The Tax Gradient:

Do Local Sales Taxes Reduce Tax Differentials at State Borders?

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Abstract

Geographic borders create a discontinuous tax treatment of retail sales and encourage cross-border shopping by residents of high-tax states. But do municipalities' local option taxes smooth these discontinuities? In a model where towns within a federation maximize revenue and compete in a Nash game, equilibrium local tax rates decrease from the nearest high-tax border and increase from the nearest low-tax border. Using driving distance from the state border and data on all local sales tax rates in the United States for 2010, I empirically test whether tax rates follow the pattern predicted by this theoretical model. Local tax rates on the low-tax side of the border are significantly higher than on the high-tax side of the border, reducing the differential in state tax rates at the border by more than half. Consistent with the model's prediction, a 100 mile increase in distance from the nearest high-tax border lowers local tax rates by 15% of the average local rate. Local taxes fall most rapidly closest to the border and when the differential in state tax rates is largest.

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1 Introduction

The total sales tax rate in America ranges anywhere between 0% and 11%. Given these disparities in tax rates, consumers may have large incentives to engage in cross-border shopping, while firms may have large incentives to locate on the low-tax side of borders. Geographic borders create discontinuous changes in tax rates, which distort individual consumption and firm location decisions. Moreover, these discrete jumps in tax rates at borders may induce towns to levy their sales tax based on an approximately continuous function of distance from the border. This motivates my main question of interest: do localities assess local sales taxes as a function of distance from the nearest state border, where tax rates decrease for localities further from a higher-tax state, and increase for localities further from a lower-tax state?

Consider the example of high-tax California and low-tax Oregon. As a possible policy, California could change taxes continuously and set lower taxes closer to the Oregon border. This policy, in comparison to the uniform discontinuous case, would not change the effective price of the good for consumers (including taxes and transportation costs), but may keep extra revenue in California. However, a tax rate that is continuous in distance from the border may have high administrative costs. Use of the local option sales tax may be an administratively feasible way of obtaining a geographically differentiated pattern of sales tax rates.

As a consequence of distortions from state tax competition, a municipality will set geographically differentiated tax rates depending on distance from the border. Therefore, the spatial arrangement of jurisdictions determines the strategic nature of local tax competition. Intuitively, the spatial arrangement matters because state borders influence the elasticity of demand with respect to prices. Local jurisdictions with a lower elasticity of demand will set higher tax rates. In the presence of discontinuous changes in state tax rates at borders, on the low-tax side, jurisdictions near the border realize a smaller elasticity of demand because the inflow of cross-state shoppers augments their tax base. On the high-tax side, the elasticity of demand is larger for jurisdictions near the border because the outflow of cross-state shoppers reduces the tax base.

In the context of a theoretical model that expands several elements from Kanbur and Keen (1993), I demonstrate that from the local government's perspective, the equilibrium tax rates in a federal system depend on the distance of each jurisdiction to a neighboring state. This contrasts with the existing tax competition literature, which has focused on the role of jurisdiction size as a determinant of tax rates and has generally concluded that if jurisdictions are the same in all characteristics, they will select the same tax rate. The model in this paper provides a novel insight that the spatial characteristics of towns – distance from the border and the size of the discontinuity in state tax rates at the border – within a federation determine tax rates. Given varying public good preferences across states, a broad uniform tax rate within the federation will not occur in equilibrium if sub-state governments exist – even if all of the sub-federal governments are identical in every respect except spatial arrangement.

The theoretical model yields four testable results. First, in a local region of the border, municipal sales taxes on the low-tax side of the border are higher than municipal taxes on the high-tax side of the border. Second, on the relatively low-tax side of the border, municipal taxes decrease as towns are further from the border; on the relatively high-tax side of the border, local taxes increase as towns are further from the border. I refer to the pattern (slope) of local option taxes, moving away from the border, as the "tax gradient." Third, local taxes rise or fall most rapidly in the vicinity of the state border. That means that the tax gradient is steepest in the vicinity of the border. Fourth, the size of the discontinuity affects the slope of the tax gradient. The tax gradient is steeper when the differential in state tax rates is larger.

Empirically, the paper examines whether localities with the option to assess local sales taxes set their tax rate in a manner consistent with the four theoretical propositions above. The methodology outlined in the paper will be applicable to research on how jurisdictions respond to any policy (e.g., environmental, labor) that varies discontinuously at the state border. The paper uses a previously unused and comprehensive data set of all local sales tax rates in the United States – municipal, county, and district rates. I also have created an accurate and detailed data set of spatial proximity to borders. I find the shortest driving distance from the population centroid of each town to a state-border major road crossing, in order to accurately measure how towns set tax rates away from the border. This distance minimizes measurement error in the actual distance a consumer would travel to cross-border shop.

First, I find that local tax rates on the low-tax side of the border are significantly higher than on the high-tax side of the border, reducing the differential in state tax rates at the border by more than half. Ignoring local option taxes, the average differential in state tax rates is 1.9 percentage points. After accounting for all local option taxes, the tax differential at state borders decreases by 1.2 percentage points. Second, the average marginal effect of distance on the local (municipal plus sub-district) tax rate in a jurisdiction is significantly negative and of the expected sign on the low-tax side. The marginal effect of distance is robust to controlling for distance from the second closest state border and the distance from county borders. A 100 mile increase in distance from the nearest high-tax border lowers local tax rates by 15% of the average local rate. Third, taxes fall most rapidly in a local region of the border. Fourth, taxes fall more rapidly if the tax differential in state tax rates is larger.

This paper will proceed as follows. After presenting background on local option taxes, I develop a model where multiple town governments face pressures from tax differentials at multiple state borders and choose the local tax rates in order to maximize revenue in the town. I show that in a Nash equilibrium, local tax rates depend on the distance from a state border. I test this theoretical result in the empirical analysis. Given that the system of local option sales taxes in the United States approximates the theoretical model, I evaluate whether such a relationship between tax rates and distance from the state border exists in the data using a global polynomial regression design. Finally, I discuss the welfare implications of the policy and offer some concluding thoughts.

2 Background

In this section, I review the standard tax competition literature that my model will build upon. I also review current studies that have incorporated a role for distance from the border in their empirical or theoretical analysis of cross-border shopping. Finally, I provide policy background on local taxes and how they vary across states.

2.1 Comparison to the Existing Literature

2.1.1 Tax Competition and Distance

Previous literature on tax competition tries to explain asymmetries in tax rates among competing jurisdictions when each jurisdiction chooses a uniform tax rate within its boundaries. The approach to solving this problem has varied substantially. Kanbur and Keen (1993) develops a model with a single good in partial equilibrium where governments are revenue maximizers. Nielsen (2001) extends Kanbur and Keen (1993) to welfare maximizing governments, but relies on an additively separable relationship between consumer surplus and revenue. Hoyt (2001) studies the optimality of sales taxes within a federation.

The conclusions from these models highlight the way jurisdictions may reach an equilibrium with different tax rates. Haufler (1996) implies that a state like California may have higher tax rates than Oregon because of stronger preferences for public goods. This is in contrast to models such as Bucovetsky (1991), Kanbur and Keen (1993), Nielsen (2001), and Trandel (1994), which focus on country size or population as an explanation for variation in tax rates and find that larger jurisdictions set higher rates. This paper uses the result that tax differentials will exist at state borders as a starting point. The model proposed in my paper will extend Kanbur and Keen (1993) by incorporating multiple competitors and distance from the border as an explanation for tax differences within states. My model will help to explain responses of jurisdictions to tax notches, which according to Slemrod (2010) are widespread in any federalist tax system.

