities on borrowing costs. While we explore these effects

. . .

4. A 3 pp. increase in the effective tax rate is less than a 1 standard deviation increase, and is equivalent to moving from the 50th percentile to the 75th percentile as shown in Table 1. The tax advantage of excludable interest income, relative to taxable interest income, is $(1-\tau)$, where τ is the effective rate. Given an average τ of 40.87%, a 3 pp. increase implies an increase in the tax advantage of 5%, implying a passthrough elasticity at the mean of $1.8 \left(\approx \frac{9\%}{5\%}\right)$.

5. 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 controlling for the size of the bond issuance, for callable bonds, for current and expected interest rates from municipal bonds, to excluding issuers that set income tax rates, to using bidder fixed effects and issuer fixed effects, and to restricting the effects of taxes on bidder participation. We also use an event study approach to show that the timing of tax changes coincides with changes in borrowing costs, and, as a placebo, that future taxes do not predict changes in borrowing costs.

through the lens of our model, we provide non-parametric evidence that this mechanism is at play in the data.

Finally, we use the model estimates to evaluate the effects of a range of policies that include (i) increasing or decreasing the size of the federal exemption, (ii) eliminating the state exemption altogether, and (iii) limiting SALT in concordance with the TCJA17. We find that capping the excludability of municipal bond interest income 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 somewhat more modest effects from removing the excludability of municipal bond interest income from state taxation. Limiting the SALT deduction would *increase* the tax advantage of municipal bonds at the federal level, and we predict that this tax change will lead state and local government borrowing costs to fall by over 6%. Combined with personal income tax cuts in the TCJA17, which would otherwise increase borrowing costs, we predict that the net effect of recent the Trump tax cuts will be a decrease in borrowing costs of 2.5%. 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 of municipal bond offerings makes it a cost-effective 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. (2018) 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. Like previous studies, we too use methods from the empirical auction literature to study market power in a key financial market. Our paper is set apart from this literature not only by its focus on municipal bonds (e.g. Tang (2011)), but additionally, and perhaps more importantly, by its concentration on the interaction between tax policy and market structure,[6] including bidders' endogenous participation decisions. Recent work has shown the importance of allowing for endogenous participation in auctions (e.g. Li and Zheng (2009)) for a variety of mechanism design and policy-related questions in both theoretical and empirical settings.[7] This paper contributes further evidence to this literature by showing that endogenous participation influences the effect of taxes on municipal borrowing costs.

Second, we contribute to the literature on municipal bonds, which is important for three reasons. First, interest payments on municipal bonds are a significant component of state and local governments' budgets. Second, the borrowing rate for specific projects (such as schools, airports, museums) directly determines the scale of public good provision. The rationale for the tax advantage of municipal bonds is that local governments may not internalize the value of public goods for the residents of nearby locations.

. . .

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

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

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 focuses on the primary market, and particularly on the impact of municipal bonds' tax advantage on local government borrowing costs.[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. Critics of the tax-excludability of interest from municipal bonds argue that it allows top income earners to lower their effective tax rates. Indeed, the push to cap the excludability was part of a broader campaign during the Obama administration to close "loopholes" for top-earners that allowed them to avoid paying higher marginal taxes (Walsh, 2012). It is thus a first-order concern to understand whether this expenditure serves a public purpose, and whether it is efficient at reducing borrowing costs, which current conventional wisdom believes it is not.[10]

Finally, 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, there are few real-world examples of policies designed to promote more

. . .

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. (2017) show that exogenous changes in borrowing rates lead to additional spending by local governments. Cellini et al. (2010) show that investments in school facilities through bond measures in California raise home prices by more than the cost of the bond, suggesting an under-provision of bond-financed public goods.

9. A prominent literature compares tax-exempt municipal bonds to bonds with different tax treatments (e.g., Green (1993), Schultz (2012), Ang et al. (2010b), Cestau et al. (2013), Liu and Denison (2014), and Kueng (2014)). While previous papers address important interactions between tax advantages and the behavior of financial markets, they do not directly measure the passthrough of tax advantages to the borrowing costs of state and local governments with the exception of Kidwell et al. (1984), which examines how preferential tax treatment of within-state bond income lowers in-state bond yields. This paper contributes to the literature by analyzing the direct effects of tax advantages on the borrowing costs in the initial bond issuance, which distinguishes our results from the existing literature that studies transactions in secondary financial markets. Nonetheless, the existence of markups in our analysis is consistent with results in Green et al. (2007) that show that broker-dealers benefit from the losses of uninformed investors in secondary markets.

10. Liu and Denison (2014) discuss potential rents by high income individuals from the municipal bond exemption. Some highlights of this literature include Poterba (1989, 1986), as well as more recent papers that compare expenditures between tax-exempt bonds and Build America Bonds (Cestau et al., 2013; Ang et al., 2010a). We focus on the efficacy of the tax-exemption directly, instead of analyzing other mechanisms that may also lower municipal borrowing costs. Our paper is also related to papers that study the implications of removing the tax subsidy for municipal debt for individual portfolio substitution (Feenberg and Poterba, 1991; Poterba and Verdugo, 2011), and for changes in municipal spending (Gordon and Slemrod, 1983; Galper et al., 2014).

competition in auctions.[11] [12] In contrast, our paper analyzes a real-world policy that subsidizes the value of the auctioned good, which affects the set of all potential bidders, as well their entry and bidding decisions. In our study of the role that imperfect competition plays in dictating passthrough, our paper complements other work investigating related questions in different settings like electricity markets or import markets.[13] Subsidizing good valuations may be justified in other markets from a social welfare perspective and may be particularly important for the efficient provision of public goods.

The rest of the paper is organized as follows. We describe the institutional context and our data in Section 2. Section 3 describes reduced-form relationships between tax advantages, borrowing costs, and imperfect competition in auctions for municipal bonds. In Section 4, we develop an auction model for municipal debt with tax advantages. Section 5 describes the estimation procedure and results of this model, and Section 6 explores the mechanisms through which taxes influence municipal borrowing costs. We simulate the effects of policy counterfactuals in Section 7. Section 8 concludes.

2. Institutional details of municipal bond auctions, tax advantages, and data

In the U.S., municipal bonds are 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 currently surpasses $3.8 trillion, 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 municipal 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

. . .

11. 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.

12. 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), and Krasnokutskaya and Seim (2011). 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.

13. Fabra and Reguant (2014) analyze how emission costs pass through to electricity prices and Goldberg and Hellerstein (2008) study exchange rate passthrough.

place bids.[14] In practice, municipalities often sell a series of bonds in a single batch, and potential underwriters compete for the whole series at the same time by placing true interest cost bids. These interest costs correspond to the interest rate 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.[15]

2.2 Tax advantages of municipal debt

Interest income from most municipal debt is exempt from both federal corporate tax and federal personal income tax, as well as from many state-level taxes. The Revenue Act of 1913, which established a federal income tax in the U.S., explicitly stated that interest paid on state and local government debt could not be taxed by the federal government. This exemption was largely unchanged until the Tax Reform Act of 1986 limited the use of municipal debt to fund non-municipal projects — so-called "private activity" bonds.[16] The focus of this paper is on personal income taxes but we include controls for corporate tax rates in the empirical analysis.

As noted in the Introduction, the favorable tax treatment of municipal bonds has been a controversial policy issue for several years. Indeed, in the past few years there has been continued interest in changing the tax status of these bonds. For example, the Simpson-Bowles Commission on Fiscal Responsibility and Reform of 2010 sought, but failed, to eliminate the tax exemption on all interest from new municipal bonds. Afterwards, in each of its last four years, the Obama administration proposed, but did not achieve, a reduction in the tax advantage these bonds receive. However, state treasurers warn that eliminating or capping the exemption would "hurt taxpayers in every state, because municipalities will have to either curtail infrastructure projects or raise taxes on sales, property or income" (Ackerman, 2016). The TCJA17 includes policy changes that may increase the tax advantage of municipal bonds (by limiting the SALT deduction) as well as measures that would decrease the tax advantage (by cutting top personal income tax rates). We discuss proposed reforms in more detail in Appendix F, and we simulate the effects of some of these proposals in Section 7.

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

. . .

14. 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.

15. 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.

16. 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.

rate can be higher in states that do not have a personal income tax. The effective tax advantage in state s, at time t, is given by:[17]

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

Equation 1 contains two major sources of variation that we use to identify how tax rates affect borrowing costs for municipal debt. First, the effective tax rate depends on state tax rates and on whether states exclude interest income from taxation. Second, when federal rates change, as with the sunsetting of the Bush tax cuts in 2012, states with relatively higher tax rates will have marginally smaller changes in overall effective tax rates than states with no or low income taxes. Note, however, that most of the issuers in our data are municipalities that cannot directly influence the state tax rate.

From 2008 to 2015, many states increased their top marginal rates by introducing a new tax bracket with higher marginal rates for top incomes.[18] In addition, several states cut the top state income tax between 2011 and 2013. The large variation in federal rates happens at the end of 2012, when the federal top marginal rate increased from 35% to 39.6%. Overall, this time period presents significant variation in both state and federal tax rates. This allows our identification to be driven by within-state changes in the effective rate, avoiding cross-sectional comparisons of states with different tax rates. Our analysis exploits changes in both state and federal taxes as sources of variation, and we also show that our main result is robust to relying only on tax changes at the state level.

2.3 Data

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

Our analysis focuses on issuances of General Obligation bonds, which are not associated with a particular revenue source, that were issued between February 2008 and December 2015. Complete details of the sample construction are given in Appendix B.[19] Our final sample of 14,631 auctions for tax-exempt

. . .

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

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

19. Note that we focus exclusively on federally tax-exempt bonds, which are not subject to the Alternative Minimum Tax (AMT). In particular, we exclude private activity bonds, which may be subject to the AMT. Our sample does not include municipal debt issued as auction rate securities, as these types of bonds were not issued during our sample period. We exclude small issuances, as these bonds are overwhelmingly very short term and are commonly issued for the purpose of refunding as opposed to supporting public improvement projects, by focusing on bonds larger than $5 million, which covers over 90% of all the debt issued through competitive placements. As we discuss below, our results are robust to size-weighted specifications that include all bonds issued through competitive placement.

bonds 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 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:

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

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]

. . .

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.

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 use data from the NBER TAXSIM on maximum state income tax rates (Feenberg and Coutts, 1993).[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 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 (2008-2015) provides an annual report detailing state-level fiscal policies including balanced budget amendments and taxation and expenditure limitations. We use political party strength data from Caesar and Saldin (2006), as well as data on state sales tax rates, corporate tax rates and rules, and property tax rates gathered by Suárez Serrato and Zidar (2016). We collect data on overall financial market outcomes including the average short term yield on high quality, variable rate municipal debt from SIFMA (2017) and 1-year LIBOR swap rates from Board of Governors of the Federal Reserve System (2018) to control for daily market conditions and perceptions of interest rate risk.

3. Reduced-form effects of tax rates on borrowing costs and imperfect competition

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

. . .

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. We also calculate marginal tax rates at the 90th percentile household income using TAXSIM, which we use in a robustness check.

3.1 The effect of tax advantages on borrowing costs

We start by estimating regressions of the form:

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

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

Column (1) in the first panel of Table 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 0.010. 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. Columns (3) and (4) control for personal tax base policies, corporate tax rate and base policies, property tax rates, and state sales tax rates to allay the concern that changes in the effective rate are correlated with other tax policies that may be the true drivers of borrowing costs.[23] Column (5) controls for the size of the bond package and shows that the inclusion of this control has a negligible effect on the estimated coefficient. Our estimate of β is remarkably stable with a range of 6.5-7.0 basis points.

To gauge the magnitude of these coefficients, consider that at the mean borrowing rate of 2.14%, a 3 pp. increase in the effective rate would imply reductions in borrowing costs between 9.2-9.8%. Since state and municipal governments spent $124 billion on interest payments in 2014, these estimates would imply cost reductions of $11.4-12.2 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.[24] Given a median effective tax of 40.8% and a median winning bid of 221 basis points,

. . .

23. The business and property tax policies include the state corporate tax rate, business tax apportionment rules, and a measure of the average property tax rate in the state from Suárez Serrato and Zidar (2016). We include 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, whether own- or other-state municipal bond income is excluded from taxation. We considered controlling for other institutional variables such as budget balance amendments and debt limits as in Poterba and Rueben (2002). However, no states changed these policies in our sample period, so these variables would be absorbed by the state fixed effects.

24. As is common in the public finance literature, we study the net-of-tax rate elasticity. As is well known, for small values of τ this elasticity is better behaved than the tax elasticity. In addition, the literature comparing corporate to municipal bonds also focuses on the effects of the net-of-tax rate.

these estimates imply passthrough elasticities between 1.7-1.9. The estimated elasticities in columns (2)-(5) reject the hypothesis of a passthrough elasticity below unity at the 10% level.

3.2 The effect of tax advantages on auction participation

We now explore the interaction between tax policy and participation in auctions. First, we estimate 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. This is a large effect as it would move an auction from the median to the 75th percentile of the distribution of potential bidders. These estimates are also stable across specifications, and Table A.6 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 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.[25] Comparing the results from the first and third panels of Table 2, we find that between 23% and 31% of the coefficient in the first panel is due to auction competitiveness, which suggest that the effect of taxes on bidders' participation decisions are an important determinant of borrowing costs.[26] 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.

3.3 Robustness and causal identification

This section provides evidence that the reduced-form effects from Sections 3.1 and 3.2 are driven by state tax changes that are plausibly exogenous from other drivers of municipal borrowing costs. We first discuss how an omitted variable might affect our results. We show that potential confounders, such as budget or rating shocks, would bias our estimates in the direction of finding a null effect. We then show in Section 3.3.1 that our estimates are robust to controlling for a battery of potential confounders. Finally, in Section 3.3.2 we exploit the panel nature of our data to show that the timing of tax changes lines-up with changes in borrowing costs, and we provide a placebo test that shows that future tax changes are not predictive of borrowing costs.

. . .

25. 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.

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

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

$$bias = \frac{Cov(Z_{st}, \tau_{st})}{Var(\tau_{st})} \frac{Cov(Z_{st}, b1_{ist})}{Var(b1_{ist})}$$

Since investors would demand a higher interest rate following a negative economic, budget, or rating shock, we would expect $Cov(Z_{st}, b1_{ist}) > 0$, if Z_{st} is one of these events. In order for the omission of Z_{st} to bias our estimates in any direction, states would need to respond to these shocks by changing tax rates, i.e. $Cov(Z_{st}, \tau_{st}) \neq 0$. This is an unlikely source of bias since most of the bonds in our dataset are issued by school districts, cities, and counties who do not set state tax rates, and it is unlikely that states will adjust state taxes in response to a shock to a local government.

Moreover, the existing literature on how states respond to fiscal pressure shows that states generally increase taxes when facing state budget shortfalls, so that, if anything, $Cov(Z_{st}, \tau_{st}) > 0$. For instance, Poterba (1994) describes how many states have policies in place that forbid extended periods of deficit spending, which can force states with unexpected negative fiscal shocks to raise taxes, in which case the bias would be positive.[27] This discussion shows that the most likely potential confounders would bias our estimates toward zero, and against finding a negative effect of taxes on borrowing rates.

3.3.1 Controlling for potential confounders

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

The estimated effects of tax rates on the winning bid after controlling for the bidder, issuer, and economic characteristics are in the range between -6.1 and -7.2, with the lowest and highest estimates both coming from specifications with issuer fixed effects. These results are remarkably robust across these

. . .

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

specifications, which suggests that the exclusion restriction is likely to hold. We formalize this evidence of coefficient stability by using the methods proposed by Altonji et al. (2005) and Oster (2017). Appendix C.5 discusses the results in Table A.9, which suggest that it is extremely unlikely that our main effects are driven by selection on unobservables. The effect on the number of potential bidders is also stable, with effects between 0.54 and 0.64 with the additional controls.

We use Table 4 to explore additional potential threats to identification, as well as potential biases due to variable measurement. One potential concern is that changes in the top marginal tax rate coincide with market trends in borrowing costs that are not captured by year fixed effects. Columns (2) and (3) of Table 4 expand our baseline specification by including controls for interest rate risk and whether the bond is callable. Column (2) includes the swap rate between the 3-month and 1-year the London Inter Bank Offering Rate (LIBOR), which is a strong proxy for bond market uncertainty (Board of Governors of the Federal Reserve System, 2018), as well as the Securities Industry and Financial Markets Association (SIFMA) 7-day variable rate demand obligation yield for municipal debt (SIFMA, 2017), which proxies for market conditions in the municipal bond market. Both of these measures track market conditions at a high frequency, given that bond market conditions may vary widely within a given year. In Column (2), we estimate an effect of -6.347, which is very close to our baseline specification from Table 2 included in Column (1). In addition, in Column (3), we add a dummy variable for whether a bond is callable or not, as well as fixed effects for the number of years until the first call date. These additional controls result in a coefficient equal to -6.721, which also lies in the range of the estimates in Table 2.

As discussed in Section 2.3, our measure of effective rates uses the top marginal tax rate in a given state. This is a reasonable measure since high income individuals are the primary holders of municipal debt. Moreover, the effects of this variable are of policy interest since the top marginal tax rate is a policy lever that states can change. However, since the marginal buyer of municipal bonds may not be in the top income tax bracket, we now show that our results are also robust to using an alternative measure of the effective tax rate. In Column (4) of Table 4, we re-estimate our baseline model using a measure of the effective tax rate for the 90th percentile of household income. This specification results in an estimated effect of -6.394, which is very similar to our baseline estimate.[28]

3.3.2 Panel data and event study analyses

We now exploit the panel dimension of our data to explore the identifying variation in the effective tax rate. We start by showing that most of the variation is driven by sub-state agencies that cannot affect the tax advantage for their bonds. Column (5) of Table 4 reproduces our preferred reduced-form estimates but excludes all entities that have the ability to change tax rates (states and state agencies) from the sample. The resulting estimates are nearly identical to those from the regression including entities that have control over their own tax rates. This result shows that our main estimate is not driven by reverse causality, where states may change tax rates to influence their borrowing costs. In Appendix C, we provide

. . .

28. Appendix C discusses additional robustness checks. In Table A.5 we show that the standard errors for our estimates are not overly sensitive to the clustering level. This table also shows that our results are robust to the inclusion of monthly, and even daily, fixed effects, which assuage concerns that our results are driven by the financial crisis, when large macroeconomic shocks were happening with greater than annual frequency. Finally, this table shows that our results are not sensitive to including small bonds, which we exclude from our main specification since they are systematically different from larger bonds that fund public improvement projects, and since they make up a small fraction of the total value of all issuances.

further evidence against the reverse causality hypothesis by showing that state tax rates are unaffected by previous, current, and future state interest payments.

We now show that changes in state tax rates are an important source of variation in our data. Column (6) of Table 4 shows that our results are robust to dropping observations from the five states that do not exempt interest income from state taxation. In column (7) of Table 4 we show estimates of Equation 2 using only variation in state tax rates. For this specification, effective rates are defined according to Equation 1 except that the federal tax rate is held constant at its 2008 level for all later years. The estimated coefficient using only state variation in taxes is -5.5, which is not statistically distinguishable from the preferred estimates. This result gives evidence that the most important identification assumptions involve state tax changes.

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

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

where the state fixed effect are absorbed in the difference. We restrict the sample of issuers to those with issues in at least three sets of consecutive years in 2008-2015, which leaves us with 4,692 issuer-year observations. 48% of the issuer-years in this sample have an associated tax change. We display estimates of the first differences regression using year fixed effects, quality controls, refund controls, maturity controls, political controls, other state policy controls, and size controls in panel (a) of Figure 2. The estimate of β is -9.73 with a standard error of 2.59, which allows us to reject the hypothesis of a null effect with a p-value of 0.001.

We now show that the timing of the change in borrowing costs lines up with the change in taxes. In panel (b) of Figure 2 we present a placebo test by replacing $\Delta \tau_{st}$ with $\Delta \tau_{st+1}$ so that the tax changes happen in the future. We estimate a placebo coefficient equal to 1.07 with a standard error 2.76 and fail to reject a null effect in the placebo test with a p-value of 0.701. This shows that municipalities experience a reduction in borrowing costs immediately after the change in taxes, and that borrowing costs do not predict tax changes. We provide further evidence that municipalities in states that changed taxes were not experiencing a secular decline in borrowing costs by estimating an event study of the form:

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

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

The reduced-form results presented in this section have some immediate implications. First, the results on borrowing costs suggest that the tax advantage plays a major role in determining municipalities' borrowing costs, and that removing the exclusion of municipal bond income from taxation may significantly affect this market. Second, understanding how tax advantages interact with entry into auctions is crucial to a full understanding of the passthrough of tax advantages into borrowing costs.