Recently, several studies have focused on the role of distance to a competing jurisdiction, which will be a key variable in this paper. Lovenheim (2008) studies how distance from the nearest lower-tax cigarette state relates to the demand elasticity of home state consumption. He finds that cigarette demand becomes more elastic to the home state price the further individuals live from a lower price cigarette border because the cost to obtain a given amount of saving rises. This implies that cross-border shopping is most problematic for border localities.[1] In a similar light, Harding, Leibtag and Lovenheim (Forthcoming) find that the incidence of taxation varies depending on a firm's distance from the nearest lower-tax border. Both papers find that the nearest low-tax border is the only border which results in any geographic differentiation. Merriman (2010) also analyzes distance from the border and shows the likelihood of having an Indiana cigarette tax stamp (the low-tax neighboring state to Illinois) is decreasing in the distance from the Indiana border. The results from these papers clearly indicate that distance from the border shapes the responsiveness of individuals to cross-border shop.

2.1.2 Competition Among Localities

Many studies have analyzed how local sales taxes influence cross-border shopping with little emphasis on the geographic distribution of these local sales tax rates within a state. Empirically, a large literature attempts to quantify the price responsiveness of consumers to state border effects. The findings suggest that a 1% increase in a sales tax rate results in a 1% to 6% reduction in sales, although the geographic unit of analysis varies across different studies (Mikesell 1970; Fox 1986; Walsh and Jones 1988; Tosun and Skidmore 2007). This behavioral response is indicative of the degree of cross-border shopping and will play an important role in the following model.

The behavioral response is also important to determine with whom localities compete. Using data on local sales tax rates in Tennessee, Luna (2003) demonstrates that the sales tax rates in neighboring states influence the tax rate that a local government selects, both in the long run and in the short run. Similar inter-dependencies are found in Georgia (Sjoquist et al. 2007). However, Luna, Bruce and Hawkins (2007) find that a jurisdiction does not decide to reach the maximum statutory rate based on its neighbors' decisions to do so.

[1] Using a similar methodology, Lovenheim and Slemrod (2010) studies the effect of having a neighboring county with a lower minimum legal drinking age on the number of accident fatalities.

2.1.3 Summary

Although the location of state borders are not chosen as a matter of policy, geographic borders between different states create a discontinuous tax policy. State borders are an example of a "line" in the tax system. The line creates a "notch" – or a discontinuous jump in the tax rate of the good based on the characteristics of the good – where the characteristic of the good is the location of purchase.

The existing literature indicates that competition over sales will naturally result in tax "notches" at state borders, but has ignored how localities will respond to these differentials. Given that these differentials arise, the empirical literature indicates cross-border shopping is highly elastic to tax rate changes. But, the responsiveness of cross-border shopping is empirically not uniform in a state, resulting in larger responses closer to the border. In light of this, local option taxes may provide a mechanism for smoothing tax differentials, which result in cross-border shopping and distorted firm location choices at state borders.

2.2 Background on the Local Option Sales Tax

Local option sales taxes (LOST) are widely used in the United States. Of the forty-five states that impose a sales tax ranging between 2.9% and 7%, thirty-six allow local or county governments to set LOST. Over 7,500 localities utilize this option. Among these towns, the local sales tax contributed anywhere from 1% to 52.2% of municipalities' revenues during fiscal year 2006 (Mikesell 2010). Sales taxes in the United States are levied *de facto* according to the origin principle.[2] This implies that the jurisdiction of sale rather than the jurisdiction of residence effectively determines the tax paid.

There is substantial variation in the way the local option sales tax works.[3] Fourteen states do not allow for LOST. Of the remaining states that allow for LOST, the locality's degree of autonomy varies greatly. For example, the smallest unit that is granted autonomy to assess a tax varies from the county level (example: Wyoming) to the town level (most states), to within-town jurisdictions such as fire, school or transportation districts (examples: Colorado or Georgia). Of states that allow municipalities to set a tax, some do not allow counties to assess an additional tax (example: South Dakota), although most do. In other

[2] When an individual cross-border shops, the sales tax is paid in the jurisdiction of purchase. However, the individual is legally responsible for filing a use tax – the excise tax on purchases of items for which the home state's sales tax was not previously paid – in the state of residence. The use tax is notoriously under-enforced. Because the use tax is often evaded, taxes are implicitly paid based on the sales tax and, therefore, are based on the origin of the purchase rather than the destination of the sale.

[3] All of the descriptions in this section come from my own review of the Department of Revenue sites for each state. The *Guide to Sales and Use Taxes* (Research Institute of America 2010) also provides state-by-state information on state sales taxes.

states, a mandatory county rate is set uniformly across the state with the option to increase the rate (example: California). Some consumers face different tax rates street blocks away while others need to travel more than 50 miles before the tax rate changes.

States also vary in terms of how the tax base is defined. Lines are drawn on what goods are taxed under the retail sales tax. In most states, the definition of the tax base at the state level is the base that applies to LOST. Some exceptions exist. For example, in the state of Florida, only the first $5,000 of a purchase is taxable under LOST. Other states impose restrictions on the rate increases that localities can impose at any given time. For example, counties in Ohio can only select taxes in increments of $1/4$ of a percentage point and the maximum rate a county can assess is capped (at a fairly high rate). On the other hand, the maximum LOST in Iowa is capped at 1 percentage point, so "maxing out" is common.

The method in which localities determine whether to implement LOST and the rate at which to set it also varies by state. In most states, only a city or town government needs to pass LOST. In other states, such as Iowa, the process is more complicated. In Iowa, a referendum determines LOST. Voters determine the rate of the tax, the purpose of the tax, and the sunset provisions on the tax. North Carolina, on the other hand, requires approval of the state legislature for LOST rates. The method of collection also varies; businesses remit taxes directly to the state or the locality, depending on the state.

Finally, two states allow local jurisdictions to set implicitly negative tax rates. Within Urban Enterprise Zones in New Jersey and Empire Zones in New York, localities may set tax rates lower than the state tax rate at no revenue cost to the locality. In fact, some locations elect to implement the favorable rate.

3 Theory of Local Competition with Heterogeneous States

In this section, I develop a model to evaluate the equilibrium commodity tax rates when local jurisdictions can assess a local sales tax. The goal of this model is to show that the equilibrium local sales tax rates are not uniform within a state – even if the towns are identical in preferences and size.

My paper extends Kanbur and Keen (1993)'s two-state partial equilibrium model of cross-border shopping by allowing for multiple jurisdictions and multiple levels of government. Compared to standard models, I place jurisdictions on a Salop Circle rather than a Hotelling line so that all jurisdictions have two neighbors.

3.1 Setup of the Model

The model features three states located on a circle that are indexed by $j = H, M, L$ for high-, medium-, and low-tax states.[4] Each state has three identical towns[5] indexed $i = A, B, BB$, where I arrange the towns along the circumference of a circle as depicted in Figure 1. "A" denotes the towns "Away" from the border. "B" and "BB" denote the towns close to the "Border" in their respective states. Each town is of equal length and each town covers a distance of x units along the line segment.

Modeling jurisdictions on a circle rather than a line has important implications. On a line segment, the towns furthest away from the state border have only one neighbor rather than two by virtue of their position at the end of the line segment. The purpose of this model is to determine – from a town government's perspective – the pattern of geographic differentiation resulting from the notch at the state border. When considering such a problem, the local government will take into account the town's position along the line segment, which includes both the number of towns away from the state border and the number of borders with other towns. Therefore, if I use a line segment in the model, towns on the exterior of the line will possibly have different rates for two reasons – one, because they are far from the state border and two, because they can only undercut one town rather than two and therefore have a different elasticity. However, all the variation in the tax rates is a result of distance from the border and not from the number of neighbors present, when I place the states along the circumference of a circle.[6]

The model has three agents: producers, consumers, and governments. I assume firms providing one private consumption good locate exogenously at any point along the circle's circumference. Firms are perfectly competitive and set price equal to marginal cost. When purchases at a particular point along the circle are high, more stores enter. Although the distribution of stores need not be uniform, firms are simply responding to consumption decisions; firms do not manipulate cross-border shopping. The implication of perfect competition is that increases in the demand of a good in a particular town – resulting from cross-border shopping – will not alter the pre-tax price relative to the pre-tax price in another town. Nor will taxes alter the pre-tax price. Therefore, the pre-tax price is the same in all jurisdictions and is normalized to one.[7]

State governments levy a state sales tax rate, τ^j, on commodity purchases within the

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[4] A two state-model is available online at http://www-personal.umich.edu/~dagrawal/research.htm.