4. Model of participation and bidding in municipal bond auctions

In this section we present a model of participation and bidding in municipal bond auctions. Motivated by the reduced-form facts in the previous section, the model aims to capture 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. Capturing these margins is important to measure equilibrium markups in each auction (Section 5), to understand how the effects of taxes on winning bids depends on changes in markups (Section 6), and in order to analyze counterfactual changes to tax policy (Section 7). Our modeling approach most closely resembles that of Li and Zheng (2009).[29]

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 $[\underline{v}, \bar{v}]$. 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 $[\underline{d}, \bar{d}]$. We interpret these costs as including the cost of researching the bond for sale, as well as the potential for resale opportunities in the secondary market, which can reasonably vary across bidders. Section 5 describes how we take this model to the data, where we allow the model primitives to depend on bond characteristics, including τ. For simplicity, we omit this dependence in the description of the model in this section.

The informational assumptions of the model are as follows. 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, as bidders in municipal bond auctions do not observe the number of

. . .

29. Appendix D provides additional details behind the model derivation.

other competing bidders, which we denote n.[30] We assume conditionally independent private values, similar to other recent work on auctions for financial products (e.g., Hortaçsu et al. (2018)).[31]

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.

4.1 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:

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

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

$$\boldsymbol{Pr}^*[n=k] = C_{N-1}^{k-1}(p^*)^{k-1}(1-p^*)^{N-k}, \quad (3)$$

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

. . .

30. Even though bidders in municipal bond auctions do not observe the number of other actual bidders, since the set of firms that bid in these auctions is relatively stable over time, and typically consists of local branches of large banks, we assume they know the number of potential entrants, N . Additionally, since 2005, information on every secondary market transaction for municipal bonds is made available online, and so it is reasonable to assume that auction participants stay at least partially informed of their competitors' activities, which is also informative of N , even if, in any particular auction, they don't know n.

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

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 condtion of the above maximization problem is:

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

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:

$$\begin{aligned} \beta(v) &= v + \frac{\sum_{k=1}^{N} \boldsymbol{Pr}^*[n = k] \int_v^{\overline{v}} (1 = F(q)))^{\max(k-1,1)} dq}{\sum_{k=1}^{N} \boldsymbol{Pr}^*[n = k]\big(1 - F(v)\big)^{\max(k-1.1)}} \qquad (4) \\ &= v + \mu(v), \end{aligned}$$

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

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

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

$$\frac{1}{b_i - v_i} = \frac{\sum_{k=1}^{N} \boldsymbol{Pr}^*[n = k](k-1)g(b_i)(1 - G(b_i))^{\max(k-2,0)}}{\sum_{k=1}^{N} \boldsymbol{Pr}^* [n = k](1 - G(b_i))^{\max(k-1,1)}}. \qquad (5)$$

4.2 Entry

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

$$E\pi\big(v_i \big| p^*(d^*)\big) = d^*, \qquad (6)$$

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

4.3 Tax advantage elasticity

In our empirical application, the distribution of values and, consequently, markups and bids depends on the tax rate τ. Noting the dependence on τ, Equation 4 then becomes:

$$b(\tau) = v(\tau) + \mu(\tau).$$

For instance, a change in the tax advantage $(1 - \tau)$ could signal to a bank that the individual investors' demand for the bond will change, so that $v(\tau)$ may be affected. Moreover, the strategic considerations in the optimal bidding function and zero profit conditions (Equations 4 and 6) may also impact equilibrium information rents, leading to a change in $\mu(\tau)$.

The expression above provides a simple way to decompose the elasticity of a bidder's bid with respect to the tax advantage, $1-\tau$:

$$\frac{\partial b}{\partial(1-\tau)}\frac{(1-\tau)}{b}=\frac{\partial v}{\partial(1-\tau)}\frac{(1-\tau)}{b}+\frac{\partial \mu}{\partial(1-\tau)}\frac{(1-\tau)}{b}$$

or,

$$\varepsilon^{b}_{1-\tau}=(1-m)\varepsilon^{v}_{1-\tau}+m\varepsilon^{\mu}_{1-\tau}, \quad (7)$$

where m is the markup rate μ/b, and ε are elasticities of the model variables in $1-\tau$. This expression allows us to relate the model to the reduced-form results in Section 3, and to decompose the tax advantage elasticity of bids into the effects on values and markups, which we do in Section 6.

5. Structural estimation and implied markups

We now outline the estimation of the model, discuss estimation results, and describe the estimated equilibrium markups. To take the model 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 is observable to the bidders but not the econometrician, and $\tilde{v}_{ij}$ are i.i.d. for each bidder i.[32] 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.

5.1 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).[33]

We parametrize the model as follows:

. . .

32. 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.

33. 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.

$$\text{Bid Distribution: } g(\tilde{b};\theta_{\tilde{b}}) = \overline{\mathcal{N}}(X_j\beta, e^{X_j\gamma}, X_j\delta, \infty)$$

$$\text{Entry Cost Distribution: } h(d_j;\theta_d) = ln\mathcal{N}(k_1, k_2)$$

$$\text{Unobservable Heterogeneity Distribution: } f_U(u;\theta_U) = \mathcal{N}(Z_j\Gamma, \sigma_U)$$

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,[34] $ln\mathcal{N}(c, d)$ 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.[35]

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:

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

where $g\left(b_1, \ldots, b_{n_j}; \theta\right)$ 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 5, define the expected profits of submitting bid $\tilde{b}$ for any given probability of entry p as

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

with $\boldsymbol{Pr}^*[n = k]$ defined in Equation 3. 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 6.[36] After maximizing Equation 8 to recover estimates $\hat{\theta}$, we recover the implied value v_{ij} corresponding to each bid b_{ij} using Equation 5.

. . .

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

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

36. To determine the unique solution to Equation 6 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.

We note that our model is nested within the framework of Gentry and Li (2014), who study nonparametric 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 adopt a parametric estimation approach, which allows us to include an extensive set of covariates in the model.

5.2 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.[37] The standard deviation is parameterized as the exponential of a linear function of the number of potential bidders, the maturity of the bond, and the effective rate. The lower threshold of the distribution of bids is parametrized as a linear function of the same observables.

Estimation results for the baseline model are reported in Table 5. 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.[38] 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, which may affect equilibrium markups.

The estimated model fits the data well. Figure 4 shows that the model fits the entire distribution of winner's bids across the sample.[39] We also match entry rates, n/N , well. For example, the average (median) probability of entry in the data is 0.701 (0.714), and our model predicts it to be 0.728 (0.728).

We use the model estimates to simulate entry costs and bidder markups. 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 with the costs of engaging in pre-sale marketing activities, as well as performing due diligence on the particular bond offering. Table 6 presents our model's estimates of bidder markups. The first row in Table 6 shows that markups are 16.8 basis

. . .

37. 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.

38. 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.

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

points, on average. Relative to the winning bid, m_1/b_1, the average markup rate is 17.4%. Table 6 also reports the dollar value of the markup over the life of the bond, m_1st, with an average value of $173,476.[40]

Our model predicts rich patterns of heterogeneity in markups. The remaining rows in Table 6 show that auctions for state bonds result in smaller markups, both in levels and as a percent of borrowing costs. However, since state bonds are larger and have longer durations, the dollar value over the life of the bond is greater than average. We also find that bonds for school districts and smaller jurisdictions, such as cities and counties, have significantly larger markups. In particular, bonds issued by local governments are hurt in part by less participation. On average, about five bidders submit bids for bonds issued by cities, towns, and villages, whereas more than eight typically submit bids for bonds issued by states. This suggests that there is substantial scope for lowering municipalities' borrowing costs by targeting auctions with high markup rates, or with low participation.[41]

Figure 5 shows how markups vary with the effective rate and the number of potential bidders. As expected, we find larger markups in auctions with low numbers of potential bidders, and we find that 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, which is consistent with the results across issuer types discussed above.

We illustrate the robustness of our results to alternative models that allow for different parameterizations, flexible effects of covariates, and different definitions of potential bidders. Appendix E discusses these models, and Table A.12 shows that we obtain good model fit, and similar estimated markups, across these alternative specifications.

6. Tax incidence in auctions

In this section we explore in more depth the mechanisms by which the tax exemption for municipal debt affects bidder behavior, and consequently, borrowing costs. Our analysis characterizes the within-auction incidence assuming that the supply of bonds is not affected by changes in tax advantages. In the appendices we provide empirical support for this assumption, which is also in line with other findings in the literature, as well as the institutional features of this market.[42] Equation 7 shows the basic intuition behind the effects that tax rates have the borrowing costs. First, if there is perfect competition, $m = 0$ and

. . .

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

41. In ongoing work (Garrett et al., 2018), we are exploring in greater detail the heterogeneity across auctions, and dynamics over time, of markups in municipal bond auctions.

42. For instance, Adelino et al. (2017) find that municipalities do not react to rating changes by borrowing more often, and Gordon and Metcalf (1991) discuss that municipalities do not invest more with lower interest rates caused by the tax exemption in part due to caps on tax-exempt borrowing. This assumption is consistent with the institutional setting, since many of these bonds are authorized by popular referenda or by public budgeting processes that limit municipalities' ability to respond by changing the size of the issuance or by issuing additional bonds. We provide empirical evidence for this assumption by showing in column (5) of Table 2 that controlling for the size of the issuance does not affect our reduced-form results, and by showing in Appendix C.3 that there is not a meaningful response in the supply of issuances to changes in τ .

$\varepsilon^b_{1-\tau} = \varepsilon^v_{1-\tau}$. Second, when $m > 0$, $\varepsilon^b_{1-\tau}$ may be greater than or less than one depending on the effect of changing taxes on markups and bidder values. For example, if $\varepsilon^v_{1-\tau} = 1$ then if $\varepsilon^b_{1-\tau} > 1$, it must be the case that $\varepsilon^\mu_{1-\tau} > 1$.[43] This points to the central role played by the responsiveness of markups to changes in taxes in determining how taxes pass through to borrowing costs.

The following example, shown in Table 7, decomposes this passthrough using our model and a representative auction from our data. Consider an auction with six potential bidders, $\tau = 0.35$, other observables set to their median realizations, and a bidder whose value is such that, according to our estimated model, he would submit a bid equal to the median bid in our data for auctions with these characteristics. At the original tax rate, the bidder has a value of 1.621 and an optimal bid of 1.896, which implies a markup rate of 15%. If τ increases from 0.35 to 0.39, his bid will change for a variety of reasons. First, his value will change, which will lead him to submit a lower bid, even when holding constant his probability of winning and the number of potential entrants in the auction. This is illustrated in the second row of the table, which shows that the optimal bid decreases from 1.90 to 1.83 ($\varepsilon^b_{1-\tau} = 0.567$), when the value drops from 1.62 to 1.52 ($\varepsilon^v_{1-\tau} = 1.002$). Second, because other bidders' values change, the bidder's probability of winning changes, which forces him to further lower his bid. This is shown in the third row of the table, where we adjust the probability of winning to reflect the model estimated winning probability at the new tax rate and original number of potential bidders. The optimal bid falls to 1.76, which implies a bid elasticity of 1.16. Finally, the four percentage point effective tax rate increase is associated with two more underwriters joining the pool of potential bidders (see Table 2). The increase in competition for the bond, captured by our further adjustment of the probability of winning to reflect the model estimated winning probability at the new tax rate and the new number of potential bidders, further depresses the bidder's bid to 1.69, for a bid elasticity of 1.75. The importance of markups for generating greater-than-one passthrough of taxes to bids is evident in the final column of the table. In row three, when all but the effect of τ on N is allowed for, $\varepsilon^\mu_{1-\tau} = 2.07$. Once N is allowed to increase in τ, $\varepsilon^\mu_{1-\tau} = 6.15$.

This example is representative of the rest of our data, in which the average markup rate is 17% (compared to 15% in the example). According to our model estimates, the average elasticity of bid with respect to take-home rate in the sample is 2.09, which is comparable to the bid elasticity shown in row four of Table 7 equal to 1.75, and to our reduced-form estimates in Table 2. The average elasticity of markups with respect to take-home rate in our sample is 4.93, which also closely mirrors the example's value of 6.15.

The example in Table 7 also illustrates that as the tax rate increases, bidder markups decrease, from 0.28 in row one, to 0.17 in row four, and it is the large decline in these markups that leads to greater-than-one pass through to borrowing rates. We now explore how taxes impact markups and provide non-parametric evidence that these mechanisms are at play in the data. As made clear in Equation 4, a bidder trades off the benefit of increasing their bid and enjoying a greater markup over their value in the event they win the auction, against the possibility that they lose the auction with this higher bid. In particular, denoting the dependence of values, and thus the probability of winning an auction, on the tax rate,

. . .

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

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

where $\mathbf{P}r(v;\tau)$ is the equilibrium probability of winning the auction when a bidder's value is v and the tax rate is τ. The markup, or difference between a bidder's bid and the value, depends on the expected market share, given by $\mathbf{P}r$ and the slope of the inverse supply, given by $-\frac{\partial}{\partial b}\mathbf{P}\mathrm{r}$. 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.[44] The fundamental expression of market power in this case is the ability of bidders to improve their expected surplus by shading their bid, which is controlled by the slope of the inverse supply.

Therefore, the question of how taxes affect markups, and consequently the cost of borrowing via Equation 7, hinges on how taxes affect the probability associated with a bidder winning an auction at any particular submitted bid. Specifically, the elasticity of markups with respect to taxes can be decomposed as follows:

$$\varepsilon_{1-\tau}^{\mu} = \underbrace{\varepsilon_{1-\tau}^{\mathbf{P}\mathrm{r}}}_{\text{change in own market share}} + \underbrace{\varepsilon_{1-\tau}^{-1/\frac{\partial}{\partial b}\mathbf{P}\mathrm{r}}}_{\text{change in inverse supply slope}}. \qquad (9)$$

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 $\varepsilon_{1-\tau}^{-1/\frac{\partial}{\partial b}\mathbf{P}\mathrm{r}}$ 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 $\varepsilon_{1-\tau}^{-1/\frac{\partial}{\partial b}\mathbf{P}\mathrm{r}}$. This is consistent with results from Babina et al. (2015), who show that there is a higher degree of tax-induced ownership segmentation in states with a larger tax advantage for municipal bonds. Intuitively, since only residents of the issuing state receive the full tax benefit, as the state tax rate increases, it is more likely that residents of the state own the bonds, and that the distribution of their valuations is more compressed. This is also consistent with

. . .

44. 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.

our structural estimates in Section 5.2, where we find that an increase in τ is associated with a smaller variance of the distribution of bids.

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

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

where j is an indicator for each auction, and $\mathbf{1}\left(b_j > b\right)$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 6 plots this estimated probability for different values of N and τ . The fundamental expression of market power in our setting is the ability of bidders to trade-off higher surplus for a smaller expected market share. The data reveal whether bidders may profit from such strategic bidding by showing that the probability of winning has a finite slope around the winning bid. The blue solid lines correspond to estimated probabilities of winning for the mean value of $\tau = 0.35$ and for $N = 4, 6, 8, 10$. These lines show that auctions for municipal bonds are far from the ideal of perfect competition as the finite slope allows 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 6 show that the intuition from the example in Table 7 is apparent in the raw bidding data. For each value of N , the red dashed line plots the estimated probability of winning with a higher $\tau = 0.39$. These plots show that auctions with larger tax advantages 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 above, higher effective rates also lead to increases in N . In particular, a reform that increases τ from 0.35 to 0.39 would also lead the average N to increase by about two additional potential bidders. The green dotted lines plot the probability of winning with a higher rate and the accompanying increase in N . Highlighting the intuition from the representative bidder above, these graphs show that the scope for markups is further reduced by the indirect effect of the tax advantage on the level of competition.

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

7. 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 F. 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 Tax Cut and Jobs Act of 2017 (TCJA17) which lowers the top federal rate to 37% and limits the deduction for state and local taxes (SALT), 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:[45]

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

Relative to the average federal rate from 2011 to 2015, eliminating the federal exemption corresponds to $\alpha = 0$; the Obama proposal corresponds to $\alpha = 0.73 \approx 0.28/0.386$; and the TCJA17 sets $\alpha = 0.96 \approx 0.37/0.386$. We can also consider the effect of a *super exemption* of municipal bond interest by evaluating reforms that set $\alpha > 1$. Additionally, we use the model to evaluate the impact of other policies such as removing the state exemption of municipal bond interest income from state taxation (for those states that currently allow it), and to consider the elimination of the deduction for state and local taxes (SALT). Finally, we study the total effect of the TCJA17, as the decrease in marginal rates and limiting of SALT affect borrowing costs in opposite directions.

We begin by focusing on changes to the federal tax code that limit or expand the exemption of municipal bond interest income from federal taxation. 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 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

. . .

45. 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.

over the next decade would be close to \$135 billion (≈ (1 − 0.73) × \$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.[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 few 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 three additional tax policy analyses. First, we consider the effects of completely eliminating the excludability of municipal bond interest income at the federal level; that is, setting $\alpha = 0$. While this policy represents a level of variation that is outside of our sample, our model implies that moving to a full repeal of the exemption would result in significantly larger borrowing rates with an average of 3.64%, of= which 43% ($\approx \frac{1.58\%}{3.64\%}$) would correspond to markups. Figures A.6-A.7 showcase the large and heterogeneous effects from this policy. Second, Figures A.8-A.9 simulate the effects of eliminating the state exemption. While eliminating the state exemption leads to an increase in the

. . .

46. 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, which is in line with the existing the results from this and other papers. 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 35.40% $\left(\approx \frac{10.37\% \times 6.53}{1.91}\right)$ and imply a ratio of 3.25 $\left(\approx \frac{35.40\% \times 124}{13.5}\right)$.

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

importance of the federal subsidy, this potential reform results in an overall decrease in the subsidy. As expected, we find that states with higher taxes would see larger increases in borrowing costs. As shown in Table 8, average borrowing costs would rise nearly 16%, and markups would nearly double, if this policy were enacted.

Lastly, we investigate the effects of policy changes motivated by the TCJA17. We find that eliminating the SALT deduction results in higher effective rates, which are then accompanied by lower markups and borrowing rates. Table 8 shows that, on average, our model predicts that borrowing costs would fall by over 6%. Figures A.10-A.11 show that this decrease would be concentrated in states with higher taxes, as these states are the biggest beneficiaries of the SALT deduction. While the lower tax rates in the TCJA17 would increase borrowing costs for municipalities, changes to the SALT deduction would dominate this effect. Overall, our model estimates suggest that the TCJA17 will lead to a 2.5% reduction in borrowing costs, and a 9.5% reduction in markups.

In Tables A.13-A.17, we show that all of these counterfactual policy analyses are robust across different versions of our structural model.

8. Conclusions

The excludability of municipal interest income from taxation is one of the largest tax expenditures faced by the U.S. Treasury. Advocates of this policy argue that the tax advantage of municipal bonds is crucial to lowering the borrowing rates of municipal governments, who use these funds to finance public goods, services, 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, our reduced-form estimates show 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 use an empirical auction model to provide three insights into how taxes affect auctions for municipal bonds. First, we use the model to quantify equilibrium markups. The estimated markups are larger for smaller jurisdictions, school districts, and in auctions with few bidders, which suggests there is substantial scope for reducing the borrowing cost of municipalities by targeting those with high markups. Second, we show that the passthrough of taxes to borrowing costs is driven by the interaction between tax policy and imperfect competition, and, in particular, by the effects of taxes on markups. We provide non-parametric evidence that, as the tax advantage for municipal bonds increases, bidders are less able to extract information rents in the form of markups. This effect is responsible for the greater-than-unity passthrough elasticity we find in our reduced-form analysis.

Finally, we use the model to simulate the effects of policy proposals from the Obama and Trump administrations, and to evaluate how different components of the Tax Cuts and Jobs Act of 2017 will affect municipal borrowing costs. We find that reductions in the tax advantage for municipal bonds translate to substantial increases in both borrowing rates and markups. The 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. While different provisions in the Tax Cuts and Jobs Act of 2017 may serve to raise or lower borrowing costs, we find that, overall, the legislation may result in small reductions in borrowing costs.

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 for these bonds in the primary market.

REFERENCES

Ackerman, Andrew, "Hundreds of Local Officials Defend Municipal Bond Tax Exemption," *The Wall Street Journal*, 2016. Available at: http://www.wsj.com/articles/ hundreds-of-local-officials-defend-municipal-bond-tax-exemption-1456830002 (Accessed: March 24, 2017).

Adelino, Manuel, Igor Cunha, and Miguel A Ferreira, "The Economic Effects of Public Financing: Evidence from Municipal Bond Ratings Recalibration," *Review of Financial Studies*, 2017, 9 (30), 3223– 3268.

Alan, Cole, "Details and Analysis of Donald Trump's Tax Plan, September 2016," Tax Foundation, 2016. Available at: https://taxfoundation.org/details-analysis-donald-trump-tax-plan-2016/ (Accessed: March 26, 2017).

Altonji, Joseph G., Todd E. Elder, and Christopher R. Taber, "Selection on Observed and Unobserved Variables: Assessing the Effectiveness of Catholic Schools," *Journal of Political Economy*, 2005, 113 (1), 151–184.

Anderson, Tom, "How Trump's proposals may affect every income tax bracket," *CNBC*, 2017. Available at: http://www.cnbc.com/2017/01/22/how-trumps-proposals-may-affect-every-income-tax-bracket.html (Accessed: March 25, 2017).

Ang, Andrew, Richard C. Green, and Yuhang Xing, "Advance Refundings of Municipal Bonds," Working Paper 19459, National Bureau of Economic Research, September 2013.

_, Vineer Bhansali, and Yuhang Xing, "Build America Bonds," Working Paper 16008, National Bureau of Economic Research May 2010.

_, _, and_, "Taxes on Tax-Exempt Bonds," *The Journal of Finance*, 2010, 65 (2), 565–601.

Athey, Susan, Dominic Coey, and Jonathan Levin, "Set-Asides and Subsides in Auctions," *AEJ Microeconomics*, 2013, 5 (1), 1–27.

_, Jonathan Levin, and Enrique Seira, "Comparing Open and Sealed Bid Auctions: Theory and Evidence from Timber Auctions," *Quarterly Journal of Economics*, 2011, 126 (1), 207–257.

Auerbach, Alan J. and James R. Hines, "Perfect Taxation with Imperfect Competition," Working Paper 8138, National Bureau of Economic Research February 2011.

Babina, Tania, Chotibhak Jotikasthira, Christian T. Lundblad, and Tarun Ramadorai, "Heterogenous Taxes and Limited Risk Sharing: Evidence from Municipal Bonds," Technical Report 2015. CEPR Discussion Paper No. DP10971. Available at SSRN: https://ssrn.com/abstract=2701245 (Accessed: April 4, 2017).

Bhattacharya, Vivek, "An Empirical Model of R&D Procurement Contests: An Analysis of the DOD SBIR Program," *Working Paper*, 2017.

_, James W. Roberts, and Andrew Sweeting, "Regulating Bidder Participation in Auctions," *RAND Journal of Economics*, 2014, 45 (4), 675–704.

Board of Governors of the Federal Reserve System, "1-Year Swap Rate (DISCONTINUED) [DSWP1]," FRED, Federal Reserve Bank of St. Louis 2018. Available at: https://fred.stlouisfed. org/series/DSWP1 (Accessed: April 18, 2018).

Brancaccio, Giulia, Dan Li, and Norman Schu¨rhoff, "Learning by Trading: The Case of the U.S. Market for Municipal Bonds," Working Paper 2017.

Bulow, Jeremy and Paul Klemperer, "Auctions Versus Negotiations," American Economic Review, 1996, 86 (1), 180–194.

Bureau of Economic Analysis, "Annual Gross Domestic Product (GDP) by State," 2017. Available at: https://www.bea.gov/regional/downloadzip.cfm (Data Accessed: April 26, 2017).

Bureau of Labor Statistics, "Local Area Unemployment Statistics," 2017. Available at: https://www. bls.gov/lau/ (Data Accessed: April 26, 2017).

Butler, Alexander R, "Distance Still Matters: Evidence from Municipal Bond Underwriting," *Review of Financial Studies*, 2008, 21 (2), 763–784.

Caesar, James W and Robert P. Saldin, "A New Measure of Party Strength," *Political Research Quarterly*, 2006, 58 (2), 245–256.

Cassola, Nuno, Ali Horta¸csu, and Jakub Kastl, "The 2007 Subprime Market Crisis Through the Lens of European Central Bank Auctions for Short-Term Funds," *Econometrica*, 2013, 81 (4), 1309–1345.

CCH, *State Tax Handbook 2008-2015*. CCH Incorporated State Tax Handbook, Toolkit Media Group, 2008-2015.

Cellini, Stephanie Riegg, Fernando Ferreira, and Jesse Rothstein, "The Value of School Facility Investments: Evidence from a Dynamic Regression Discontinuity Design," *Quarterly Journal of Economics*, 2010, 125 (1), 215–261.

Census Bureau, "State and Local Government Finance Historical Data," 1994-2014. Available at: https://www.census.gov/govs/local/historical_data.html (Data Accessed: April 26, 2017).

Cestau, Dario, Richard C. Green, and Norman Schürhoff, "Tax–Subsidized Underpricing: the Market for Build America Bonds," *Journal of Monetary Economics*, 2013, 60 (5), 593–608.

Conlon, Christopher T. and Nirupama Rao, "The Price of Liquor is Too Damn High: Alcohol Taxation and Market Structure," Technical Report 2015. Available at SSRN: https://ssrn.com/abstract= 2610118 or http://dx.doi.org/10.2139/ssrn.2610118 (Accessed: March 24, 2017).

_ and _, "Discrete Prices and the Incidence and Efficiency of Excise Taxes," Technical Report 2016. Available at SSRN: https://ssrn.com/abstract=2813016 or http://dx.doi.org/10.2139/ssrn.2813016 (Accessed: March 23, 2017).

Crowder, William J. and Mark E. Wohar, "Are Tax Effects Important in the Long–Run Fisher Relationship? Evidence from the Municipal Bond Market," *The Journal of Finance*, 1999, 54 (1), 307– 317.

De Silva, Dakshina, Timothy P. Hubbard, and Georgia Kosmopoulou, "An Evaluation of a Bidder Training Program," Working Paper, 2017.

Fabinger, Michal and Glen Weyl, "Pass-Through as an Economic Tool: Principles of Incidence under Imperfect Competition," *Journal of Political Economy*, 2013, 121 (3), 528–583.

Fabra, Natalia and Mar Reguant, "Pass-Through of Emissions Costs in Electricity Markets," *American Economic Review*, 2014, 104 (9), 2872–2899.

Feenberg, Daniel and James M. Poterba, "Which Households Own Municipal Bonds? Evidence from Tax Returns," *National Tax Journal*, 1991, 44 (4), 93–103.

Feenberg, Daniel Richard and Elizabeth Coutts, "An Introduction to the TAXSIM Model," *Journal of Policy Analysis and Management*, 1993, 12(1), 189–194. http://users.nber.org/~taxsim/state-rates/ (Data Accessed: March 21, 2017).

Fortune, Peter, "The Municipal Bond Market, Part 1: Politics, Taxes, and Yields," *New England Economic Review*, September 1991, pp. 13–36.

Galper, Harvey, Kim S. Rueben, Richard Auxier, and Amanda Eng, "Municipal Debt: What does it Buy and Who Benefits?," *National Tax Journal*, 2014, 67 (4), 901–924.

Garrett, Daniel, Andrey Ordin, James W. Roberts, and Juan Carlos Suárez Serrato, "Measuring Markups for Muni Bonds: Shedding Light on an Opaque Market," Working Paper, Duke University 2018.

Gentry, Matthew and Tong Li, "Identification in Auctions with Selective Entry," *Econometrica*, 2014, 82 (1), 315–344.

Gibbons, Charles E., Juan Carlos Suárez Serrato, and Michael B. Urbancic, "Broken or Fixed Effects?," Working Paper 20342, *National Bureau of Economic Research* July 2014.

Goldberg, Pinelopi Koujianou and Rebecca Hellerstein, "A Structural Approach to Explaining Incomplete Exchange-Rate Pass-Through and Pricing-to-Market," *American Economic Review*, 2008, 98 (2), 423–429.

Gordon, Roger H., "An Optimal Taxation Approach to Fiscal Federalism," *The Quarterly Journal of Economics*, 1983, 98 (4), 567–586.

_ and, Gilbert E. Metcalf, "Do Tax-Exempt Bonds Really Subsidize Municipal Capital?," *National Tax Journal*, 1991, 44 (4), 71–79.

_ and Joel Slemrod, "A General Equilibrium Simulation Study of Subsidies to Municipal Expenditures," *Journal of Finance*, 1983, 38 (2), 585–594.

Gordon, Tracy, "Buy and Hold (on Tight): The Recent Muni Bond Rollercoaster and What It Means for Cities," Washington, DC: Urabn Institute 2011. Available at: http://www.urban.org/research/publication/buy-and-hold-tight-recent-muni-bond-rollercoaster-and-what-it-means-cities (Accessed: May 8, 2017).

Government Finance Officers Association, "Tax-Exempt Financing: A Primer," Public Finance Network 2000. Available at: http://www.gfoa.org/sites/default/files/Tax-ExemptFinancing__APrimer.pdf (Accessed: March 26, 2017).

Graham, John. R., "Do Personal Taxes Affect Corporate Financing Decisions?," *Journal of Public Economics*, 1999, 73 (2), 147–185.

Green, Richard C., "A Simple Model of the Taxable and Tax-Exempt Yield Curves," *The Review of Financial Studies*, 1993, 6 (2), 233–264.

_, Burton Hollifield, and Norman Schurhoff, "Dealer Intermediation and Price Behavior in the Aftermarket for New Bond Issues," *Journal of Financial Economics*, 2007, 86 (3), 233–264.

Greenberg, Scott, "Reexamining the Tax Exemption of Municipal Bond Interest," Technical Report, 2016. Available at: https://taxfoundation.org/reexamining-tax-exemption-municipal-bond-interest/ (Accessed: March 24, 2017).

Guerre, E., Isabelle Perrigne, and Quang Vuong, "Optimal Nonparametric Estimation of First Price Auctions," *Econometrica,* 2000, 68, 525–574.

Hendricks, Ken and Robert H. Porter, "An Empirical Perspective on Auctions," in M. Armstrong and R. Porter, eds., *Handbook of Industrial Organization*, Vol. 3 2007, chapter 32, pp. 2073–2143.

Hortaçsu, Ali and Jakub Kastl, "Valuing Dealers' Informational Advantage: A Study of Canadian Treasury Auctions," *Econometrica*, 2012, 80 (6), 2511–2542.

_, _, and Allen Zhang, "Bid Shading and Bidder Surplus in the U.S. Treasury Auction," *American Economic Review*, 2018, 108 (1), 147–169.

Ivković, Zoran, James M. Poterba, and Scott Weisbenner, "Tax–Motivated Trading by Individual Investors," *American Economic Review*, 2005, 95 (5), 1605–1630.

Kang, Boo-Sung and Steven L. Puller, "The Effect of Auction Format on Efficiency and Revenue in Divisible Goods Auctions: A Test Using Korean Treasury Auctions," *Journal of Industrial Economics*, 2008, 56 (2), 290–332.

Kidwell, David S., Timothy W. Koch, and Duane R. Stock, "The Impact of State Income Taxes on Municipal Borrowing Costs," *National Tax Journal*, 1984, 37 (4), 551–561.

Klemperer, Paul, "What Really Matters in Auction Design," *Journal of Economic Perspectives*, 2002, 16 (1), 169–189.

Krasnokutskaya, E. and K. Seim, "Bid Preference Programs and Participation in Highway Procurement Auctions," *American Economic Review*, 2011, 101 (6), 2653–2686.

Kueng, Lorenz, "Tax News: The Response of Household Spending to Changes in Expected Taxes," Working Paper 20437, National Bureau of Economic Research 2014.

Laffont, Jean-Jacques and Quang Vuong, "Structural Analysis of Auction Data," *American Economic Review*, 1996, 86 (2), 414–420.

Levine, Helisse, "The Impact of Debt Management Policies on Borrowing Costs Incurred by U.S. State Governments," *Public Finance and Management*, 2011, 11 (1), 1–27.

Li, Tong and Xiaoyong Zheng, "Entry and Competition Effects in First-Price Auctions: Theory and Evidence from Procurement Auctions," *Review of Economic Studies*, 2009, 76 (4), 1397–1429.

_, Isabelle Perrigne, and Quang Vuong, "Conditionally Independent Private Information in OCS Wildcat Auctions," *Journal of Econometrics*, 2000, 98 (1), 129–161.

Liu, Gao and Dwight V. Denison, "Indirect and Direct Subsidies for the Cost of Government Capital: Comparing Tax–Exempt Bonds and Build American Bonds," *National Tax Journal*, 2014, 67 (3), 569– 594.

Marion, Justin, "Are Bid Preferences Benign? The Effect of Small Business Subsidies in Highway Procurement Auctions," *Journal of Public Economics*, 2007, 91 (7-8), 1591–1624.

_ and Erich Muehlegger, "Fuel Tax Incidence and Supply Conditions," *Journal of Public Economics*, 2011, 95 (9), 1202–1212.

Miller, Merton H., "Debt and Taxes," *The Journal of Finance*, 1977, 32 (2), 261–275.

National Association of State Budget Officers, "Budget Processes in the States," 2008-2015.

National Governors Association, "Concerns with Capping the Exemption of Muni Bond Interest at 28 Percent," 2012. Available at: https://www.nga.org/files/live/sites/NGA/files/pdf/1212EDCGFOA.pdf (Accessed: March 26, 2017).

Oster, Emily, "Unobservable Selection and Coefficient Stability: Theory and Evidence," *Journal of Business Economics and Statistics*, 2017, pp. 1–17.

Pomerleau, Kyle, "Details and Analysis of the 2016 House Republican Tax Reform Plan," Tax Foundation, 2016. Available at: https://taxfoundation.org/details-and-analysis-2016-house-republican-tax-reform-plan/ (Accessed: March 26, 2017).

Poterba, James M., "Explaining the Yield Spread between Taxable and Tax–exempt Bonds: The Role of Expected Tax Policy," in Harvey S. Rosen, ed., *Studies in State and Pocal Public Finance*, 1986, chapter 2, pp. 5–52.

_, "Tax Reform and the Market for Tax–Exempt Debt," *Regional Science and Urban Economics*, 1989, 19(3), 537–562.

_, "State Responses to Fiscal Crises: The Effects of Budgetary Institutions and Politics," *Journal of Political Economy*, 1994, 102 (4), 799–821.

_, "Taxation, Risk-Taking, and Household Portfolio Behavior," in Alan J. Auerbach, Raj Chetty, Martin Feldstein, and Emmanuel Saez, eds., *Handbook of Public Economics*, Vol. 3 2002, chapter 17, pp. 1109– 1171.

_ and Andrew A. Samwick, "Taxation and Household Portfolio Composition: US Evidence from the 1980s and 1990s," *Journal of Public Economics*, 2003, 87 (1), 5–38.

_ and Arturo Ramírez Verdugo, "Portfolio Substitution and the Revenue Cost of the Federal Income Tax Exemption for State and Local Government Bonds," *National Tax Journal*, 2011, 64 (2), 591–614.

_ and Kim S. Rueben, "Fiscal News, State Budget Rules, and Tax–Exempt Bond Yields," *Journal of Urban Economics*, 2001, 50 (3), 537–562.

_ and _, "State Fiscal Insitutions and the U.S. Municipal Bond Market," in James M. Poterba and Jürgen Von Hagen, eds., *Fiscal Institutions and Fiscal Performance*, 2002, chapter 8, pp. 1109–1171.

Puentes, Robert, Patrick Sabol, and Joseph Kane, "Revive Build America Bonds (BABs) to Support State and Local Investments," Brookings Institution 2013. Available at: https://www.brookings.edu/wp-content/uploads/2016/06/Fed-Series-Babs-82813.pdf (Accessed: March 26, 2017).

Roberts, James W. and Andrew Sweeting, "When Should Sellers Use Auctions?," *American Economic Review*, 2013, 103 (5), 1830–1861.

_ and _ , "Bailouts and the Preservation of Competition: The Case of the Federal Timber Contract Payment Modification Act," *AEJ Microeconomics*, 2016, 8 (3), 257–288.

Rubin, Richard, "How Long Will the Tax Break on Municipal Bonds Last?," 2017. Available at: https://www.wsj.com/articles/mnuchin-says-trump-will-offer-biggest-tax-cut-in-u-s-history-1493213275 (Accessed: May 24, 2017).

Saez, Emmanuel, "The Optimal Treatment of Tax Expenditures," *Journal of Public Economics, 2004*, 88 (12), 2657–2684.

Schultz, Paul, "The Market for New Issues of Municipal Bonds: the Roles of Transparency and Limited Access to Retail Investors," *Journal of Financial Economics*, 2012, 106 (3), 492–512.

SDC Platinum, "SDC Platinum Global Public Finance," Thomson SDC Platinum Database 2016. Available at: Subscription Service (Data Accessed: March 21, 2017).

Shneyerov, Artyom, "An Empirical Study of Auction Revenue Rankings: the Case of Municipal Bonds," *RAND Journal of Economics*, 2006, 37 (4), 1005–1022.

SIFMA, "Statistics," Securities Industry and Financial Markets Association 2017. Available at: http://www.sifma.org/research/statistics.aspx (Accessed: March 23, 2017).

Skelton, Jeffrey L., "Banks, Firms and the Relative Pricing of Tax–Exempt and Taxable Bonds," *Journal of Financial Economics*, 1983, 12 (3), 343–355.

Snider, Conan and Thomas Youle, "The Fix is In: Detecting Portfolio Driven Manipulation of the Libor," Working Paper, 2014.

Sogo, Takeharu, Dan Bernhardt, and Tingjun Liu, "Endogenous Entry to Security-Bid Auctions," *American Economic Review*, 2016, 106 (11), 3577–3589.

Suárez Serrato, Juan Carlos and Owen Zidar, "Who Benefits from State Corporate Tax Cuts? A Local Labor Markets Approach with Heterogeneous Firms," *American Economic Review*, 2016, 106 (9), 2582–2624.

Swearingen, Joel, "Lawmakers Target the Tax-exemption for Municipal Bonds Again," *The National Law Review*, 2016. Available at: http://www.natlawreview.com/article/lawmakers-target-tax-exemption-municipal-bonds-again (Accessed: March 24, 2017).

Tang, Xun, "Bounds on Revenue Distributions in Counterfactual Auctions with Reserve Prices," *RAND Journal of Economics*, 2011, 42 (1), 175–203.

Tax Policy Center, "What are Municipal Bonds and How are they Used?," Urban Institute and Brookings Institution 2015. Available at: http://www.taxpolicycenter.org/briefing-book/what-are-municipal-bonds-and-how-are-they-used (Accessed: March 23, 2017).

The Bond Buyer, "Competitive Sales Results," *The Bond Buyer* 2016. Available at: Subscription Service http://www.bondbuyer.com/ (Data Accessed: March 21, 2017).

Trzcinka, Charles, "The Pricing of Tax-Exempt Bonds and the Miller Hypothesis," *The Journal of Finance*, 1982, 37 (4), 907–923.

U.S. Census Bureau, "State and Local Government Finances by Level of Government and by State: 2014," *American Fact Finder* 2017. Available at: https://factfinder.census.gov/bkmk/table/1.0/en/SLF/2014/00A1 (Accessed: March 24, 2017).

U.S. Department of the Treasury, "Tax Expenditures FY2017," 2016. Available at: https://www.treasury.gov/resource-center/tax-policy/Documents/Tax-Expenditures-FY2017.pdf (Accessed: March 23, 2017).

U.S. Securities and Exchange Commission, "Report on the Municipal Securities Market," 2012. Available at: https://www.sec.gov/news/studies/2012/munireport073112.pdf (Accessed: March 23, 2017).

Walsh, Mary Williams, "Municipalities Fight a Proposal to Tax Muni Bond Interest," *New York Times*, Dec. 19 2012.

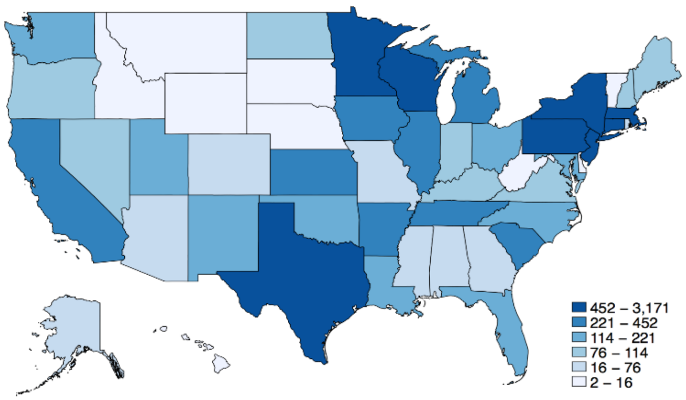
Youle, Thomas, "How Much Did Manipulation Distort the Libor," Working Paper, 2014.

Zweig, Jason, "Trump Unveils Broad Tax-Cut Plan," 2011. Available at: https://www.wsj.com/articles/SB10001424052748704810504576307233579693982 (Accessed: March 26, 2017).