[5] The towns could be equally sized sub-regions. The word "town" only need imply a governing entity.

[6] Of course, the linear model may be more descriptive to some states. One example is Florida, where the northern border touches two states. The Florida peninsula is surrounded entirely by ocean water, which implies that there are many Florida towns that are likely to have "one" less neighbor.

[7] The model assumes the incidence of the tax is fully passed forward to consumers as well.

state. In this analysis, I assume that state tax rates are exogenous and known to all localities before localities compete over taxes.[8] Exogenously different preferences for a state public good will imply that the state tax rates will differ across the states.[9] State H sets the highest tax rate and State L sets the lowest tax rate. State M has a rate in between the other two rates such that $\tau^H > \tau^M > \tau^L$. Denote $S = \tau^M - \tau^L$, $R = \tau^H - \tau^M$, and $D = \tau^H - \tau^L$ so that it measures the size of the "notch" induced by the state tax differential. Note that because states are around a circle, it must be that $D = S + R$. Town governments i in state j levy local taxes on the consumption good at rate t_i^j.[10] Taxes are assessed under the origin principle so that the location of purchase defines the tax rate that the consumer pays. Denote the sum of the state and local tax rate in jurisdiction i of state j as T_i^j so $T_i^j = \tau^j + t_i^j$. Towns compete in a Nash game over the local sales tax rates. The objective of the local government is to maximize the tax revenue it raises from the local tax on the consumption goods purchased within its town borders.[11]

Consumers are distributed uniformly across each town and the populations are identical in all towns. Consumers cannot migrate. Demand is perfectly inelastic. Each consumer will purchase one unit of the consumption good, but will have a choice over the location of purchase and can travel along the circumference of the circle to do so. Transportation costs make purchasing goods in another jurisdiction less beneficial.

Let V denote the reservation value net of the producer price for each consumer. V is

[8] The explicit assumption requires that tax competition over local sales tax rates has no effect on equilibrium state sales tax rates. The intuition for this is that most localities in the United States are small. Therefore, small changes in the local tax rates should not induce a response in the state sales tax rates. Of course, changes in large city tax rates may violate this assumption. An alternative model would be one where states are Stackelberg leaders.

[9] All states are the same in size and population density. Haufler (1996) shows that differences in preferences for the public good are an alternative explanation for varying tax rates in equilibrium. I assume that these exogenously different preferences for state public goods result in different state tax rates, but make no further use of this assumption.

[10] The model assumes governments only have access to a sales tax. If other tax instruments were available, the results below would be similar so long as governments rely on sales taxes to some extent.

[11] An alternative to modeling revenue maximizing governments is to model welfare maximizing governments. If governments maximize welfare, the government will care not only about the revenue raised, but also the amount of the consumption good its residents can purchase. Revenue maximizing governments can be interpreted in several ways. The solution to the problem of revenue maximizing governments approximates the solution to welfare maximizing governments when consumers have a high marginal value of the public good financed by the government. Second, so long as borders are open, the solution for revenue maximizing governments will approximate the welfare maximizing government's solution when the marginal utility of consumption is constant (which will be the case when the utility function of the individual is quasi-linear in consumption). Linearity in the consumption good seems to be a realistic assumption for cross-border shopping, which often results in many purchases of a few similar items. I use revenue maximizing governments in my model because the introduction of multiple towns and levels of government complicates the already complex problem of two competing jurisdictions and I need this simplifying assumption to make the model tractable.

assumed to be large enough so that all consumers either purchase one unit of the good from their home town or elsewhere. If the individual decides to purchase in the home town, she simply goes to the store at the point of the circle corresponding to where she lives and does not incur any transportation costs. If the consumer elects to do this, she purchases the good for a price equal to the tax-inclusive marginal cost of production. The surplus she will receive from such a purchase is $V - T_i^j$.

Alternatively, each consumer can purchase the consumption good elsewhere.[12] If she elects to do so, she will drive along the circumference to the nearest town border and purchase the good from the store located exactly at the border. Let the distance to the nearest town border for any consumer be denoted s. The transportation cost of traveling to the border (and back) is denoted $\delta > 0$ per unit of travel. The surplus the consumer will receive from purchasing one unit of the private good abroad is $V - T_k^l - \delta s$, where $k \neq i$ indexes the tax rate in a foreign town of state l, which may be equal to j if she does not cross state lines.

A consumer will purchase the private good from the neighboring town if the surplus of purchasing the good is strictly greater than zero and if the surplus from buying the good elsewhere is strictly greater than buying the good at home. Comparing the consumer surplus from purchasing the good elsewhere with the surplus from purchasing the good from home, it is evident that a consumer will purchase the good elsewhere if:

$$\frac{T_i^j - T_k^l}{\delta} > s \text{ for } T_i^j > T_k^l. \tag{1}$$

The implication of Equation 1 is that all residents who live farther than $\frac{T_i^j - T_k^l}{\delta}$ units from a low-tax border will purchase the good at home, while all other consumers cross-border shop in the nearest low-tax jurisdiction. The model assumes that x is sufficiently large so that towns do not have incentives to target consumers multiple towns over.[13]

[12] In reality, individuals also have the option to purchase goods on the Internet and completely evade taxes. As long as some people in each state still cross-border shop and the use of the internet does not vary by town, all the results of the model will carry through. The presence of an Internet with tax-free purchases will only affect the number of people cross-border shopping and the relative slopes of local tax rates, but the qualitative pattern will be the same.

[13] The assumption of shopping no more than one town over simplifies the nature of the problem, but would not change the qualitative results. Relaxing this assumption would require checking incentive constraints on the individual for all towns to which cross-border shopping is feasible. The assumption of a linear transport cost and a sufficiently large x rules out this possibility. Intuitively, relaxing this assumption would reduce the degree of geographic differentiation and the level of local tax rates as towns will compete over the tax rates more aggressively.

3.2 Benchmark Solutions

Given the assumptions outlined above, it is easy to see that each town government will extract all the surplus from its residents in equilibrium if all borders are closed or if a use tax could be perfectly enforced. Therefore, the equilibrium tax rates will be to set $t_i^j = V - \tau^j$ for $i = A, B, BB$ in $j = L, M, H$. If all states have equal state tax rates and borders are open, the equilibrium local tax rates would not be geographically differentiated and would be characterized by $t_i^j = \delta x$ for all i. This contrasts with a model where towns are located along a line segment. Along a line segment, the Nash equilibrium is for Town A to set local tax rates that are 4/5 of the level of the tax rates at the extremity because of their ability to undercut two towns rather than one. If all state taxes are uniform or if all town borders are closed (e.g., use taxes are perfectly enforced), the equilibrium town tax rates are uniform within a state.[14]

3.3 Equilibrium with Three Heterogeneous States

It is essential to know the direction of cross-border shopping to solve the model. Recall that although the state rates are exogenous, the towns within the state are free to set whatever tax rate they desire. I consider all possible patterns of local option taxes along the circle; taxes increase from borders, decrease from borders, or taxes are random. I must also allow for the possibility that after local option taxes are assessed, the total tax rate on the low-tax side of the border may be higher than on the high-tax side.

The revenue for each town can be derived using Equation 1. The tax base is defined as the total number of consumers within a town i of state j minus those individuals in that town who shop elsewhere plus individuals from other towns who shop in i. Multiplying the tax base by t_i^j yields total revenue and the municipality maximizes total revenue by selecting t_i^j. The best response functions are linear and will be continuous when changing from a high- to a low-tax jurisdiction. This continuity as towns change regimes implies that one set of best response functions characterizes the equilibria for all possible cases – including non-symmetric cases.