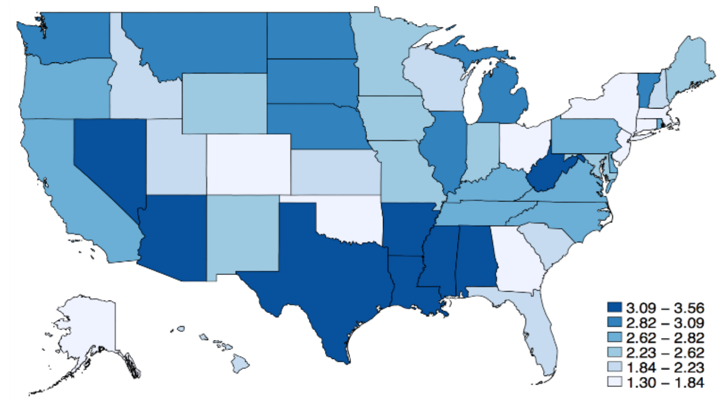
FIGURES AND TABLES

Figure 1. Maps of summary statistics

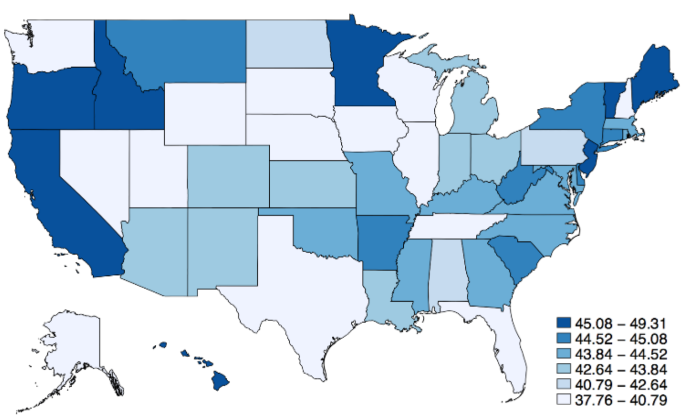
(a) Number of acutions



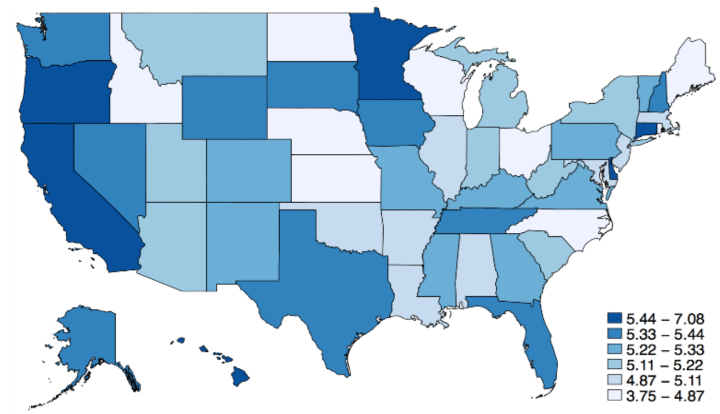
(b) Average winning bid



(c) Effective rate in 2015



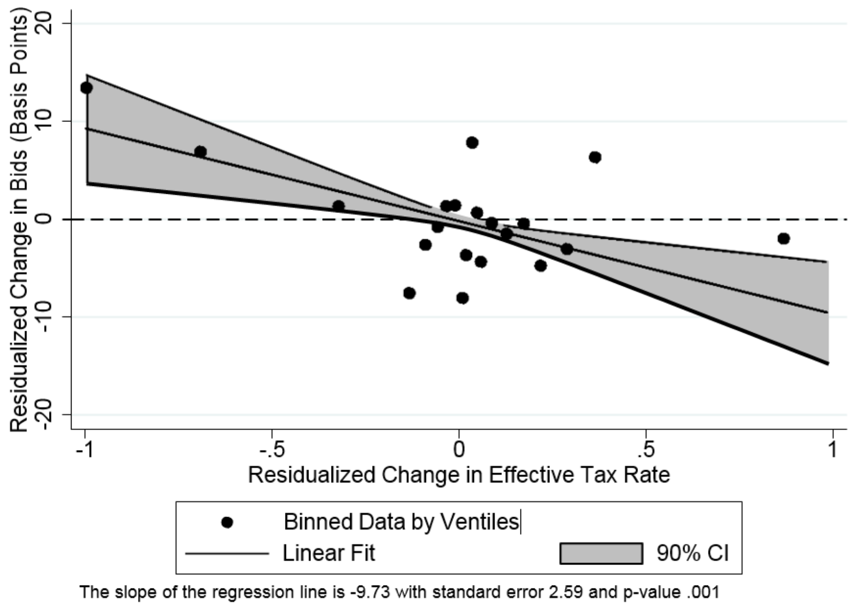
(d) Change in effective rate 2008-2015



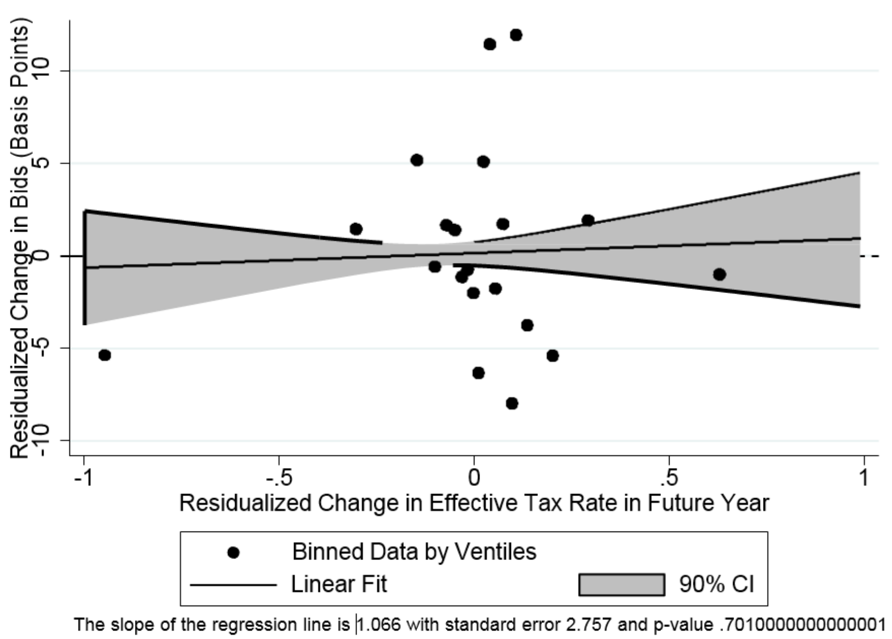
Notes: These maps show the spatial distribution of several important variables. Panel (a) shows the number of auctions in the estimation sample from each state and panel (b) shows the average winning bid or interest rate paid by the locality. Panels (c) and (d) show the distribution of effective tax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

(a) Change in winning bid as a function of current change in tax rate

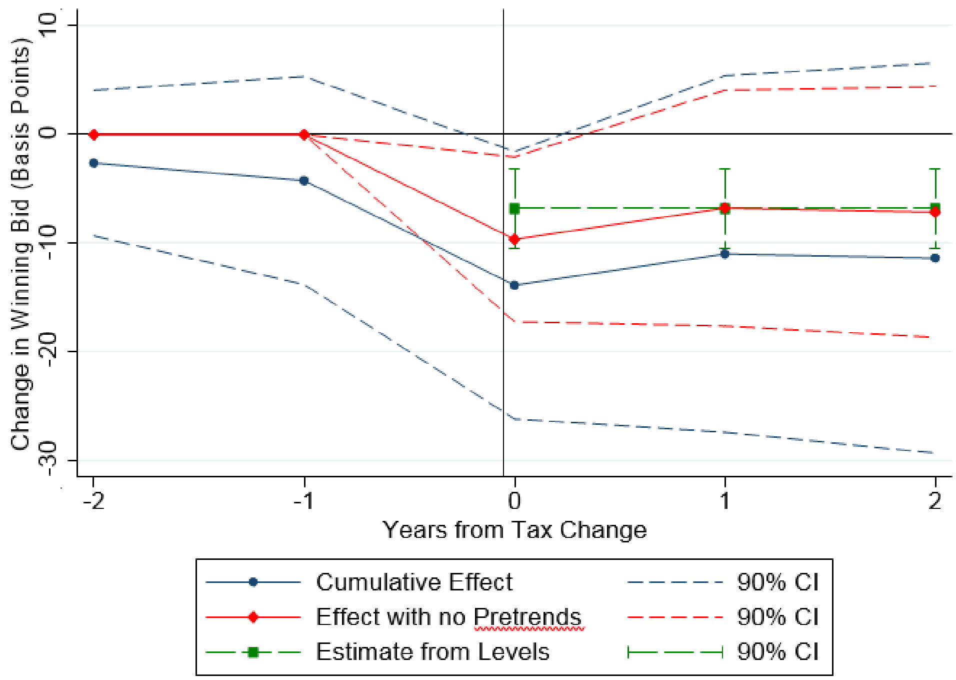


(b) Placebo: Change in winning bid as a function of future change in tax rate



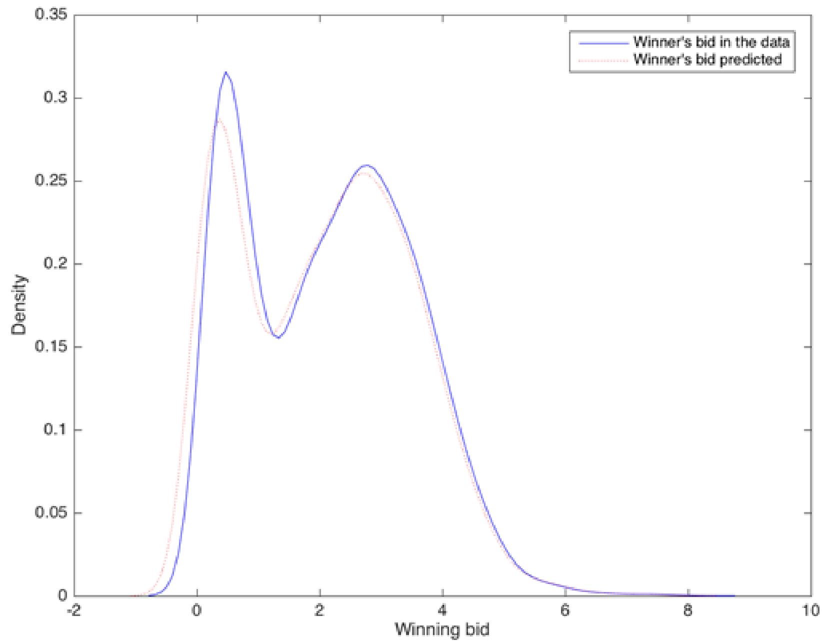
Notes: These figures show the results of the first differences regression of winning bid on tax rates for a current tax change and a future tax change. Panel A shows the results of a regression of change in bid on change in current tax rate for tax rate changes from 2008-2015. This regression finds a coefficient of -9.73 with a standard error of 2.59, which is close to the preferred regression estimates of -6.8. Panel B shows the results of a regression of change in bid on change in the tax rate in the following year ranging from 2009-2016. This placebo test finds a coefficient equal to 1.066, which is statistically indistinguishable from zero. The controls included in these regressions are the same as those used in column (5) of Table 2. See Section 3 for more information.

Figure 3. Cumulative effect of a tax change at year *t* = 0



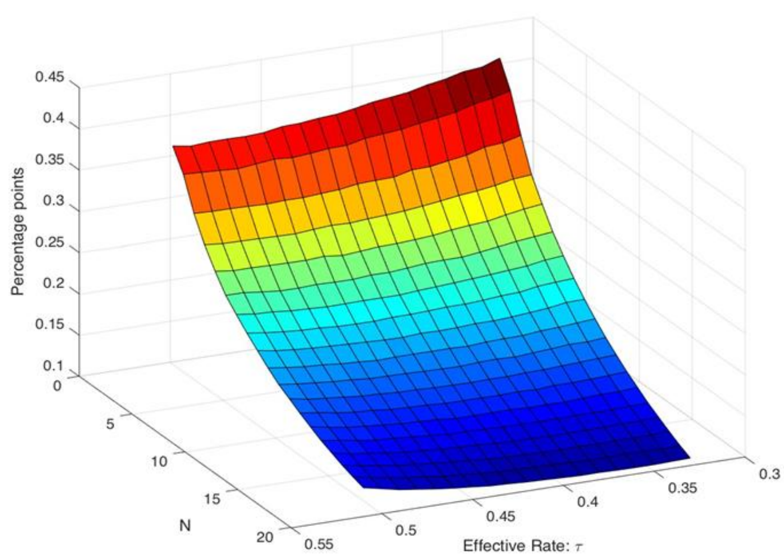
Notes: This figure shows the results of the event study regression of change in bid on several leads and lags of change in effective tax rate. The first line shows the total cumulative effect of a tax change event on average winning bid in each year surrounding the event. In the period of the tax change, the borrowing cost is 13.85 basis points lower on average for each percentage point of the effective rate tax increase and the long run effect is -11.35 basis points. The second line shows the cumulative effect of the tax change without allowing pretrends. The effect in the year of the tax change is 9.62 basis points while the long run effect is 6.75 basis points. The controls included in these regressions are the same as those used in column (5) of Table 2. Figure 2 shows the results of a regression of changes without the inclusion of leads and lags of tax changes. See Section 3 for more information.

Figure 4. Simulated and observed winner's bids



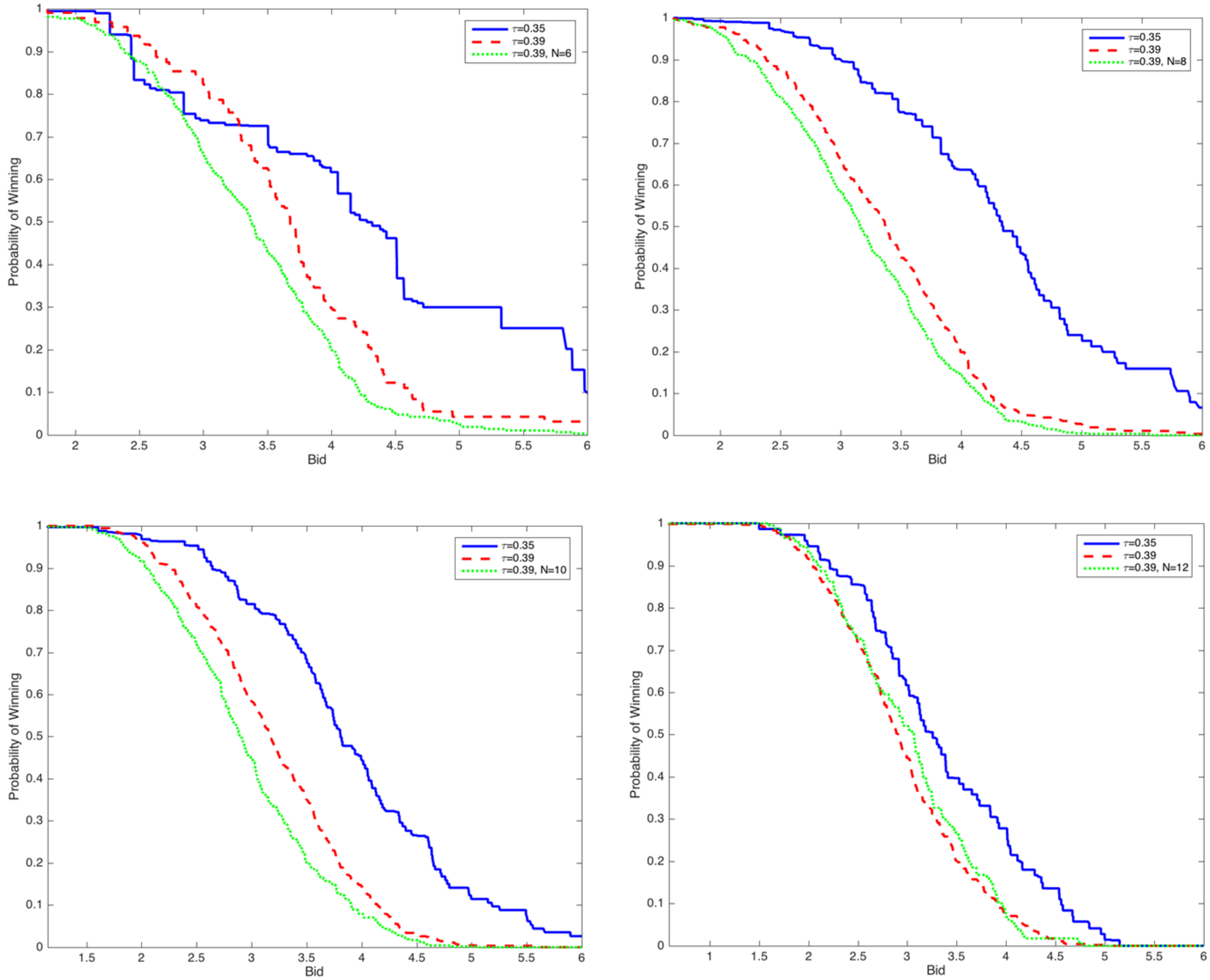
Notes: This figure visually displays the goodness of fit of the model relative to the observed data in the distribution of bids. See Section 4 for the discussion of the model and Table 5 for the associated parameter estimates.

Figure 5. The ratio of winner's makeup to bid



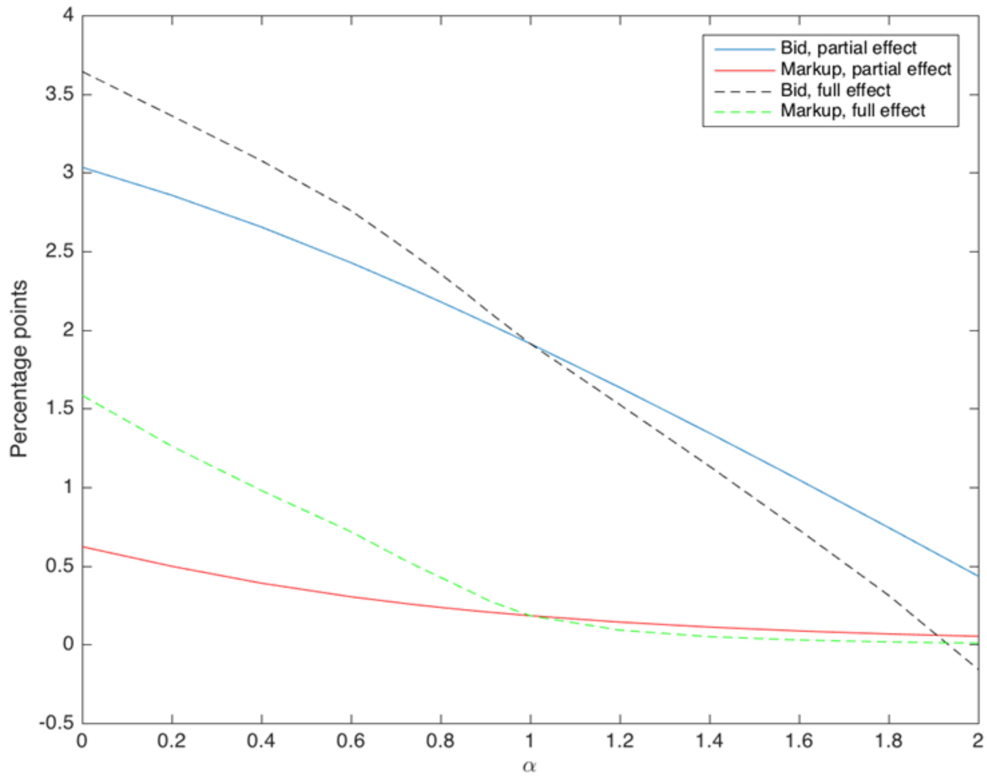
Notes: This figure shows the percent of the winner's bid that is attributable to the markup for different values of potential bidders (N) and effective tax rates (τ) in the baseline model. See Section 4 for additional discussion and Table 5 for the associated parameter estimates.

Figure 6. Non-parametric estimates of the probability of winning



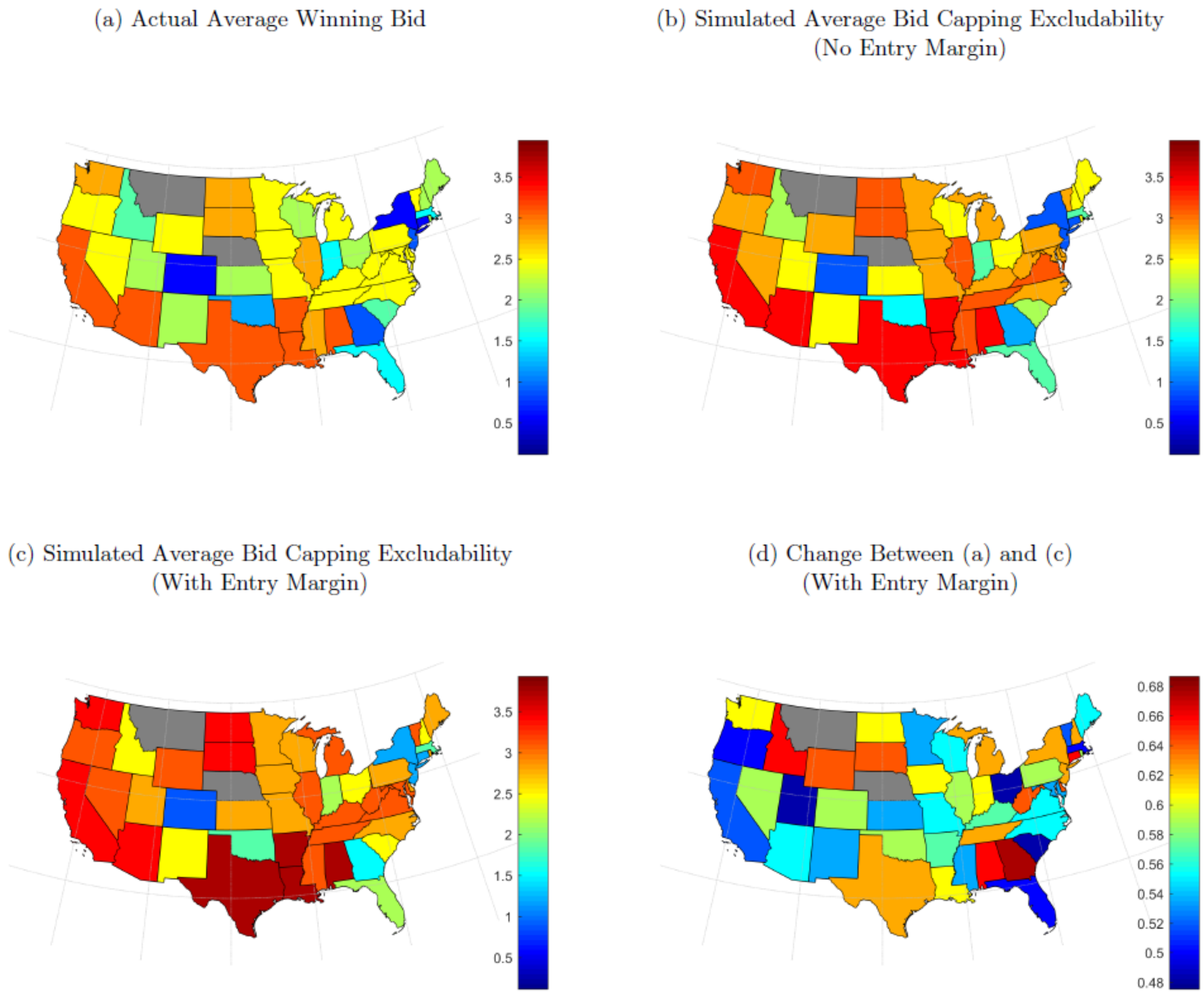
Notes: These figures show the non-parametric estimates of winning probability for a given bid conditional on maturity between 2 and 17 years, which is the middle third of the maturities. The non-parametric estimates here are also used to estimate optimal bids and elasticities for a given value. See Section 6 for more information about these estimates and the discussion of optimal bid responses.

Figure 7. α-policy outcomes for borrowing rates and markups



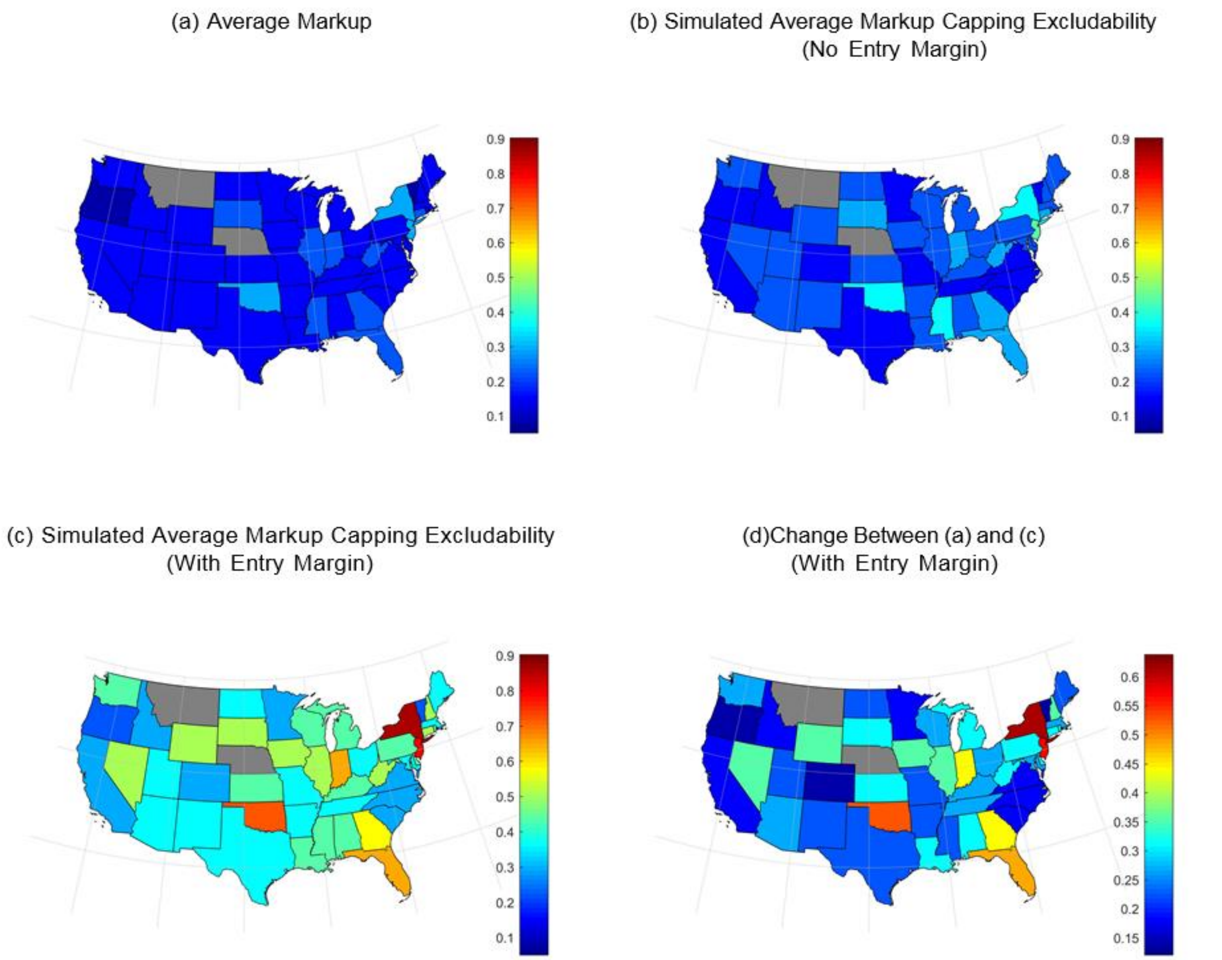
Notes: This figure shows counterfactual bids for different ratios of the current federal exemption. α = 0 is equivalent to eliminating the exemption and α = 2 would be doubling the exemption by subsidizing municipal bond interest income by an amount equal to the federal tax rate in addition to the exemption. See Section 7 for additional discussion and Figures 8 and 9 for the spatial distribution of counterfactual changes associated with α = 0.7.

Figure 8. Effect of capping federal excludability at 28% on winning bids



Notes: This figure shows spatial heterogeneity in counterfactual estimates of winning bids if the federal exclusion were capped at 28%. See Section 7 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.6 and A.8, respectively. The average effects from the policy reforms are shown in Table 8, the parameter estimates are displayed in Table 5, 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



Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the federal exclusion were capped at 28%. See Section 7 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.7 and A.9, respectively. The average effects from the policy reforms are shown in Table 8, the parameter estimates are displayed in Table 5, 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	220.10	317.90	430.54
Standard Deviation of Bids in Auction	15.428	16.547	2.72	6.37	10.65	18.21	45.06
State Characteristics							
Sales Tax Rate	5.664	1.328	4.00	4.50	6.00	6.50	7.00
Corporate Income Tax Rate	7.108	2.709	0.00	6.50	7.50	9.00	9.99
Sales Tax Apportionment Weight	77.839	24.598	33.34	50.00	93.00	100.00	100.00
Property Tax Rate	1.619	0.511	0.74	1.20	1.79	2.03	2.27
Alternative Minimum Tax (Dummy)	0.429	0.495	0.00	0.00	0.00	1.00	1.00
Federal Taxes Deductible	0.038	0.190	0.00	0.00	0.00	0.00	0.00
Muni Interest Exempt	0.804	0.397	0.00	1.00	1.00	1.00	1.00
Governor Vote (R)	0.477	0.102	0.31	0.39	0.50	0.54	0.66
Senate Vote (R)	0.433	0.112	0.28	0.32	0.44	0.51	0.65
Presidential Vote (R)	0.442	0.079	0.37	0.37	0.43	0.48	0.59
Tax Characteristics							
State Personal Income Tax Rate	6.160	3.069	0.00	5.00	6.85	8.97	10.44
Federal Personal Income Tax Rate	35.293	2.959	31.86	32.61	34.30	38.06	40.79
Effective Marginal Income Tax Rate	40.872	3.638	34.30	38.74	40.79	43.96	46.21

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

Table 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	-6.531	-6.994	-6.819	-6.813	-6.806
	(2.527)	(2.349)	(2.273)	(2.248)	(2.244)
	0.010	0.003	0.003	0.003	0.003
Effect of Effective Rate on N					
Effective Rate	0.581	0.571	0.559	0.559	0.547
	(0.118)	(0.122)	(0.131)	(0.131)	(0.133)
	0.000	0.000	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid					
Effective Rate	-4.525	-5.082	-5.102	-5.100	-5.222
	(2.514)	(2.359)	(2.313)	(2.283)	(2.282)
	0.073	0.032	0.028	0.026	0.023
Observations	14,631	14,631	14,631	14,631	14,631
Median Bid	221.2	221.2	221.2	221.2	221.2
Median Effective Rate	40.79	40.79	40.79	40.79	40.79
Elasticity (Median)	1.748	1.872	1.825	1.824	1.822
	(0.677)	(0.629)	(0.609)	(0.602)	(0.601)
	0.010	0.003	0.003	0.002	0.002
Year Fixed Effects	Y	Y	Y	Y	Y
State Fixed Effects	Y	Y	Y	Y	Y
Maturity, Quality, and Refund Controls	Y	Y	Y	Y	Y
Political Party Controls		Y	Y	Y	Y
Personal, Business, and Prop. Tax Controls			Y	Y	Y
Sales Tax Controls				Y	Y
Size of Bond Package Controls					Y

Notes: This table reports regression estimates of the effect of effective marginal tax rates 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 3 with other measurement approaches shown in Table 4. The first panel 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 panel. All specifications include fixed effects for the state and year as well as controls for maturity, credit rating, and refund status. Political party controls include the proportion of votes cast for the republican candidate in the most recent senate, gubernatorial, and presidential elections in the state. Personal, Business, and Property Tax Controls include indicators for alternative minimum taxes, exemption of instate and out-of-state federally tax-exempt debt, deductibility of federal income taxes, corporate tax rates, property tax rates, and sales apportionment rules. Sales Tax Controls include state sales tax rates. The natural logarithm of size of the bond package in millions of USD is included in column (5). Standard errors clustered at the state-year level are shown in parentheses and p-values for each estimate are displayed below standard errors.

Table 3. Reduced-form effects of the effective rate on winning bid and the number of potential bidders: Extended controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Unconditional Effect of Effective Rate on Bid								
Effective Rate	-6.531	-6.686	-6.169	-6.572	-6.709	-6.708	-6.531	-7.159
	(2.527)	(2.361)	(2.440)	(2.484)	(2.560)	(2.577)	(2.574)	(2.249)
	0.010	0.005	0.012	0.009	0.009	0.010	0.012	0.002
Effect of Effective Rate on *N*								
Effective Rate	0.581	0.557	0.642	0.581	0.574	0.583	0.566	0.545
	(0.118)	(0.107)	(0.156)	(0.118)	(0.103)	(0.117)	(0.107)	(0.125)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid								
Effective Rate	-4.525	-4.813	-4.417	-4.553	-4.684	-4.663	-4.575	-5.901
	(2.514)	(2.350)	(2.425)	(2.474)	(2.464)	(2.565)	(2.548)	(2.315)
	0.073	0.041	0.069	0.066	0.058	0.070	0.073	0.011
Observations	14,631	14,631	14,631	14,631	14,631	14,631	14,631	14,631
Median Bid	221.2	221.2	221.2	221.2	221.2	221.2	221.2	221.2
Median Effective Tax	40.79	40.79	40.79	40.79	40.79	40.79	40.79	40.79
Elasticity (Median)	1.748	1.790	1.651	1.759	1.796	1.796	1.748	1.916
	(0.677)	(0.632)	(0.653)	(0.665)	(0.685)	(0.690)	(0.689)	(0.602)
	0.010	0.005	0.011	0.008	0.009	0.009	0.011	0.001
Base Controls	Y	Y	Y	Y	Y	Y	Y	Y
Bidder Fixed Effects		Y						Y
Issuer Fixed Effects			Y					Y
Unemployment Rate				Y				Y
Gross Domestic Product (log)					Y			Y
State Government Spending (log)						Y		Y
State Intergov Spending (log)							Y	Y
Political Party Controls								Y
Personal, Business, and Prop Tax								Y
Sales Tax Controls								Y
Size of Bond Package Controls								Y

Notes: This table presents more estimates corresponding to Table 2. The base controls include state, year, maturity, quality, and refund status fixed effects in addition to effective rate, which is the same as column (1) in Table 2. See Appendix C for details and Appendix A for variable definitions. Standard errors clustered at the state-year level are shown in parentheses and p-values for each estimate are displayed below standard errors.

Table 4. Reduced-form effects of the effective rate on winning bid and the number of potential bidders: Primary robustness checks

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

Notes: This table presents more estimates corresponding to Table 2. The base controls include state, year, maturity, quality, and refund status fixed effects in addition to effective rate, which is the same as column (1) in Table 2. See Appendix C for details and Appendix A for variable definitions. Standard errors clustered at the state-year level are shown in parentheses and p-values for each estimate are displayed below standard errors.

Table 5. 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: 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 5. Standard errors are in parentheses.

Table 6. Summary of average estimated markups by issuer type

	Markup (BP)	Markup Rate (%)	Markup Value ($)
Total	16.803	17.402	173,476
States and State Authorities	10.141	6.374	893,260
Counties, Parishes, and Colleges	15.088	14.131	214,318
School and Utility Districts	17.447	16.300	155,743
Cities, Towns, and Villages	16.876	20.124	128,612

Notes: This table showcases the average markups estimated in the structural model by issuer type. The row titled "Total" includes all issuers including those for which an issuer type is not listed by SDC Platinum while the other rows take the average of a subset of issuers by type. The markup is estimated directly from the model, the markup rate is the markup divided by the winning bid, and the markup value is the markup multiplied by size and maturity. Markup estimates are trimmed at the 2.5% level to adjust for outliers. The average bond issue has an estimated markup up of 16.8 basis points, which is 17.4% percent of their interest cost and adds up to $173,476 over the lifetime of the bond. The issuer types are organized from higher levels of government to more local levels of government. States and state authorities have lower markups on average that are a smaller percent of the total interest costs. The total value of the markups for these issuers is larger because their average issue size is larger. See Section 5 for more information.

Table 7. Elasticity decomposition illustration (tax from 35% to 39%)

	N	Value v	Optimal b	$\varepsilon^b_{1-\tau}$	$\varepsilon^\mu_{1-\tau}$
1. Baseline	6	$v_0 = 1.621$	1.896		
2. Own-value Changes No Change to $Pr[win]$	6	$v_1 = 1.521$	1.830	0.567	
3. All-values Change $Pr[win]$ reflects τ_1, N_0	6	v_1	1.761	1.155	2.068
4. All-values + Entry $Pr[win]$ reflects τ_1, N_1	8	v_1	1.692	1.748	6.145
Unit-Passthrough		v_1	1.779	1	1

Notes: This table shows an example using the case of the median winning bidder in auctions with six potential bidders. An unobservable is chosen so as to match the median bid in simulation to the median bid in the data. The columns show the number of potential bidders, the value of the bidder, the optimal bid given the value, the intermediate elasticity of the bid, and the intermediate elasticity of the markups. The rows of the table decompose the change in optimal bid for the median winning bidder. The first row shows the optimal bid for a value of 1.621 and the second row shows how the optimal bid changes if the tax rate increases by 4 percentage points but the probability of winning is held constant. The third row allows the bidder's own value to change as well as other bidders' values. The fourth row allows own and other bidder values to change as well as other bidders to enter into the auction where the total elasticity of the bid is 1.748 and the elasticity of the markup is 6.145. For more information, see Section 6.

Table 8. Average effects from counterfactual policy reform

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

	(1)	(2) Trump Proposal	(3) Obama Proposal	(4) No Federal Exclusion	(5) No State Exclusion	(6) No SALT	(7) TCJA17
	$\alpha = 1$	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid							
Partial (No Potential Entry)	1.91	1.96	2.27	3.03	2.10	1.83	1.88
Full	1.91	2.00	2.50	3.64	2.21	1.79	1.86
Markups							
Partial (No Potential Entry)	0.18	0.19	0.26	0.62	0.22	0.17	0.08
Full	0.18	0.22	0.52	1.58	0.35	0.15	0.07

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

	(1) Trump Proposal	(2) Obama Proposal	(3) No Federal Exclusion	(4) No State Exclusion	(5) No SALT	(6) TCJA17
	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid						
Partial (No Potential Entry)	2.56%	18.56%	58.59%	9.61%	-4.57%	-1.81%
Full	4.32%	30.65%	90.42%	15.76%	-6.36%	-2.54%
Markups						
Partial (No Potential Entry)	4.65%	40.67%	240.21%	21.30%	-8.07%	-3.50%
Full	20.34%	185.28%	766.71%	92.00%	-20.47%	-9.49%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 96% of its current level. The last three columns represent simulations under which state tax exemption for muni bonds is lifted, SALT is repealed, or SALT is repealed and the exemption is limited to 96% of its current level. Section 4 discusses the setup of the model while Section 7 discusses the counterfactual simulations. Robustness checks for five additional specifications are discussed in Appendix E with results presented in Tables A.13 to A.17.

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. The derivation of the full model is shown in Appendix D, and robustness checks for alternative model specifications are presented in Appendix E. Appendix F 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 (1994-2014) with 2015 entries imputed.
4. State intergovernmental transfers. Total annual transfers from state to local governments. Data from Census Bureau (1994-2014) with 2015 entries imputed.
5. State interest payments. Total annual interest payments for all local governments and state agencies within a state. Data from Census Bureau (1994-2014).
6. 1-year LIBOR swap rate. The fixed rate paid on a 1-year interest rate swap. Data from Board of Governors of the Federal Reserve System (2018).
7. 7-day municipal VRDO yield. Variable rate demand obligation yields from SIFMA is an index of yields on a sample of large, AAA rated municipal bonds with variable rates. Data from SIFMA (2017).

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 described as $ATI = Income(1 - \tilde{t}_f - \tilde{t}_s)$. The effective tax rate is simply $\tau \equiv 1 - ATI/Income = \tilde{t}_f + \tilde{t}_s$. However, the variables from TAXSIM already account for interactions of state and federal rates so they cannot be used directly for counterfactual simulations of changes in one rate or the other.

Let T_f be the total federal tax liability and 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.

$$T_f = t_f(Income - T_s)$$

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

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

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:

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

$$\tilde{t}_s = t_s - t_s t_f + \tilde{t}_s t_s t_f$$

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

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 5.2. Column (3) uses every control in the robustness table plus every control in Table 3. The estimated coefficients are very stable between 6.5 and 6.7 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 5.4 basis points.

. . .

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.

Table A.5 shows additional specifications of the regression equation estimated in Table 2. Columns (1) to (4) show different versions of the choice of standard errors. We use standard errors clustered at the state-year level in the main specifications, which are more conservative than standard errors clustered at the state-month level and robust standard errors. Columns (5) and (6) show the robustness of the results to monthly and daily fixed effects, respectively. The specification in Column (7) expands the sample universe to include all bonds sold at auction including those for less than $5 million. The specification including small bonds is weighted by size bins.

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.6 shows similar results for the actual 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. (2017) find that supply of municipal debt increases at the local level when the cost of debt decreases on the intensive margin but not the extensive margin. Since we control for the size of the bond, we are primarily concerned with any supply response on the extensive margin. Table A.7 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.8 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.

C5. 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 (2017) 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 (2017). The following is helpful notation used to define the estimator:

- $\dot{\beta}$ and $\dot{R}$. The estimates of β and R^2 from a regression with base controls.
- $\tilde{\beta}$ and $\tilde{R}$. The estimates of β and R^2 from a regression with additional controls.
- β^*. The bias-adjusted estimate of β.
- δ. "Coefficient of Proportionality" or proportion of variation in the 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 (2017). 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^*:

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

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.9. 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 (2017). The interpretation of this estimate is that selection on unobservables would need to be 113.9 times more important than selection on observables for our results to be negated. 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.

C.6 Effect of interest costs on tax rates (reverse causality)

As discussed in Section 3, there is a potential that states could adjust tax rates to deal with changes in local borrowing cost such as raising revenue to cover past or future increases in interest rates. To investigate this possibility we gather data from Census Bureau (1994-2014) on total interest payments made by governments in each state from 1994 to 2004 and regress tax rates on these interest payments as well as leads and lags of interest payments. Tables A.10 and A.11 show that interest payments are not associated with a change in tax rates.