The revenue functions for towns in State M are defined in Equation 2. The revenue

[14] International borders are much more likely to be "closed" to cross-border shopping. Transportation costs, broadly defined, are much higher for crossing an international border. International borders usually take more time to cross, have some probability of vehicle search, and require individuals to exchange their currency before they can purchase goods abroad.

functions for State H and L are omitted for simplicity, but are defined in a similar manner.

$$R_i^M = \begin{cases} t_A^M(x + \frac{t_{BB}^M - t_A^M}{\delta} + \frac{t_B^M - t_A^M}{\delta}) & \text{for Town A} \\ t_{BB}^M(x + \frac{t_B^H - t_{BB}^M + R}{\delta} + \frac{t_A^M - t_{BB}^M}{\delta}) & \text{for Town BB} \\ t_B^M(x + \frac{t_{BB}^L - t_B^M - S}{\delta} + \frac{t_A^M - t_B^M}{\delta}) & \text{for Town B.} \end{cases} \tag{2}$$

Notice that xt_i^j denotes the revenue in the absence of cross-border shopping. The second and third terms represent the in- and out-flows resulting from cross-border shopping with both neighbors. If these terms are positive, then cross-border shopping is inward. If they are negative, cross-border shopping is outward. If the neighboring state is a high-tax state, the discontinuity in tax rates enters positively, but if the neighboring state is a low-tax state, the differential in the state tax rates enters negatively.

Solving the problem by differentiating the revenue functions yields the following best response functions:

$$\begin{array}{lll} t_{BB}^H(\cdot) = \frac{1}{4}(\delta x - (R+S) + t_A^H + t_B^L) & t_A^H(\cdot) = \frac{1}{4}(\delta x + t_{BB}^H + t_B^H) & t_B^H(\cdot) = \frac{1}{4}(\delta x - R + t_A^H + t_{BB}^M) \\ t_{BB}^M(\cdot) = \frac{1}{4}(\delta x + R + t_B^H + t_A^M) & t_A^M(\cdot) = \frac{1}{4}(\delta x + t_{BB}^M + t_B^M) & t_B^M(\cdot) = \frac{1}{4}(\delta x - S + t_A^M + t_{BB}^L) \\ t_{BB}^L(\cdot) = \frac{1}{4}(\delta x + S + t_B^M + t_A^L) & t_A^L(\cdot) = \frac{1}{4}(\delta x + t_{BB}^L + t_B^L) & t_B^L(\cdot) = \frac{1}{4}(\delta x + (R+S) + t_{BB}^H + t_A^L), \end{array} \tag{3}$$

which imply that municipality i's neighboring local tax rates are strategic complements, but that t_i^j and τ^j are strategic substitutes.

Solving this system of equations for a Nash equilibrium yields the following results:

$$\begin{array}{lll} t_{BB}^H = \kappa(\omega - 12R - 11S) & t_A^H = \kappa(\omega - 6R - 3S) & t_B^H = \kappa(\omega - 12R - S) \\ t_{BB}^M = \kappa(\omega + 11R - S) & t_A^M = \kappa(\omega + 3R - 3S) & t_B^M = \kappa(\omega + R - 11S) \\ t_{BB}^L = \kappa(\omega + R + 12S) & t_A^L = \kappa(\omega + 3R + 6S) & t_B^L = \kappa(\omega + 11R + 12S), \end{array} \tag{4}$$

where $\kappa = 1/53$ and $\omega = 53\delta x/2$. The first section of the Appendix proves that the Nash equilibrium derived above is unique for a general number of states and towns.

Differencing the local tax rates on the high- and low-tax side of borders shows that border towns in a low-tax state will set relatively higher tax rates than border towns within a high-tax state. The differential in tax rates at the state border shrinks to $\frac{30}{53}$ of the differential when there is no competition over local option taxes and this pattern holds for all three discontinuities.

To determine if the Nash equilibrium exists and its pattern, I need to verify three conditions. First, I need to verify that T_i^j is larger on the high-tax side of the border in any equilibrium and that all taxes are positive. Second, I need to determine the direction of the inequality between $t_A^j \gtreqless t_B^j$ and $t_A^j \gtreqless t_{BB}^j$ for all states. Finally, I need to verify whether the direction of these inequalities is consistent with the assumption that cross-border shopping occurs only one town over along the continuum. For a Nash equilibrium to exist, I must also verify that the number of residents of each town that cross-border shop is strictly less than the total population of the town.

From Equation 4, the Nash equilibrium will always have the following properties: $t_A^H > t_{BB}^H$, $t_{BB}^M > t_A^M > t_{BB}^M$, and $t_B^L > t_A^L$. The intuition of this result is explained below. However, in a Nash equilibrium, $t_A^H \gtreqless t_B^H$ and $t_A^L \gtreqless t_{BB}^L$. The direction of these inequalities depends on the relative sizes of the model's parameters – specifically the differentials in state tax rates. It can be shown that $t_A^H > t_B^H$ if $R > \frac{1}{4}D$ and $t_{BB}^L > t_A^L$ if $S > \frac{1}{4}D$. If the reverse is true then the pattern of those two tax rates will flip. It is also easy to verify that total taxes, T_i^j, on the high-tax side of the border are always greater than total taxes on the low-tax side of the border in equilibrium.

For a Nash equilibrium to exist, I must find the size of each town that guarantees that tax rates are strictly positive, all towns have some residents that shop at home, and that no one will shop more than one town away.[15] Denoting the value of x that satisfies all three of these conditions as x^*, a Nash equilibrium exists in pure strategies so long as $x > x^*$. Strictly positive tax rates can be guaranteed by setting $x > \kappa\frac{22D+2R}{\delta}$. Verifying that no one shops more than one town over and that some shoppers purchase the good at home requires $x > \kappa\frac{30D}{\delta} > \kappa\frac{22D+2R}{\delta}$. Therefore, this guarantees that a small deviation in the tax rate of a particular town cannot change revenues discontinuously. Thus, $x > \kappa\frac{30D}{\delta}$ guarantees these assumptions hold. If $x < \kappa\frac{30D}{\delta}$, then no Nash equilibrium exists in pure strategies. But, $x > \kappa\frac{30D}{\delta}$, combined with continuity and concavity of the best response functions in the strategies, guarantees the existence of the unique Nash equilibrium described above.

After defining two terms, I can state a proposition that characterizes the Nash equilibrium for a general model with many towns.

Definition. The *tax gradient* is defined as the slope of local option taxes away from the border. Define the distance of a town to its relevant state border as the length along the circumference from the center of the town to the relevant state border. Then, the tax gradient is increasing in distance from the border if local option taxes increase as towns are further from the relevant state border. The tax gradient is decreasing in distance from the border if local option taxes decrease as towns are further from the relevant state border.

In the presence of multiple borders, the gradient will likely switch slopes at some point within the state.

[15] This is equivalent to finding a value of δ that is sufficiently large.

Definition. The *critical town* is defined as the town where the tax gradient changes sign from increasing to decreasing (or vice-versa) within a state. If the tax gradient is increasing for both state borders in a state, then the critical town corresponds to the town with the maximum tax rate. If the tax gradient is decreasing for both state borders in a state, the critical town corresponds to the town with the minimum tax rate. If the tax gradient is increasing for one border and decreasing for the other border, then no towns are critical.

Proposition 1 characterizes the Nash equilibrium for a model with multiple states and multiple towns. The general solution to an n town model, where states can have more than three towns, is in the appendix .

Proposition 1. *If towns are sufficiently large in size and a state has two heterogeneous tax differentials at state borders, a Nash equilibrium for local option taxes exists in pure strategies and is characterized by the following statements:*

(1) A state with one high-tax neighbor and one low-tax neighbor will have a tax gradient that is decreasing from the high-tax border to the low-tax border.

(2) A state with two neighbors that set relatively low state tax rates of different magnitudes will have tax gradients that are increasing away from each border.