D. Detailed model derivation

In this section we consider an auction with N potential bidders. As with most standard results in the auctions literature, we assume here that valuations of bidders are distributed over some compact support $[\underline{v}, \bar{v}]$, 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

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

where $\boldsymbol{v}_{-i}$ 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

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

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

$$\beta(v) = v + \frac{\int_v^{\bar{v}} \boldsymbol{P}r[v_{-i} > s]ds}{\boldsymbol{P}r[v_{-i} > v]}.$$

This equation represent the unique monotone smooth equilibrium bidding strategy under our assumption $\beta(\bar{v}) = \bar{v}$.[49] We denote the corresponding profits as

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

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

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

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

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

. . .

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

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

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

$$\boldsymbol{Pr}[v_{-i} > v] = C_{N-1}^{0}(1-p^*)^{N-1}\big(1-F(v)\big) + \sum_{j=1}^{N-1} C_{N-1}^{j}\,(1-p^*)^{N-1-j}(p^*)^j\big(1-F(v)\big)^j,$$

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

E. Robustness of structural estimates

We now show that our implications for passthrough elasticities, markups, and counterfactual policies are robust to different model specifications. The model fit and markups are presented in Table A.12 for all robustness checks to the structural model. 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

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

  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 policy simulations are presented in Table A.13. 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 policy simulations are presented in Table A.14. 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 policy simulations are presented in Table A.15. 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 policy simulations are presented in Table A.16. 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

$$E\pi(p) = \int_{q_b(0.001)}^{\infty} g(b)\pi(b|p)db \qquad (10)$$

  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 policy implications, which are presented in Table A.17, and model fit and markups, which are presented in Table A.12. The estimated average entry margin threshold is slightly lower in this specification.

F. Proposed reforms

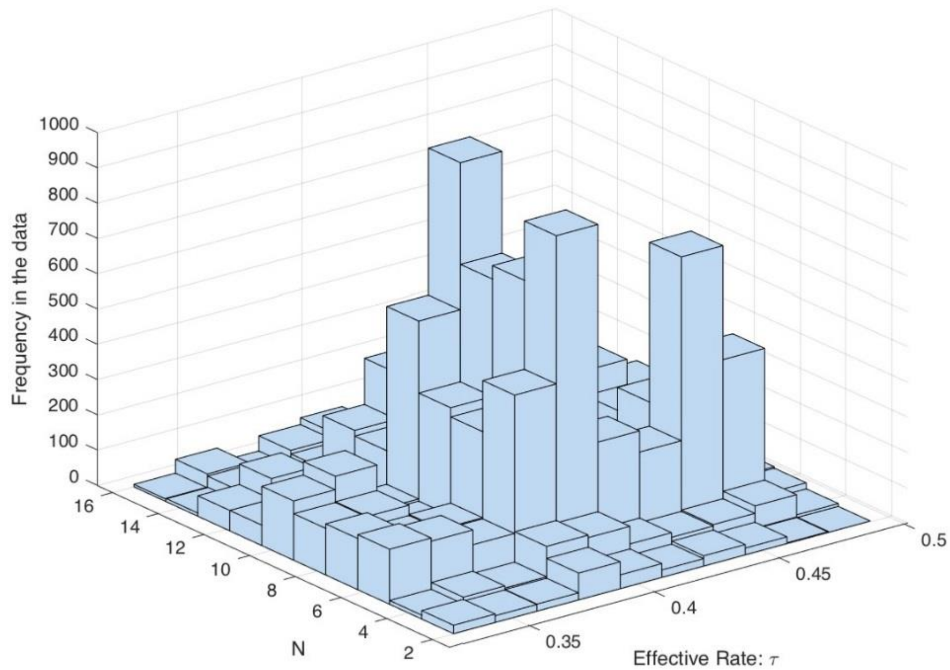
There are several recent and current tax reform proposals at the federal level that would change the borrowing cost of municipalities and demand for municipal debt. Broadly speaking, proposed reforms fit into 3 categories: changing the federal tax rate of the exemption, permanently introducing other 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 the Tax Cut and Jobs Act of 2017, the top marginal rate was cut from 39.6% down to 37%. Former President Obama proposed a larger cut to the municipal bond interest exemption in particular without necessarily adjusting the top statutory federal income tax rate. The Obama White House 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 ratesin the counterfactual simulations at $\alpha = \frac{0.28}{0.386} \approx 0.73$ and $\alpha = \frac{0.37}{0.386} \approx 0.96$ where 0.386 is marginal rate in the subsample for years 2011-2015.

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.

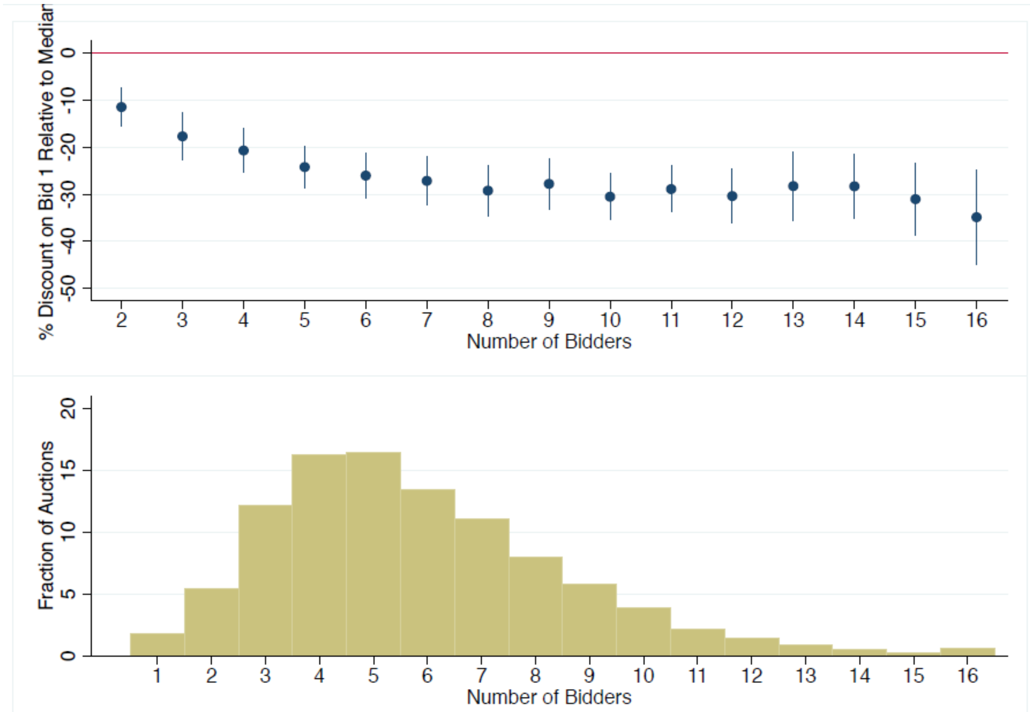
APPENDIX GRAPHS

Figure A.1. Frequency of auctions by (N, τ) pairs



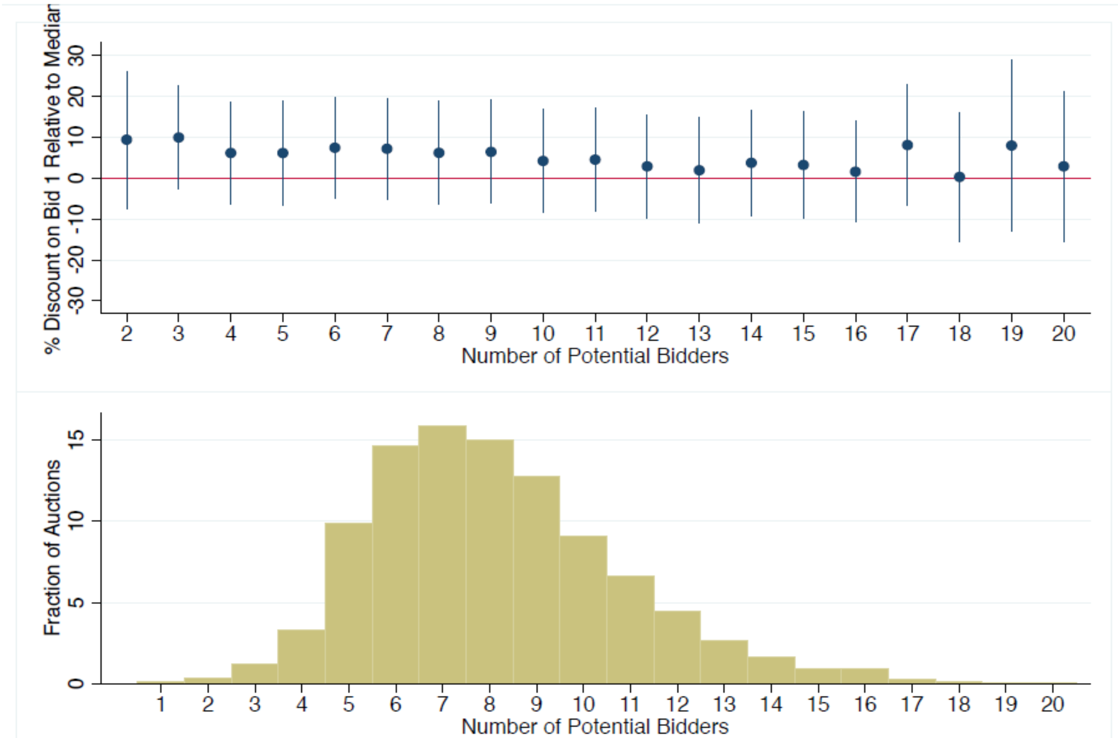
Notes: This figure shows the frequency of observations by number of potential bidders (N) and bins of effective tax rate. See Section 2 for more information about the data and variables.

Figure A.2. Number of bidder fixed effects and distribution of number of bidders



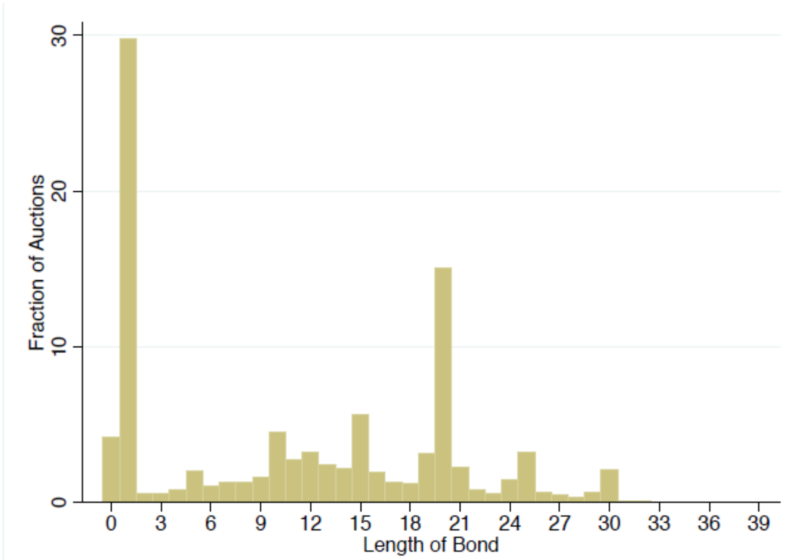
Notes: This figure shows the number of bidder fixed effect estimates from specification (4) of Table 2 normalized to the median bid in addition to the empirical distribution of the number of bidders in our sample. The reduced-form analysis is discussed in Section 3 and robustness checks are presented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

Figure A.3. Number of potential bidder fixed effects and distribution of number of potential bidders



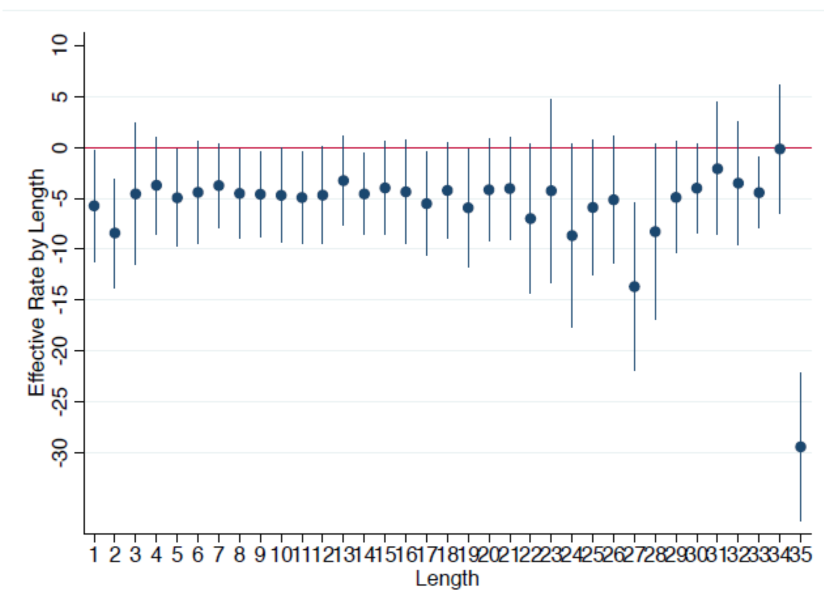
Notes: This figure shows the frequency of observations by number of potential bidders (N) and the associated fixed effect estimates from Table 2, column (4). See Section 3 for discussion of the reduced-form model.

Figure A.4. Empirical distribution of bond lengths



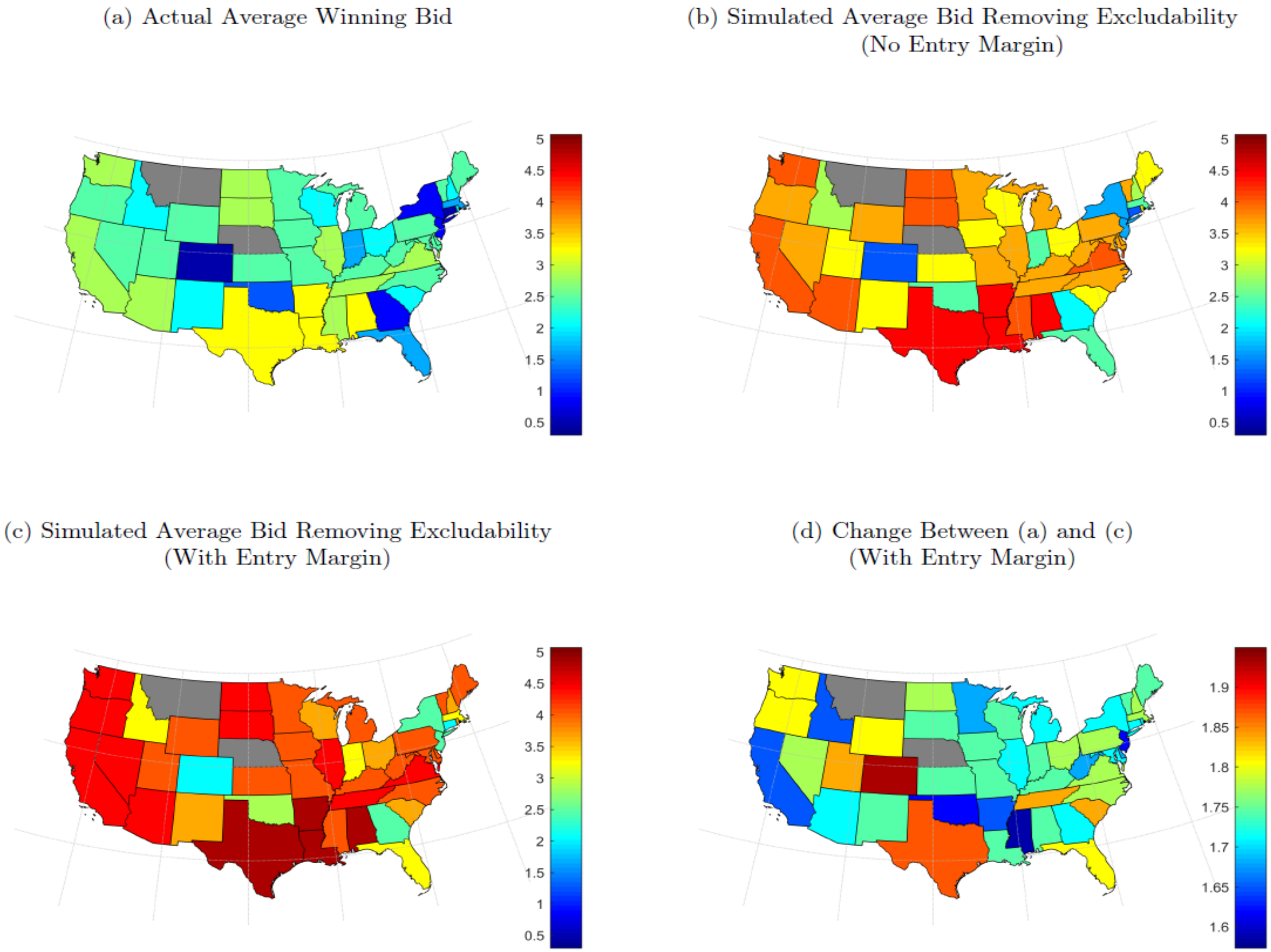
Notes: This figure shows the frequency of observations by length of bond. We test for heterogeneity of effect by length of bond in the reduced-form model in Appendix C.

Figure A.5. Effect of effective rate on winning bid by length of bond



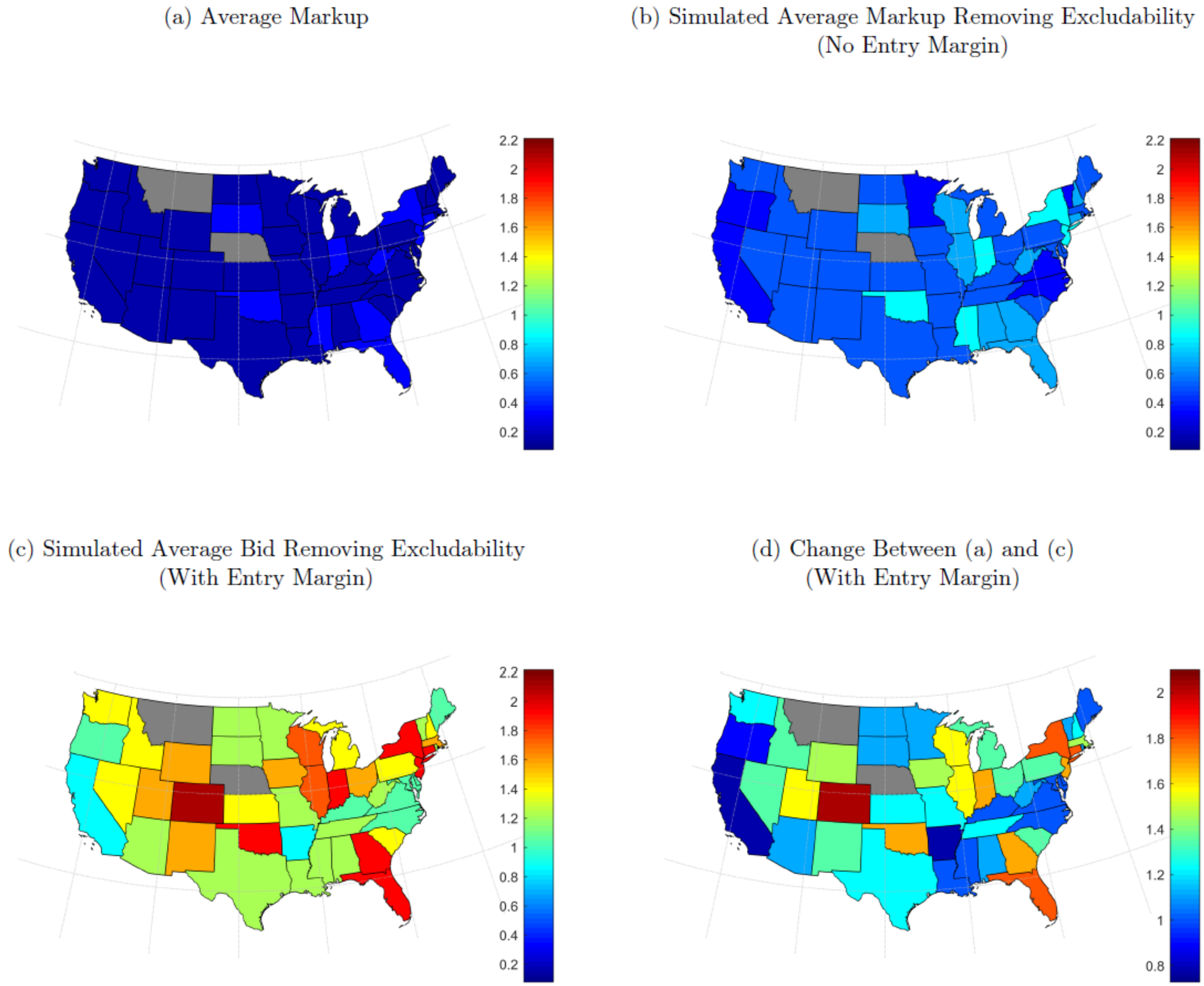
Notes: This figure shows the estimated coefficients of effect of effective rate on winning bid. See Appendix C form more information and Table A.8 for the associated statistical tests.

Figure A.6. Effect of removing federal excludability on winning bids



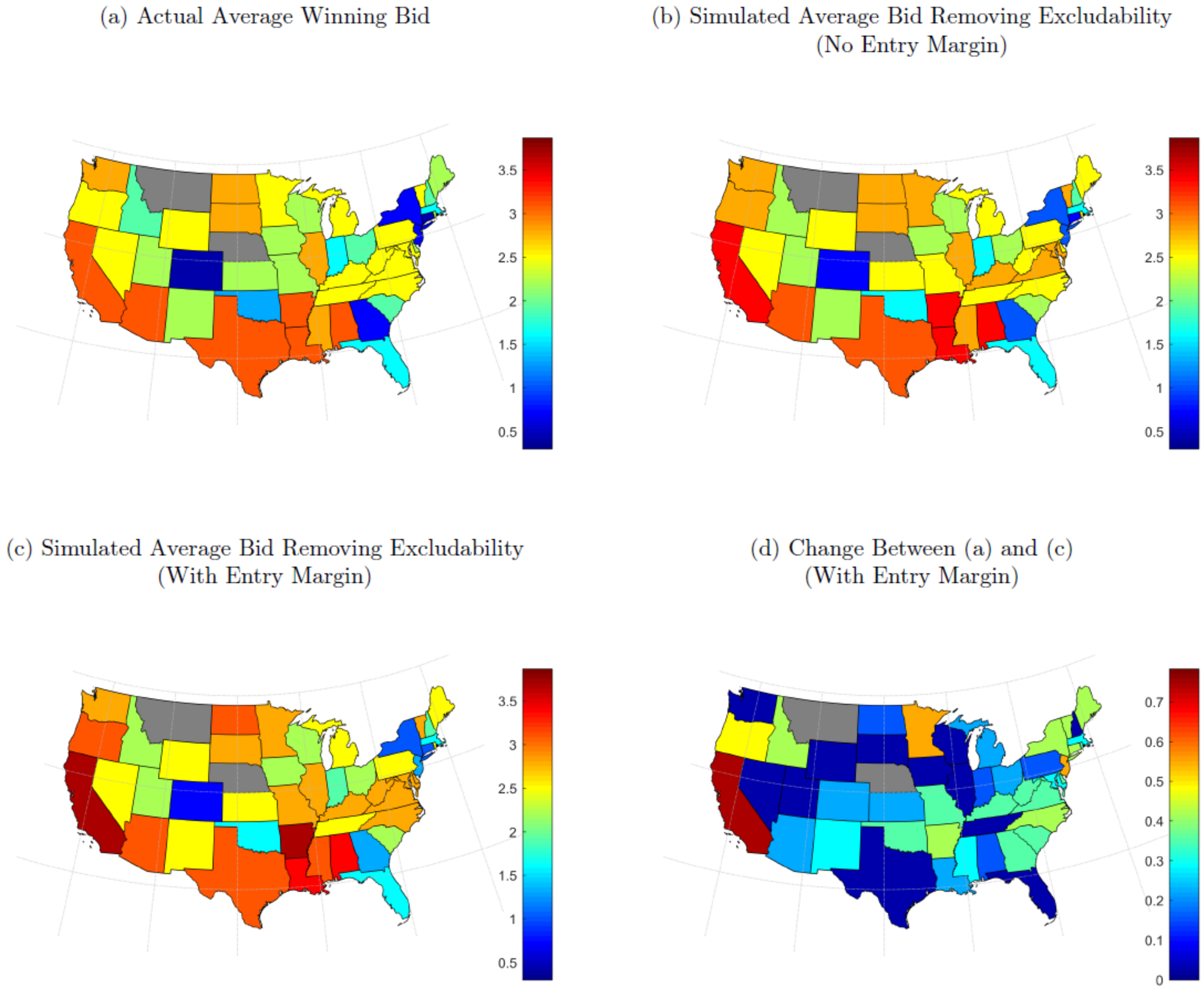
Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the federal exclusion was removed. See Section 7 for additional discussion and Figure A.7 for the corresponding markups. The comparable estimates of winning bids when capping the federal exemption at 28% is shown in Figure 8. The average effects from the policy reforms are shown in Table 8, the parameter estimates are displayed in Table 5, and federal α-policy outcomes for borrowing rates and markups are shown in Figure 7.

Figure A.7. Effect of removing federal excludability on markups



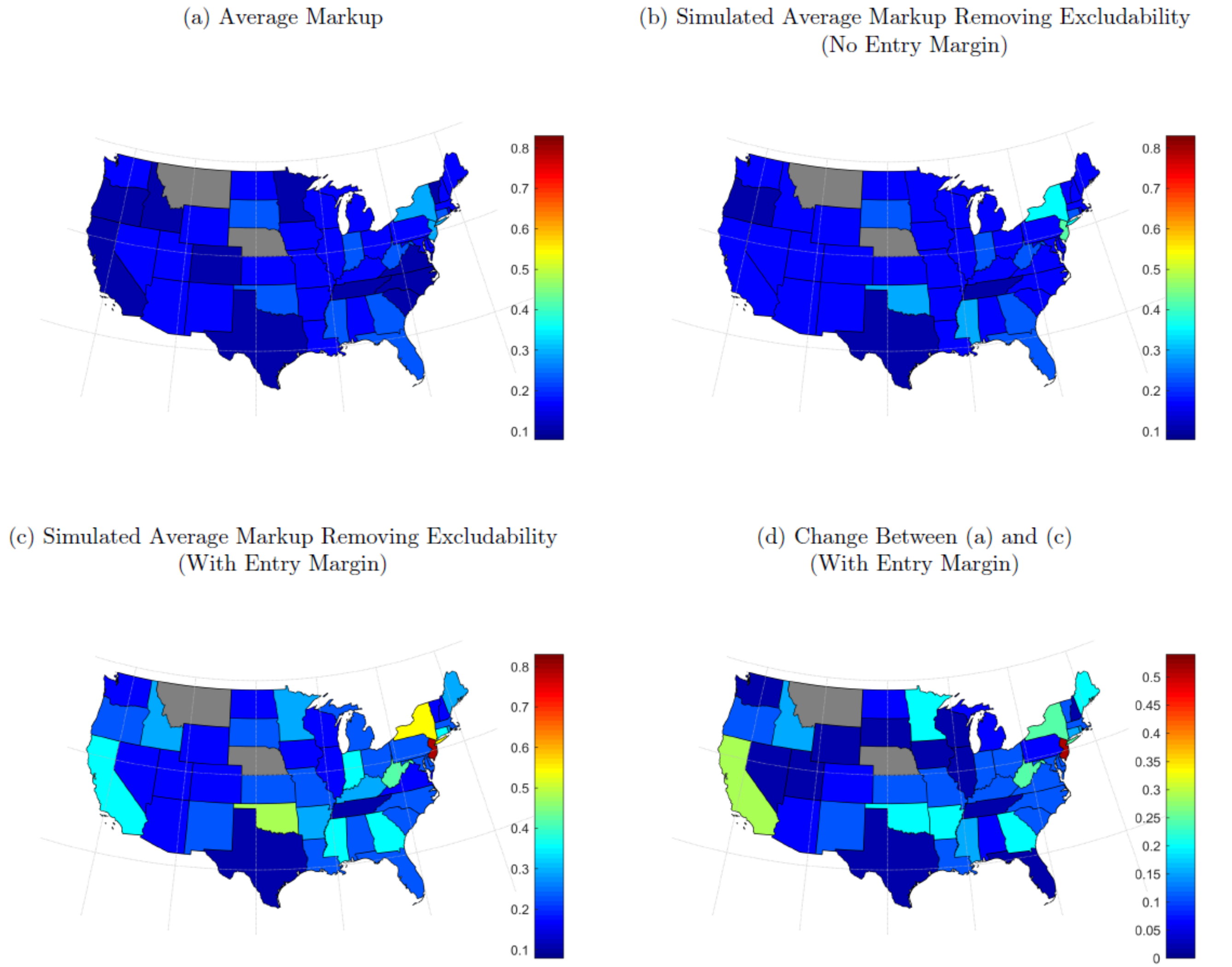
Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the federal exclusion was removed. See Section 7 for additional discussion and Figure A.6 for the corresponding bids. The comparable estimates of markups when capping the federal exemption at 28% is shown in Figure 9. The average effects from the policy reforms are shown in Table 8, the parameter estimates are displayed in Table 5, and federal α-policy outcomes for borrowing rates and markups are shown in Figure 7.

Figure A.8. Effect of removing state excludability on winning bids



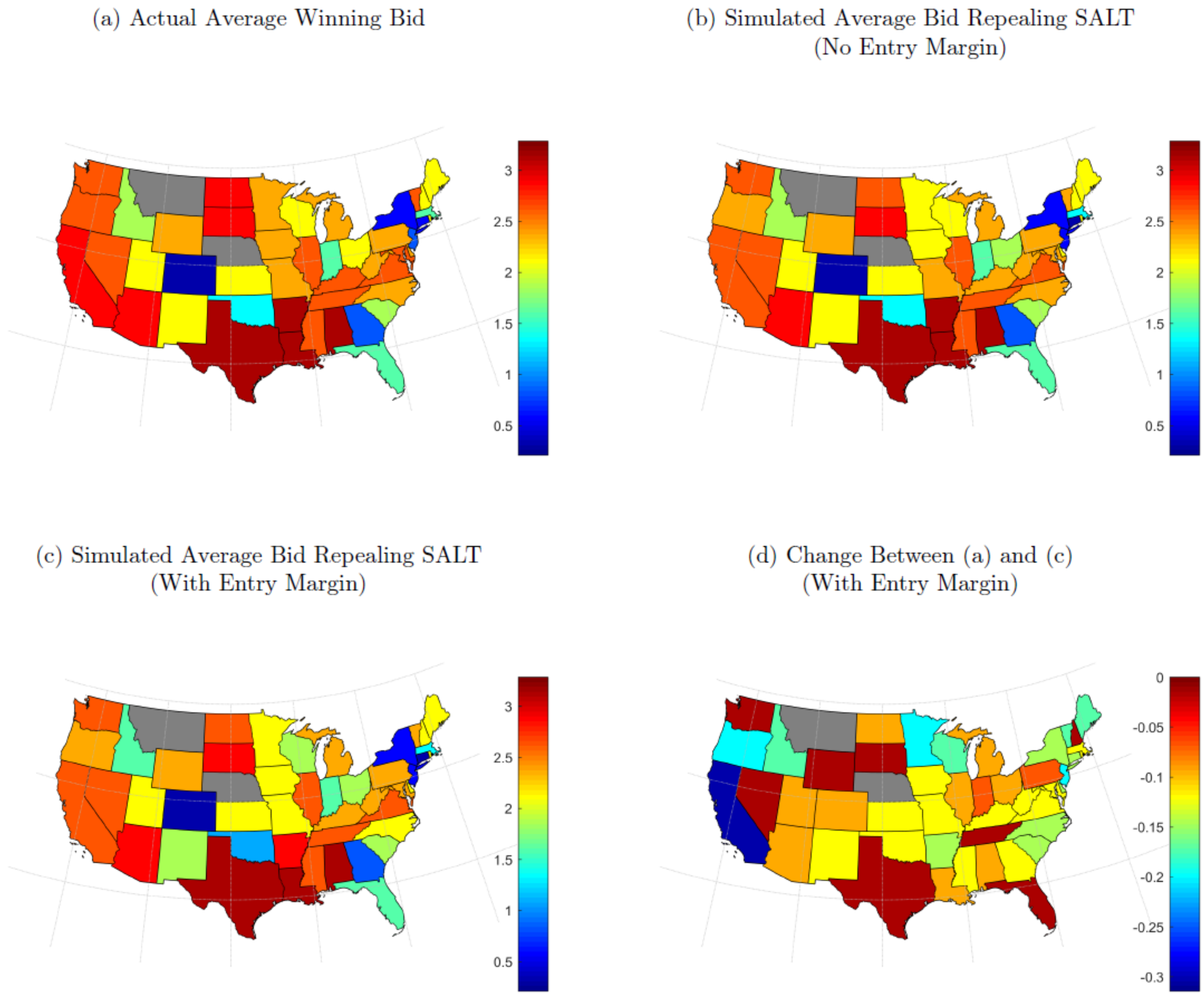
This figure shows spatial heterogeneity in counterfactual estimates of markups if the state exclusion was removed. See Section 7 for additional discussion and Figure A.9 for the corresponding markups. The comparable estimates of winning bids when capping the federal exemption at 28% is shown in Figure 8. The average effects from the policy reforms are shown in Table 8 and the parameter estimates are displayed in Table 5.

Figure A.9. Effect of removing state excludability on markups



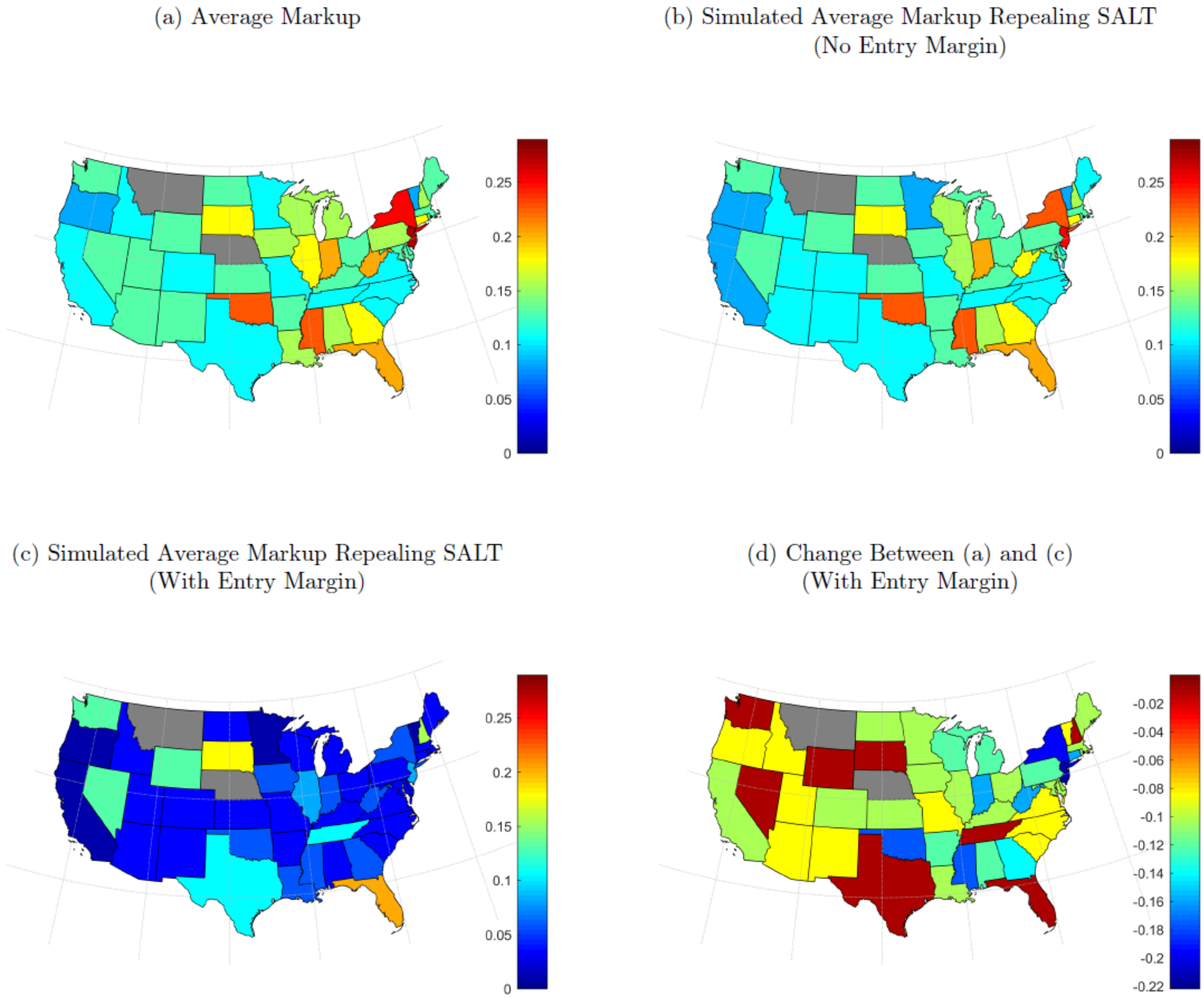
Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the state exclusion was removed. See Section 7 for additional discussion and Figure A.8 for the corresponding bids. The comparable estimates of markups when capping the federal exemption at 28% is shown in Figure 9. The average effects from the policy reforms are shown in Table 8 and the parameter estimates are displayed in Table 5.

Figure A.10. Effect of repealing SALT on winning bids



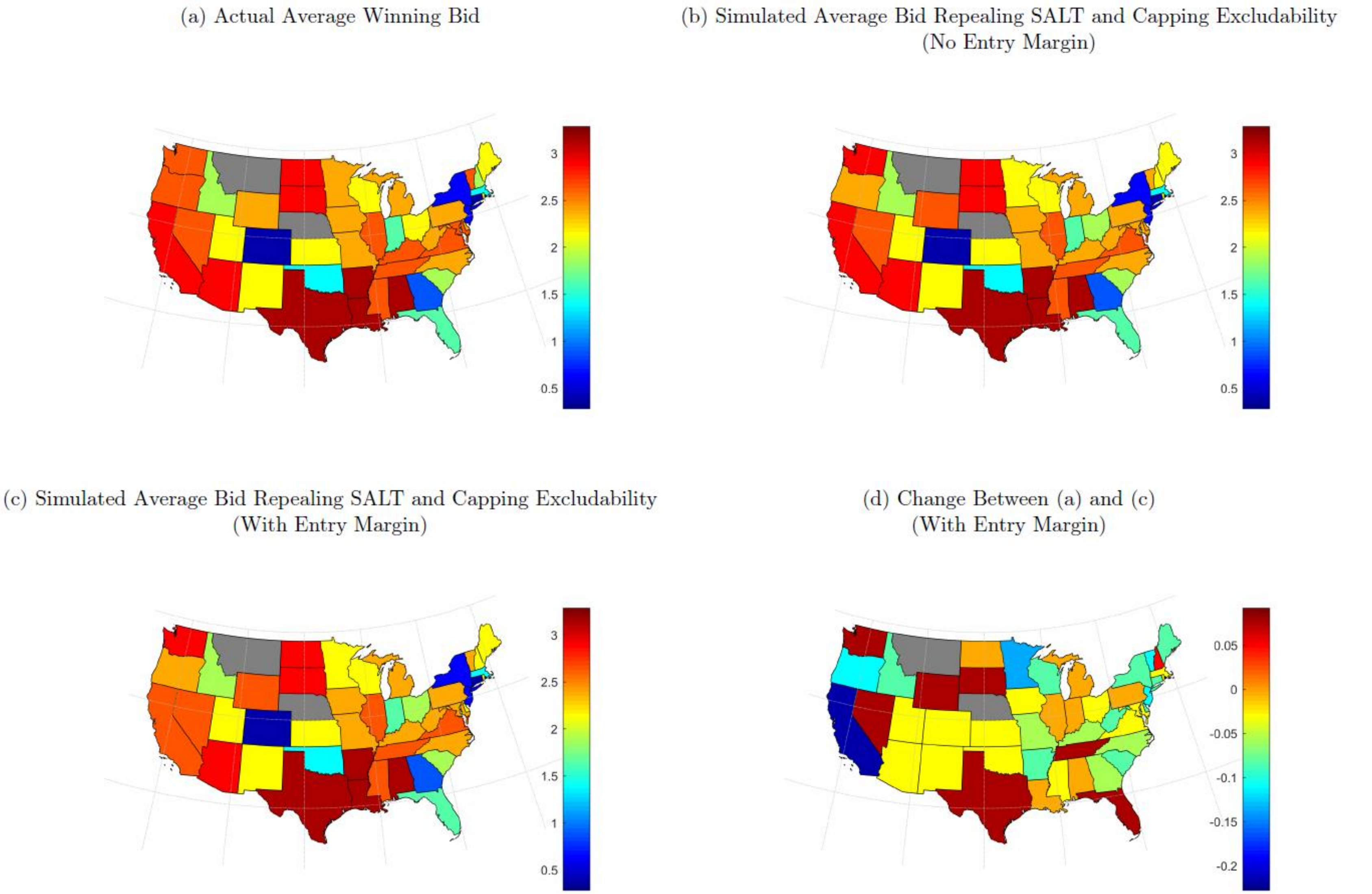
Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the SALT deduction was removed. See Section 7 for additional discussion and Figure A.11 for the corresponding markups. The comparable estimates of winning bids when capping the federal exemption at 28% is shown in Figure 8. The average effects from the policy reforms are shown in Table 8 and the parameter estimates are displayed in Table 5.