(3) A state with two neighbors that set relatively higher state tax rates of different magnitudes will have tax gradients that are decreasing away from each border.

(4) In the high- and low-tax states, the critical town will be located closer to the border with the smaller state tax differential. How close it is depends on the relative sizes of the state tax differentials.

Border towns in the low-tax state will set higher taxes than towns at the interior of a low-tax state; border towns in the high-tax state will set lower taxes than towns at the interior of a high-tax state. Combined with the result that tax differentials are smaller after local competition, the results of the theory suggest that local option taxes do help to reduce the size of the discontinuity at the state border and that this reduction occurs gradually. A tax gradient begins to emerge where in high-tax states, taxes rise as distance from the border increases, while in low-tax states, taxes fall as distance from the border increases. Additionally, the changes in local taxes within a state are largest for the towns located near the state border with the largest discontinuities. The model in the appendix adds one additional insight; the tax gradient will be steeper in a local region of the border than in regions far from the closest border.

For illustrative purposes, Figure 2 shows the Nash Equilibrium tax rates when the parameters of the model are set such that $\delta x = 4$, $D = 5$, $R = 3$, and $S = 2$. Notice local taxes are highest in the lowest-tax state and that the tax gradient is steepest for the largest discontinuities. For the three state, nine town model, the solution can be characterized as follows. If $x < x^*$, then no Nash equilibrium exists in pure strategies. If $x > x^*$, the Nash equilibrium will have $t_A^H > t_{BB}^H$, $t_{BB}^M > t_A^M > t_{BB}^M$, and $t_B^L > t_A^L$ with the relationship between t_A^H, t_B^H and t_A^L, t_B^L determined by the relative sizes of the notches given above.

Consider the case of towns at the High-Low border when $D > 0$ and x is sufficiently large. The border town on the high-tax side can smooth the tax differential at the state border to reduce the number of cross-border shoppers while also attracting shoppers from interior towns. Any deviation that lowers the rates by Town A will result in a loss of revenue as the losses from lowering the tax rate will outweigh the gains from expanding the tax base. On the low-tax side, the border town will have a relatively high local sales tax rate. Here, the town seeks to export the tax burden to residents of the neighboring state who are already shopping within its borders. If the interior town deviates from the Nash equilibrium and increases the rate, the benefits of a higher tax rate will not be sufficient to outweigh the losses from contracting the tax base.

For a state that has a high- and a low-tax neighbor at its borders, local tax rates should always decline with the distance from the high-tax state and should increase with the distance from the low-tax border. These results are mutually consistent. Therefore, the gradients of taxes in State M are always declining as one moves away from the high-tax border. Of course, the size of the notches on the high- and low-tax side may affect the precise slope of the gradient, but they will not affect the general pattern (sign) of the gradient.

In this model, which town is critical depends on the magnitude of the differential. If the notch between the high- and low-tax state is especially large, then, additional towns past the center of the state will be pulled into its gradient. By definition, notch D must be larger than notch R so that notch R can never pull additional towns into its gradient. A similar logic applies to the low-tax state as well. Another way of thinking of this problem is to imagine that $R = 0$, so that State H and State M set the same state tax rate. If this is the case, it is as if the high-tax states now have six towns. The local tax rates will be increasing away from the border. The problem becomes symmetric with respect to the two borders with non-zero differentials so that the tax rates will increase all the way to the state border between State H and M. As towns get further and further away from the larger notch, they are less likely to be pulled out of the gradient for the smaller notch closest to them. More generally, State H is bordered by two low-tax states. Starting from State L, there is upward pressure on taxes. Starting from State M, the pressure on the towns moves is downward. These two gradients are mutually inconsistent and they need to change at some point along the circumference.

These results differ from what comes out of Kanbur and Keen (1993). In Kanbur and Keen

(1993), the "small" country, as defined by domestic population, always undercuts the large country in a Nash equilibrium. In the model I present above, towns set taxes following an inverse elasticity rule,[16] but what matters is the relative size of the "foreign" plus "domestic" market. For Town BB in State H, even if its local tax rate is zero, some residents will always shop abroad. Therefore, starting from a position where $t^H_{BB} = t^H_A > 0$, Town BB perceives a relatively small (in comparison to Town A) market of "foreign" plus "domestic" shoppers (it already has some of its residents shopping in the neighboring state, which reduces its market size). Town BB perceives the relatively larger elasticity (because its market is smaller) and undercuts Town A. On the low-tax side, starting from $t^L_B = t^L_A > 0$, Town B is already attracting residents from the neighboring states. Therefore, because of the fact that B has already attracted some foreign residents, it perceives the "foreign" plus "domestic" market as larger than that of A. Town A perceives itself as small and undercuts Town B. Thus, the town with the the largest cumulative "foreign" plus "domestic" market will always set higher rates.

The theoretical model discussed above has several testable hypotheses for the empirical analysis to follow. First, municipal tax rates are lower on the high-tax side of the state border than on the low-tax side of the border. Second, local tax rates are decreasing away from the nearest high-tax border and are increasing away from the nearest low-tax border. Third, the distance of the municipality from the state border will determine how steep the tax gradient is. The treatment effect will be heterogeneous by distance, because the tax gradient will be steepest for the towns closest to the state border. Fourth, the size of the notch will determine how steep the tax gradient is. For larger discontinuities in state tax rates, the tax gradient will become steepest. This suggests that the treatment must be continuous (as a function of the size of the notch) rather than a simple binary treatment for high- or low-tax states. In addition, the theory implies that the critical town will depend on the relative size of the discontinuities at various borders. This suggests that it is important to account for the presence of multiple borders in the regression equations. Finally, the existence of a tax gradient may be tested in other contexts; the theory will also apply to county borders.

4 Data and Evidence on the Levels of Local Tax Rates

The goal of the analysis is twofold. One, do localities on the high-tax side of a border set lower local taxes than localities on the low-tax side? Two, is there a tax gradient that is a

[16] Put differently, one needs to set the tax rate inversely proportional to the elasticity of demand to maximize revenue from a tax on sales. Here, the elasticity of demand is derived from cross-border shopping. When the elasticity of cross-border shopping is high, the town has an incentive to undercut the other town.

function of distance from the border?

4.1 Data

The data on tax rates come from Pro Sales Tax's national database.[17] The data contain state, county, municipal, and sub-municipal (district) tax rates for April 2010. Table 1 displays summary statistics for these tax rates by state. Because I am interested in combining the tax data with a measure of distance from the state border and with Census data, I restrict the sample to municipalities that are identified Census Places, which subsequently will be referred to as localities.[18] To do this, I merge Geo-coded data provided by the 2009 American Community Survey and the 2000 Census[19] SF3 file to the tax data set.[20]

A key variable in the analysis is a locality's distance from the nearest neighboring state. I draw on and substantially modify the method of Lovenheim (2008) to calculate distance from the border. Using 2000 Census geographic Tiger Line files and Arc-GIS software, I estimate the driving distance from each population weighted centroid of a locality to the closest intersection of a major road and a state border crossing. Unlike in Lovenheim (2008), I calculate distance from the nearest border rather than from the nearest low-price border. I also calculate distance from the population weighted centroid instead of the population weighted distance, which enables me to calculate driving distance

It is essential to have the most accurate measure of distance, because this paper analyzes taxes away from the border. I estimate the driving[21] distance from the population center of each locality to the nearest intersection between a state border and a major road that

[17] The data is proprietary data, but was provided to me without charge. For a complete description of the data, see http://www.prosalestax.com/.

[18] A Census Place is generally an incorporated place with an active government and definite geographic boundaries such as a city, town, or village. In many western states, a Census Place may be an unincorporated place that has no definite boundaries or government. The relationship between a Census Place and governing authority is often different across states. Census Places contain some locations that may not have legal authority or jurisdiction to set sales taxes.

[19] SF3 files for the 2010 Census are not yet available.