Figure A.11. Effect of repealing SALT on markups



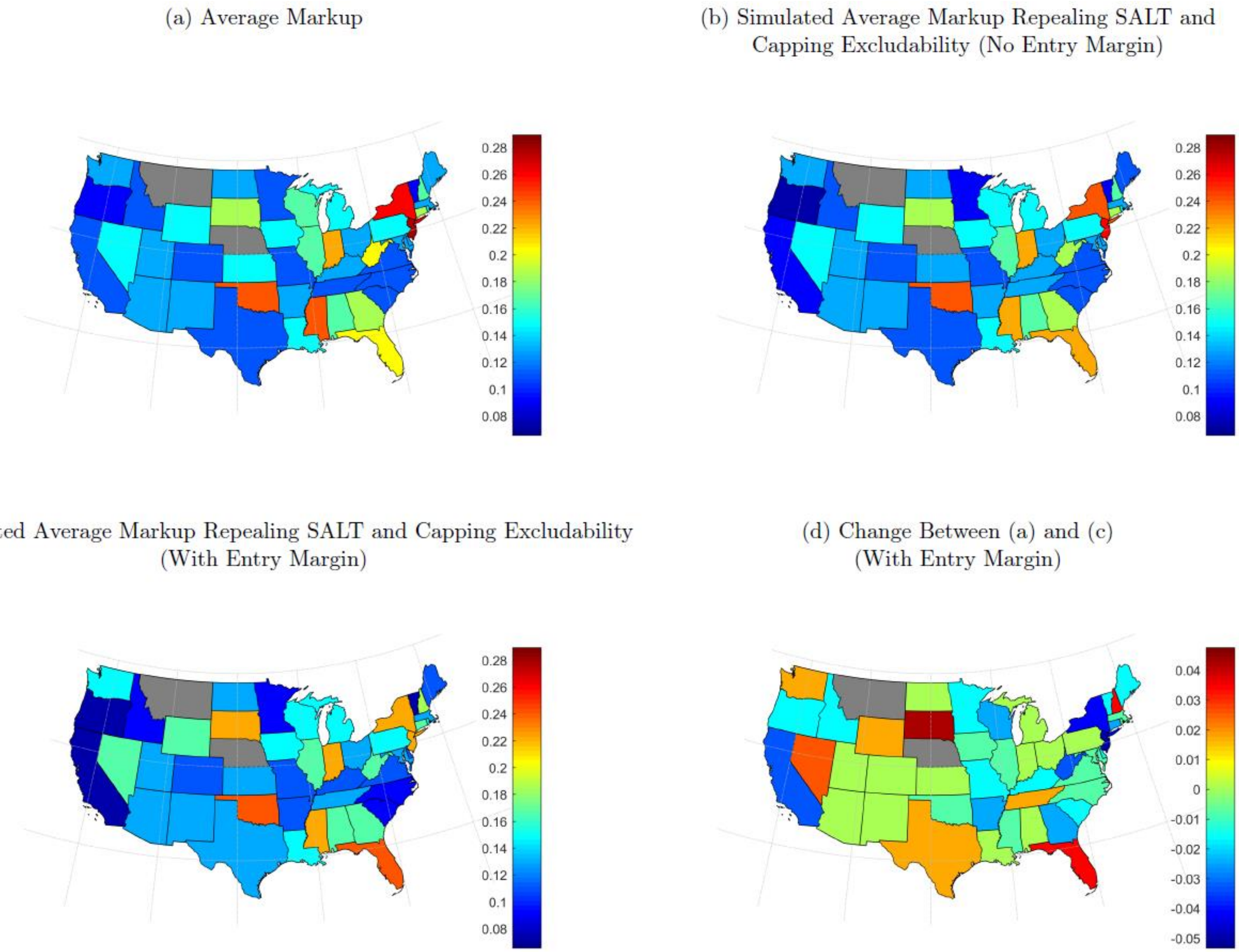
Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the SALT deduction was removed. See Section 7 for additional discussion and Figure A.10 for the corresponding bids. The comparable estimates of markups when capping the federal exemption at 28% is shown in Figure 9. The average effects from the policy reforms are shown in Table 8 and the parameter estimates are displayed in Table 5.

Figure A.12. Effect of repealing SALT and capping federal excludability at 37% on winning bids



Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the SALT deduction was removed and federal excludability capped at 37%. See Section 7 for additional discussion and Figure A.13 for the corresponding markups. The comparable estimates of winning bids when only SALT is repealed are shown in Figure A.10. The average effects from the policy reforms are shown in Table 8 and the parameter estimates are displayed in Table 5.

Figure A.13. Effect of repealing SALT and capping federal excludability at 37% on markups



Notes: This figure shows spatial heterogeneity in counterfactual estimates of markups if the SALT deduction was removed. See Section 7 for additional discussion and Figure A.12 for the corresponding bids. The comparable estimates of markups when only SALT is repealed are shown in Figure A.11. The average effects from the policy reforms are shown in Table 8 and the parameter estimates are displayed in Table 5.

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 details.

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 details.

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 details.

Table A.4. Reduced-form effects of the effective rate on winning bid and the number of potential bidders: Robustness checks part 1

	(1)	(2)	(3)
Unconditional Effect of Effective Rate on Bid			
Effective Rate	-6.531	-6.659	-6.738
	(2.527)	(2.182)	(2.218)
	0.010	0.002	0.003
Effect of Effective Rate on N			
Effective Rate	0.581	0.523	0.519
	(0.118)	(0.121)	(0.127)
	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid			
Effective Rate	-4.525	-4.704	-5.475
	(2.514)	(2.248)	(2.285)
	0.073	0.037	0.017
Observations	14,631	14,613	14,613
Median Bid	221.2	221.0	221.0
Median Effective Tax	40.79	40.79	40.79
Elasticity (Median)	1.748	1.784	1.805
	(0.677)	(0.585)	(0.594)
	0.010	0.002	0.002
Base Controls	Y		Y
Structural Model Controls		Y	Y
Bidder Fixed Effects			Y
Issuer Fixed Effects			Y
Unemployment Rate			Y
Gross Domestic Product (log)			Y
State Government Spending (log)			Y
State Intergov Spending (log)			Y
Political Party Controls			Y
Personal, Business, and Prop Tax			Y
Sales Tax Controls			Y
Size of Bond Package Controls			Y

Notes: This table presents more estimates corresponding to Table 2. The base controls include state, year, maturity, quality, and refund status fixed effects in addition to effective rate, which is the same as column (1) in Table 2. See Appendix C for details and Appendix A for variable definitions. Standard errors clustered at the state-year level are shown in parentheses and p-values for each estimate are displayed below standard errors.

Table A.5. Reduced-form effects of the effective rate on winning bid and the number of potential bidders: Robustness checks part 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Unconditional Effect of Effective Rate on Bid							
Effective Rate	-6.806	-6.806	-6.806	-6.806	-5.381	-5.323	-6.456
	(1.048)	(2.187)	(2.244)	(2.879)	(2.123)	(2.127)	(2.265)
	0.000	0.002	0.003	0.022	0.012	0.013	0.005
Effect of Effective Rate on N							
Effective Rate	0.547	0.547	0.547	0.547	0.499	0.503	0.436
	(0.050)	(0.119)	(0.133)	(0.128)	(0.122)	(0.109)	(0.113)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Conditional Effect of Effective Rate on Bid							
Effective Rate	-5.222	-5.222	-5.222	-5.222	-4.299	-4.251	-5.047
	(0.999)	(1.980)	(2.282)	(2.836)	(2.215)	(2.190)	(2.238)
	0.000	0.008	0.023	0.072	0.053	0.053	0.025
Observations	14,631	14,631	14,631	14,631	14,631	14,631	34,868
Median Bid	221.2	221.2	221.2	221.2	221.2	221.2	193.8
Median Effective Tax	40.79	40.79	40.79	40.79	40.79	40.79	40.79
Elasticity (Median)	1.822	1.822	1.822	1.822	1.440	1.425	1.971
	(0.280)	(0.585)	(0.601)	(0.771)	(0.568)	(0.569)	(0.692)
	0.000	0.002	0.002	0.018	0.011	0.012	0.004
Robust Standard Errors	Y						
SE Cluster State-Month		Y					
SE Cluster State-Year			Y		Y	Y	Y
SE Cluster State				Y			
Monthly Fixed Effects					Y		
Daily Fixed Effects						Y	
Including Small Bonds							Y

Notes: All specifications in this table include state, year, maturity, quality, and refund status fixed effects and size, which are the same controls in Table 2, column (5). Columns (1) to (4) show the results with different calculations of standard errors–robust, state-month clusters, state-year clusters, and state clusters. Columns (5) and (6) use month and day fixed effects instead of year fixed effects. Column (7) includes the whole universe of competitive bonds including those smaller than $5 million and weights bonds according to size bins. See Appendix C for details and Appendix A for variable definitions. Standard errors clustered at the state-year level are shown in parentheses and p-values for each estimate are displayed below standard errors.

Table A.6. 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
	(0.093)	(0.095)	(0.099)	(0.101)	(0.098)
	0.000	0.000	0.001	0.001	0.002
Effect of Effective Rate on N (Definition 1)					
Effective Rate	0.561	0.554	0.542	0.550	0.547
	(0.120)	(0.124)	(0.131)	(0.132)	(0.133)
	0.000	0.000	0.000	0.000	0.000
Effect of Effective Rate on N (Definition 2)					
Effective Rate	1.373	1.413	1.411	1.467	1.345
	(0.333)	(0.337)	(0.347)	(0.346)	(0.343)
	0.000	0.000	0.000	0.000	0.000
Year Fixed Effects	Y	Y	Y	Y	Y
State Fixed Effects	Y	Y	Y	Y	Y
Maturity and Size Controls	Y	Y	Y	Y	Y
Quality and Refund Controls	Y	Y	Y	Y	Y
Political Party Controls		Y	Y	Y	Y
Personal Income Tax Base Controls			Y	Y	Y
Sales Tax Controls				Y	Y
Business and Property Tax Controls					Y

Notes: Section 2 discusses the data and the primary definition of potential bidders. The second definition of N is the total unique bidders in the state-month for each auction. A version of the structural model using the second definition of N is discussed in Appendix E. Standard errors clustered at the state-year level are in parentheses and p-values are listed below standard errors.

Table A.7. Effect of effective rate on supply of bond auctions

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

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

Table A.8. 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	-6.417	-4.786
	(2.425)	(2.411)
	0.008	0.047
Fixed Effect Estimate		
Effective Rate	-6.531	-4.525
	(2.517)	(2.501)
	0.009	0.070
Observations	14,631	14,631
Score p-value (Interactions)	0.000	0.000
Hausman p-value (APE=FE)	0.846	0.613
Percentage diff (APE-FE)/FE	0.017	-0.058
	(0.088)	(0.126)
	0.843	0.649
Percentage Due to Competition (APE)		0.254
Percentage Due to Competition (FE)		0.307

Notes: Standard errors are shown in parentheses with p-values below 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.9. Oster coefficient stability tests

	(1)	(2)	(3)
	Table 2, (1)	Table 2, (1)	Table 2, (5)
Effective Rate	-6.531	-6.531	-6.806
	(2.527)	(2.527)	(2.244)
	0.010	0.010	0.003
R^2	0.898	0.898	0.899
	Table 2, (5)	Table A.4, (3)	Table A.4, (3)
Effective Rate	-6.806	-6.738	-6.738
	(2.244)	(2.218)	(2.218)
	0.003	0.003	0.003
R^2	0.899	0.953	0.953
Observations	14,631	14,613	14,613
δ such that $\beta^* = 0$	[< 0]	[< 0]	113.424
Corrected β^*	-34.614	-6.915	-6.679

Notes: Standard errors clustered at the state level are shown in parentheses and p-values are below standard errors. This table uses an estimator from Oster (2017) to test how much selection on unobservables is needed to negate the results in Tables 2 and A.4. Each cell represents the results of a previously estimated model. Under some assumptions on the nature of selection discussed in Oster (2017), 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 113.4 times more important than selection on observables for our results to be negated. For more information see Appendix C.5.

Table A.10. Effect of interest payments on effective rate, lags

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

Notes: Standard errors clustered at the state level are shown in parentheses and p-values are below standard errors. This table regresses tax rates in percentage points on percent change in governmental interest payments from 1994-2014 at the state level. This test of potential reverse causality fails to find evidence of any impact of previous and current interest costs on borrowing rates. For more information see Appendix C.6.

Table A.11. Effect of interest payments on effective rate, leads

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

Notes: Standard errors clustered at the state level are shown in parentheses and p-values are below standard errors. This table regresses tax rates in percentage points on percent change in governmental interest payments from 1994-2014 at the state level. This test of potential reverse causality fails to find evidence of any impact of current and future interest costs on borrowing rates. For more information see Appendix C.6.

Table A.12. Simulations on in-sample observables, average moments from models S1 through S5

Statistic	S1	S2	S3	S4	S5
Model Fit					
Winning Bid in Data: b_1	2.15	2.15	2.15	2.15	2.15
Simulated Winning Bid: b_1	2.07	2.10	2.08	2.07	2.08
Entry Probability in Data: n/N	0.70	0.34	0.70	0.70	0.70
Simulated Entry Probability: n/N	0.72	0.32	0.72	0.76	0.69
Simulation Results					
Markup: m_1	0.17	0.18	0.17	0.16	0.18
Markup Rate: m_1/b_1	0.20	0.23	0.20	0.19	0.20
Entry Cost Threshold: d^*	0.49	0.43	0.74	0.63	0.10

Notes: This table shows model fit and simulation results for in-sample observations from each of the variants of the baseline model. The simulation results regarding markups from the baseline model are displayed in Table 6. The model fit is still very similar to the baseline specification and markups are almost identical. The first robustness specification allows means to be a flexible piece-wise function of observables. The second specification uses the definition of a potential bidder to be all unique bidders in a state in a given month. The third specification restricts the threshold parameter to be equal to zero for all auctions. The fourth specification holds the effect of the effective rate on the standard deviation of bids to be equal to zero. The final specification truncates the distribution of bids at the entry stage. Section 4 discusses the setup of the model while Appendix E contains information about the specification of and reasoning behind each of the model robustness checks.

Table A.13. Average effects from counterfactual policy reform S1: Robustness to flexible controls

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

	(1)	(2) Trump Proposal	(3) Obama Proposal	(4) No Federal Exclusion	(5) No State Exclusion	(6) No SALT	(7) TCJA17
	$\alpha = 1$	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid							
Partial (No Potential Entry)	1.91	1.95	2.17	2.67	2.05	1.85	1.89
Full	1.91	2.00	2.48	3.38	2.21	1.80	1.87
Markups							
Partial (No Potential Entry)	0.18	0.19	0.26	0.63	0.22	0.17	0.18
Full	0.18	0.22	0.52	1.60	0.35	0.14	0.16

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

	(1) Trump Proposal	(2) Obama Proposal	(3) No Federal Exclusion	(4) No State Exclusion	(5) No SALT	(6) TCJA17
	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid						
Partial (No Potential Entry)	1.88%	13.49%	39.56%	7.00%	-3.37%	-1.33%
Full	4.51%	29.68%	76.49%	15.33%	-6.07%	-2.44%
Markups						
Partial (No Potential Entry)	4.65%	40.60%	246.17%	21.26%	-8.06%	-3.50%
Full	20.54%	185.36%	775.57%	92.10%	-20.63%	-9.56%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 96% 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 4 discusses the setup of the model while Section 7 discusses the counterfactual simulations. Appendix E contains information about specification S1 and other robustness checks.

Table A.14. Average sffects from counterfactual policy reform S2: Robustness to alternative definition of *N*

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

	(1)	(2) Trump Proposal	(3) Obama Proposal	(4) No Federal Exclusion	(5) No State Exclusion	(6) No SALT	(7) TCJA17
	$\alpha = 1$	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid							
Partial (No Potential Entry)	1.91	1.95	2.20	2.88	2.06	1.84	1.89
Full	1.91	1.97	2.36	3.33	2.14	1.81	1.87
Markups							
Partial (No Potential Entry)	0.15	0.16	0.21	0.43	0.18	0.14	0.15
Full	0.15	0.16	0.27	0.94	0.20	0.14	0.15

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

	(1) Trump Proposal	(2) Obama Proposal	(3) No Federal Exclusion	(4) No State Exclusion	(5) No SALT	(6) TCJA17
	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid						
Partial (No Potential Entry)	2.02%	14.85%	50.53%	7.70%	-3.62%	-1.43%
Full	3.12%	23.41%	73.87%	11.71%	-5.15%	-2.02%
Markups						
Partial (No Potential Entry)	3.90%	33.36%	180.40%	17.01%	-6.71%	-2.78%
Full	5.27%	73.42%	512.18%	29.15%	-6.29%	-2.45%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 96% 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 4 discusses the setup of the model while Section 7 discusses the counterfactual simulations. Appendix E contains information about specification S2 and other robustness checks.

Table A.15. 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)	(2) Trump Proposal	(3) Obama Proposal	(4) No Federal Exclusion	(5) No State Exclusion	(6) No SALT	(7) TCJA17
	$\alpha = 1$	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid							
Partial (No Potential Entry)	1.91	1.95	2.16	2.61	2.04	1.85	1.89
Full	1.91	1.98	2.39	3.21	2.16	1.82	1.87
Markups							
Partial (No Potential Entry)	0.18	0.19	0.26	0.64	0.22	0.17	0.18
Full	0.18	0.22	0.51	1.61	0.35	0.14	0.16

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

	(1) Trump Proposal	(2) Obama Proposal	(3) No Federal Exclusion	(4) No State Exclusion	(5) No SALT	(6) TCJA17
	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid						
Partial (No Potential Entry)	1.80%	12.86%	36.70%	6.68%	-3.22%	-1.27%
Full	3.62%	25.19%	67.87%	12.97%	-5.08%	-2.03%
Markups						
Partial (No Potential Entry)	4.64%	40.54%	252.13%	21.23%	-8.05%	-3.49%
Full	20.40%	182.85%	785.24%	90.87%	-20.54%	-9.52%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 96% 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 4 discusses the setup of the model while Section 7 discusses the counterfactual simulations. Appendix E contains information about specification S3 and other robustness checks.

Table A.16. 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)	(2) Trump Proposal	(3) Obama Proposal	(4) No Federal Exclusion	(5) No State Exclusion	(6) No SALT	(7) TCJA17
	$\alpha = 1$	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid							
Partial (No Potential Entry)	1.91	1.96	2.28	3.28	2.10	1.83	1.88
Full	1.91	2.00	2.50	3.61	2.22	1.79	1.86
Markups							
Partial (No Potential Entry)	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Full	0.20	0.23	0.41	0.51	0.32	0.17	0.19

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

	(1) Trump Proposal	(2) Obama Proposal	(3) No Federal Exclusion	(4) No State Exclusion	(5) No SALT	(6) TCJA17
	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid						
Partial (No Potential Entry)	2.58%	19.36%	71.70%	9.97%	-4.57%	-1.82%
Full	4.42%	30.76%	88.51%	16.03%	-6.41%	-2.58%
Markups						
Partial (No Potential Entry)	-0.00%	-0.02%	-0.06%	-0.01%	0.01%	0.00%
Full	14.74%	103.10%	155.74%	57.20%	-13.62%	-6.70%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 96% 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 4 discusses the setup of the model while Section 7 discusses the counterfactual simulations. Appendix E contains information about specification S4 and other robustness checks.

Table A.17. 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)	(2) Trump Proposal	(3) Obama Proposal	(4) No Federal Exclusion	(5) No State Exclusion	(6) No SALT	(7) TCJA17
	$\alpha = 1$	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid							
Partial (No Potential Entry)	1.91	1.96	2.28	3.05	2.10	1.82	1.88
Full	1.91	1.99	2.49	3.65	2.21	1.79	1.87
Markups							
Partial (No Potential Entry)	0.18	0.19	0.26	0.63	0.22	0.17	0.17
Full	0.18	0.22	0.52	1.61	0.35	0.14	0.16

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

	(1) Trump Proposal	(2) Obama Proposal	(3) No Federal Exclusion	(4) No State Exclusion	(5) No SALT	(6) TCJA17
	$\alpha = 0.96$	$\alpha = 0.73$	$\alpha = 0$			$\alpha = 0.96$
Winning Bid						
Partial (No Potential Entry)	2.61%	18.93%	59.58%	9.81%	-4.66%	-1.85%
Full	4.21%	30.23%	90.81%	15.53%	-6.26%	-2.50%
Markups						
Partial (No Potential Entry)	4.74%	41.58%	248.34%	21.72%	-8.21%	-3.56%
Full	20.54%	187.71%	787.52%	92.94%	-20.66%	-9.56%

Notes: This table shows counterfactual bids and markups under two policy proposals–limiting the federal exemption to 73% and 96% 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 4 discusses the setup of the model while Section 7 discusses the counterfactual simulations. Appendix E contains information about specification S5 and other robustness checks.

Hutchins Center
on Fiscal & Monetary Policy
at BROOKINGS

The mission of the Hutchins Center on Fiscal and Monetary Policy is to improve the quality and efficacy of fiscal and monetary policies and public understanding of them.

Questions about the research? Email communications@brookings.edu.
Be sure to include the title of this paper in your inquiry.