[20] Merging the data requires name matching, which can introduce some error. However, the error of incorrectly matching a name is likely to be small because I name match the Places based on state, county, and locality names, where all three must match. Census Places may cross county lines and Places are matched to Counties using a procedure outlined in the appendix. Because of spelling errors, etc., it is possible that some matches that would be correct matches remain unmatched. I hand match these. It should also be noted that some jurisdictions are in one data set but not the other.

[21] In some specifications, I derive the "as the crow-flies" distance. I do this in specifications where I account for the two-dimensional nature of borders by calculating the distance from the second closest border. Calculating driving distance from all neighboring state borders is feasible, but computationally time intensive. The crow-flies distance is a measure of the shortest distance between two points. It is not a perfect measure of the actual transportation distance because it does not account for the road system in place to move between two points nor does it make any adjustments to account for geographic impediments such as mountains or rivers.

minimizes travel time.[22] Relative to the "as the crow-flies" distance, this measure of distance more accurately captures the true commuting time from the nearest state border. Although the "crow-flies distance" is correlated with driving distance, it is not a very accurate measure of true commuting costs except in a local region of the border.

For a detailed description of how I calculate the distance from the border, please see the Appendix. Figure 3 shows that the distance calculation is accurate at the county level and gives information with regard to the range of distances.

Finally, Tribal Nations are treated as localities. Although the tax treatment of sales to non-tribal members often varies by state, most courts have ruled that sales to non-tribal members require tax collections.[23] I treat these reservations as being similar to localities within the states and thus do not consider a border with a tribal nation as being a state border. International borders are considered state borders even though crossing the border is more difficult and may restrict cross-border shopping. Canada assesses a 5% Goods and Services Tax (GST) but many provinces assess an additional provincial tax resulting in an implicit tax rate between 10 and 15.5%, depending on the province.[24] The Mexican Value Added Tax at the United States border is 11%, which is higher than the state sales tax rate along any border state.[25]

4.2 Graphical Analysis and Summary Statistics

First, I present some graphical results in Figures 4, 5, and 6. Figure 4 depicts the state sales tax and the range of tax differentials at borders. Figure 5 presents the distribution of the county tax rate plus the average municipal tax rate with the county. I demonstrate the role of municipal taxes in the case of one state, Missouri, in Figure 6. Although it is difficult to discern an immediate border effect, some examples seem to be present. Figure 6 shows that urban areas set higher tax rates regardless of their proximity to neighboring states, implying the need to control for this factor. In addition, similar tax rates are clustered in particular regions. Figure 5 indicates that the largest amount of variance in county tax rates is in the central and southern states. Western states have some variance in their county tax rates,

[22] A major road is a Census classification including most non-residential roads. As pointed out by Lovenheim (2008), the exclusion of residential roads is "trivial because the vast majority of interstate travel does not occur on such roads" and it is unlikely that retail locations are on minor (residential) roads.

[23] This is the opposite of court rulings on excise taxes, where courts have ruled that tribal nations need not collect state excise taxes under most circumstances. For a discussion of tribal regulations see "Piecing Together the State-Tribal Tax Puzzle" by the National Conference of State Legislatures.

[24] One exception is Alberta, which assesses no provincial tax so that the total GST tax is 5%. Alberta shares a border with Montana, which has no state or local sales taxes. The territories are another exception, which face the federal rate only.

[25] Mexican goods and services are taxed at 16%, but within twenty kilometers of the border with the U.S., the preferential tax rate is 11%.

but counties are also significantly larger.

Table 2 presents summary statistics of all the variables used in this analysis. Statistics are presented for town (Census Place) level data. Many of the control variables appear to have relatively similar means on both the high- and low-tax sides of the border. The average tax differential at state borders is about 1.90 percentage points and the average local plus district tax is 0.71 percentage points.

Some average summary statistics can help analyze the pattern of tax rates. On each side of a state border, jurisdictions are sorted into towns that are 0-25 miles from the border, 25-50 miles from the border, 50-75 miles from the border, etc. I calculate the mean local and state tax rate in each of these bins. Table 3 presents the unweighted averages. Some convergence of average tax rates near the border indicates smoothing of the tax rates.

4.3 Methodology: The Tax Level Effect

How much higher are local tax rates on the low-tax side of the border relative to the high-tax side of the border? Recall that the theoretical model has one discontinuity in state tax rates of $D = \tau^H - \tau^L$. After localities assess local option taxes, the tax differential at the border becomes $\frac{30}{53}D$. This implies that local tax rates on the low-tax side of the border are higher than on the high-tax side of the border. To test this hypothesis, I conduct a regression discontinuity (RD) design following the local linear regression and bandwidth selection methodology of Imbens and Kalyanaraman (Forthcoming).[26] The results of this RD design can be interpreted as the effect of the border between states with different tax rates on the level of local option tax rates. The treatment is being on the border of a high- or low-tax state and is binary. Because many policies vary at state borders, the interpretation of the results would be causal only if there are no other state policies that are discontinuous at borders correlated with being a high- or low-tax state.

To implement the regression discontinuity design, I conduct local linear regression on the local tax rates with a triangle kernel. I include the same vector of controls and state fixed effects in the summary statistics table and allow them to vary locally. The bandwidth is selected optimally according to Imbens and Kalyanaraman (Forthcoming) and towns closest to a same-tax state border are dropped.

[26]Spatial analysis using regression discontinuities at borders has been used extensively in models such as Holmes (1998) and Gopinath, Gourinchas and Hsieh (2011). A spatial fixed effects regression discontinuity model is used by Magruder (2011) to try to account for spatial proximity across localities.

4.4 Result: Are Local Taxes Higher on One Side of the Border?

Figure 7 graphically presents the results of the regression discontinuity design without controls. Table 4 shows the regression results for various specifications. Specifications 1, 2, 3 and 4 present the results for local, local and district, county, and total local rates at the state border. Specification 4 is most preferred; it demonstrates how much the tax differential at state borders falls after all local option taxes are assessed. Keeping in mind that many things change at state borders, columns 5 and 6 present the results at county borders that are not also state borders. Columns five and six are more likely to represent a causal effect, given that fewer policies vary discontinuously at county borders than at state borders.

Recall that the average tax differential at state borders is about 1.90 percentage points. The results from the RD design of the total local rate yield an estimate of -1.13: a town (located precisely near the border) on the high-tax side assesses a local sales tax rate that is 1.13 percentage points lower than an identical border town on the low-tax side. Thus, the average tax differential falls from 1.90 percentage points to 0.87 percentage points. This result is consistent with the theoretical prediction that local sales taxes reduce the state tax differential approximately by one-half. The results for local plus district tax rates are smaller, as expected, and imply that municipal taxes are about 0.352 percentage points lower on the high-tax side. With regard to county borders, the results remain negative suggesting that the discontinuity in county tax rates imply local taxes are higher on the low-tax side of the county. The results at county borders are smaller because tax differentials at county borders are much smaller than at state borders.

The RD results suggest that as the model developed in Section 3 predicts, local sales taxes reduce tax differentials at state borders.

5 Estimating the Tax Gradient

The previous section has shown that local taxes are lower on the high-tax side of the border than on the low-tax side of the border. What remains to be seen – and is the subject of this section – is if this reduction occurs gradually with distance from the border.

5.1 Methodology: The Tax Gradient Effect

My estimation strategy exploits the discontinuity in the state tax rates at borders to estimate how local tax rates depend on distance from the border. I use a global polynomial regression rather than the local linear regression above. A global polynomial regression is preferred to local linear regression because the treatment will vary with the size of the discontinuity. It is also preferred because I care about precisely estimating the marginal effects (the slope of the tax gradient) conditional on the size of the differential and on distance.

I will allow distance to have a different effect on local tax rates depending on the side of the border on which a town is located because the theory implies the geographic pattern is different on the low- and high-tax sides of the borders. The "treatment" is defined as the size of the difference in state tax rates at the border. As such, the state border will be allowed to have a different effect on local tax rates depending on the size of the notch at the border and depending on a locality's distance.

Let l index localities, c index counties and s index states. Then, X_{lc} denotes observable characteristics of locality l in county c. The matrix X includes variables from Census 2000 data at the Census Place level plus some other control variables generated using geographic files such as population, the median level of income, the fraction of the population with a college education, the fraction of seniors, the fraction of residents working in another state and county, the number of neighbors, town area and perimeter. To this matrix, I also add the vote share received by Obama in the 2008 Presidential election in case political affiliations determine a locality's choice of whether to use the sales tax, a dummy for proximity to international borders, and a dummy for proximity to oceans or water.

The variable t_{lc} will denote the local (town) plus sub-district tax rates.[27] Define R_{lc} as the difference between the state tax rate of the high-tax state and the state tax rate of the low-tax state. For locality l, if the nearest neighbor is a relatively high-tax state, this will be a positive number. If the neighbor is a relatively low-tax state, the difference will be a negative number. Also, H_{lc} is a dummy variable that denotes whether locality l's state is a high-tax state relative to the nearest neighboring state of jurisdiction l. And S_{lc} is a dummy variable that is equal to one when locality l's state has the same state tax rate as its neighboring state.

Define the distance from a locality to the nearest state border as d_{lc} and note it is always positive, so that towns located fifty miles on either side of the border are identical with respect to distance. The role that distance plays may be non-linear and differ depending on the side of the border.[28] To do analysis on the tax gradient, I need to assume that the relationship between d and local taxes is sufficiently flexible, and I allow it to be a polynomial function of degree p. Denote this function in matrix form as $G(d_l)$, where each

[27] To proceed, I must assume that local tax rates are in equilibrium in my data. Given the large number of observations that I have, this is a realistic assumption.

[28] Identifying the slope of the tax gradient will rely on a functional form dependent method. Lovenheim and Slemrod (2010) use dummy variables based on distance to obtain a flexible function of distance. Lovenheim (2008) and Harding, Leibtag and Lovenheim (Forthcoming) impose $log(D)$ as the functional form because they do not have sufficient power to use a more flexible polynomial.

column represents a higher order term of the polynomial function $\sum_{k=1}^{p}(d_{lc})^k$. Note that the locality cannot manipulate d_l, so that it cannot select whether it is on the high- or low-tax side.

The reduced form equation designed to test whether the difference in state tax rates at the border influences local tax rates has the following specification:

$$\begin{aligned} t_{lc} = \beta_0 + \beta_1 H_{lc} + \beta_2 S_{lc} + \beta_3 R_{lc} + \beta_4 R_{lc} H_{lc} + X_{lc}\varphi + \\ G(d_{lc})\rho + R_{lc}G(d_{lc})\gamma + H_{lc}G(d_{lc})\delta + R_{lc}H_{lc}G(d_{lc})\alpha + \\ S_{lc}G(d_{lc})\theta + \lambda \mathrm{T}_{lc} + \zeta_s + \varepsilon_{lc}. \end{aligned} \tag{5}$$

In expression 5, ε_l are unobservable characteristics that are specific to a locality. ζ_s are state fixed effects and T_{lc} is the county tax rate for locality l. The variables γ, ρ, δ, α, and θ are the vectors of coefficients where each element of the vector denotes the coefficient on each term in the polynomial – linear, square, cubic, etc.

A standard RD would simply define the treatment as H_{lc}, as done in in Section 4.3. The above specification allows the treatment to also vary by the size of the state tax rate discontinuity R_{lc} and estimates separate distance functions for high-, low-, and same-tax state borders. The coefficient on $G(d_{lc})$ will pick up the average effect of distance on local tax rates – or put differently, the effect of distance from the border. The interaction of the distance term with R_{lc} in $R_{lc}G(d_l)$ allows the treatment to vary with the size of the discontinuity. Because R_{lc} is negative for towns in relatively low-tax states and positive for towns in relatively high-tax states, the treatment is different on opposite sides of the border, as the theory suggests. The interaction $H_{lc}G(d_{lc})$ will allow for the effect of being at a particular distance from the border on the high-tax side to be different than being at that same distance on the low-tax side. The coefficient on $R_{lc}H_{lc}G(d_{lc})$ allows for the treatment effect to vary depending on the side of the border. Lastly, $S_{lc}G(d_{lc})$ allows the estimated distance function to be different for towns where the nearest border has the same state tax rate on both sides. The term, $\beta_1 H_{lc} + \beta_2 S_{lc} + \beta_3 R_{lc} + \beta_4 R_{lc} H_{lc}$, represents the intercept of the polynomial function of distance. It captures the effect of the notch when $d = 0$ and allows for the polynomial to have a different intercept in relatively high- or low-tax states.

The inclusion of state fixed effects controls for commonalities occurring within a state but not across borders and helps mitigate any geo-spatial correlation among towns in the same state. With state fixed effects, identification is coming from within state variation of local tax rates. The state dummies will help to control for variation in policies and unobservables that is constant within states, such as political climates or state business policies. Critically, the inclusion of the state fixed effects will also control for the level of the state tax rate in state s.

Finally, Equation 5 uses town tax rates as the left-side variable. However, towns are embedded in counties, which are within states. While the state fixed effects control for the level of the state tax rate, they do not control for the level of the county tax rate. I cannot directly include the county tax rate, T_{lc}, on the right hand side because it is likely selected simultaneously with local rates and therefore is endogenous. As a result, I instrument for the county tax rate using a standard instrument in the tax competition literature – a subset of the X's at the county level. The justification of this set of instruments can be found in Brueckner (2003). Brülhart and Jametti (2006) apply the instrument to higher levels of government as well. Instead of using the entire subset of the X's as instruments, I will only use geographic variables (which are not often controls in previous studies) as instruments because demographic variables are likely to be endogenous at the municipal level. Particularly, I use the county area, county perimeter, and county number of neighbors as instruments.

To justify these instruments, recall that the regression equation controls for town area, town perimeter, and the number of neighbors for the town. Then, the exclusion restriction requires that the instrument should have no partial effect on local taxes after controlling for these variables. The direct impact of the number of neighbors, area and perimeter of the county on local taxes is likely to be zero. County neighbors, area and perimeter affect the county's tax rates, but will have no direct impact on the locality's tax rate so long as there are multiple jurisdictions within a county and so long as counties are sufficiently large in size. County borders were likely to be historically drawn on latitudes and longitudes or broader geographic features. The number of neighbors, area, and perimeter depend on a county's characteristics such as whether along a body of water, broader geographic features, and how counties were divided historically. Because area and perimeter are historically drawn, the evolution of time with these variables helps to make them exogenous. As a contrary point, the town's area, number of neighbors and perimeter often depend on how municipalities were historically formed within the county and the characteristics within the county when the town borders were historically drawn – which in most cases were not at the same time county lines were delineated.[29] Furthermore, as an alternative to the instrumental variable approach, I present additional results where the dependent variable in the estimating equation is equal to the town plus county tax rate. Because county rates are now part of the variable of interest in these specifications, I avoid having to instrument for the county tax rate and can instead look for a gradient in the total effective tax rate. The sign and significance of the tax

[29] I conduct a Hansen J test of over-identification. The result of this test – $J = 2.28$ ($p = .32$), a failure to reject the null hypothesis that all the instruments are uncorrelated with the error – is suggestive that in the presence of one valid instrument, the other instrument is also valid.

gradient remain the same.[30] The F-statistic for instrument strength from the first stage is 30.20 ($p = .00$). I can now proceed using the regression analysis in Equation (5) to estimate the effect within a state.

The coefficients within γ , ρ, δ, and α are not informative as stand-alone parameters because the marginal effect of distance is a non-linear function of d_{lc}. In the case of a p order polynomial, the marginal effects of distance on the local tax rate for the high-, low-, and same-tax side of the border are given by Equation 6:

$$\frac{\partial t_{lc}}{\partial d_{lc}} \equiv G'(d_l) = \begin{cases} \sum_{k=1}^{p} k[\rho_k + \delta_k + (\gamma_k + \alpha_k)R_{lc}](d_{lc})^{k-1} & \text{for } H_{lc} = 1 \,\&\, S_{lc} = 0 \\ \sum_{k=1}^{p} k[\rho_k + \gamma_k R_{lc}](d_{lc})^{k-1} & \text{for } H_{lc} = 0 \,\&\, S_{lc} = 0 \\ \sum_{k=1}^{p} k[\rho_k + \theta_k](d_{lc})^{k-1} & \text{for } H_{lc} = 0 \,\&\, S_{lc} = 1, \end{cases} \quad (6)$$

where the coefficients indexed by k indicate the coefficient on the k^{th} order term of the polynomial.

From this expression, I can calculate the mean marginal effect (or mean derivative) of distance on tax rates by calculating the sample mean of the estimated derivative conditional on being in a high-, low-, or same-tax state relative to the neighbor. Letting N_b denote the number of observations on a particular side of a border, the mean marginal effects represent the slope of the tax gradient away from the discontinuity after averaging across the conditional sample:

$$E\left[\frac{\partial t_{lc}}{\partial d_{lc}}\right] = \frac{1}{N_b}\sum_{l=1}^{N_b} G'(d_l). \quad (7)$$

The mean derivative of the full sample is of little interest given that the theory indicates it will be of opposite sign on different sides of the border. Therefore, the summation in Equation 7 is separately taken over all towns on the high-tax side, low-tax side, and same-tax sides of the border and N_b adjusts appropriately. Standard errors for mean derivatives are calculated using the Delta Method. I also calculate, but do not report, the marginal effect evaluated at the mean, or $G'(\bar{d}_{lc})$. The derivative evaluated at the mean is biased and inconsistent because of non-linearity in the derivative. The marginal effect given by Equation (7) is a consistent estimate of the mean derivative in the conditional population and is the preferred effect.

If the mean marginal effect is positive, tax rates are increasing as the distance from the nearest border increases. If the effect is negative, then towns further from the border are

[30] The results of these regressions are available in an online appendix at http://www-personal.umich.edu/~dagrawal/research.htm. This is not, however, the preferred specification because it will leave me unable to compare the tax gradient at state borders to the tax gradient at county borders – where the left side variable must be the local tax rate.

setting lower tax rates than those at the border. In general, because the marginal effect need not be identical for all values of d_{lc} or R_{lc}, I will also report the mean marginal effects evaluated at different possible values of d_{lc} and R_{lc}. The theory predicts that the mean marginal effect on the high-tax side of the border will be positive and on the low-tax side of the border will be negative. When state tax rates are the same, no effect should be evident.

The polynomial order is selected using "leave-one-out" cross-validation.[31] The implied root mean squared error from leave-one-out cross-validation is decreasing in the order of the polynomial until it reaches a minimum of .6625 at a polynomial order of five; thus, the quintic polynomial is the preferred specification. In addition, I ocularly compare the fit of the predicted values from a global polynomial regression to the calculations using the local linear regression described above. Figure 8 compares the fit of a quintic polynomial to the results of the local linear regression. The quintic polynomial fits the local linear regression almost identically – both with respect to the curvature and the levels of the tax rates. Conducting the same comparison for lower degree polynomials is less accurate.

5.2 Results: How Steep Is the Tax Gradient?

Table 5 presents the full set of coefficients on several specifications of Equation 5 along with the mean derivatives associated with them, scaled to represent a 100 mile change. Specification 1 includes only a quintic polynomial in distance. Column 2 adds local controls and column 3 adds state fixed effects. Column 4 instruments for the county tax rate, which is the preferred specification.

The coefficients on some control variables are worth highlighting. Having a higher fraction of people who work in-county and in-state implies the tax base is less mobile across state lines, and results in higher local tax rates. Higher income jurisdictions have lower tax rates, suggesting that they may be more able to use the property tax as an alternative revenue source. Towns near oceans have higher tax rates, consistent with a model located along a line-segment where the jurisdictions at the end of the line set higher rates. On average, jurisdictions near international borders set lower tax rates even though the international borders are all high-tax borders. This suggests that towns near the international border see no gain to exporting the tax to foreign consumers by raising the rates, but do not view the border as closed. The number of neighbors has a positive sign. Finally, the coefficient on the instrumented county tax rate is negative and significant – suggesting that higher county

[31] The process of cross-validation estimates equation 5, omitting one observation from the data set. The process is repeated 16,781 times, omitting each observation from the data set once and calculating the root mean squared error each time. I then calculate the average root mean squared error for all the omitted observations. After repeating the cross-validation techniques for polynomials up to an order of eight, I select the polynomial that yields the smallest average root mean squared error.

taxes reduce local sales taxes.[32]

In the preferred specification, the mean derivative on the low-tax side of the state border is significant and of the expected sign: -0.102. Thus, moving a town 100 miles away from its high-tax state neighbor – assuming constant marginal effects – will decrease its local tax rate by just over one tenth of a percentage point. Alternatively said, a one mile change has a -.102 basis point change on local rates. Interpreting this in the context of the average local tax rate, which is approximately 0.71 percent, implies that average local taxes are about 15% lower 100 miles away from the border. The gradient for towns with a same-tax state neighbor is insignificant. For a town on the high-tax side of the border, the marginal effects are slightly larger in absolute value (-.197) but are unexpectedly negative.

How robust are the results to reasonable alternative specifications? With regard to the marginal effects, Table 6 presents the marginal effects for a variety of specifications, with column 1 denoting the baseline results. In general, significantly negative results on the low-tax and high-tax side of the border are found. One specification eliminates towns near international borders, in case these borders are effectively closed to purchases. Another specification eliminates towns that are most proximate to the ocean.[33] One reason for doing this is that if the theoretical model were on a line segment instead of a circle, towns at the end of the line segment have incentive to raise their tax rates because they only have one neighbor. Column 3 indicates international borders may be different than state borders. Because the gradient becomes slightly steeper when excluding these jurisdictions (always located on the low-tax side), it suggests that towns near international borders are less likely to be able to charge a mark-up over their interior neighbors – perhaps because of differences in the pre-tax price. Column 4 also seems to indicate that the towns near the ocean set higher rates than their interior neighbors in low-tax states. Because the gradient becomes steeper when excluding these towns, this suggests that towns near the ocean and away from the border are setting higher rates than border towns, which is consistent with a Hotelling style model where towns at the end of the line segment set higher rates.

Specification 5 allows the reader to determine the marginal effect in hours instead of miles. The marginal effects with a quintic in driving time indicates that a one-hour drive from the border lowers tax rates .06 percentage points on the low side and by .10 percentage points on the high side. Comparing this to specification 1 indicates that the marginal effect of driving 100 miles is approximately equal to the marginal effect of a driving time of two hours. Columns 7 and 8 are important to decompose the results when neighboring states do

[32] Such a finding – the relative magnitude of the vertical and horizontal externalities in the presence of multiple federations (counties) – is interesting in its own right, and is the subject of Agrawal (2011*b*).

[33] As an alternative, I interact the dummy variables for proximity to international borders and water with the distance functions and find similar results.

not assess local option sales taxes (LOST). Recall that 16 states do not allow LOST. It may be expected that the nature of the competition at these borders is different than at a border where both states allow LOST. When the neighbor does not allow LOST, the slope of the gradient becomes much steeper on the low-tax side. Additionally, on the high-tax side, the slope of the gradient becomes positive – and matches the predicted results of the theory. This suggests that not having a local competitor on the opposite side of the border makes it more likely that localities will reduce discontinuities in state tax rates. In addition to those particular extensions, the decreasing tax gradient for low-tax states is highly robust.[34]

Table 7 shows that the results are robust to the order of the polynomial (columns 2 and 3). Columns 4 and 5 suggest that giving all states equal weight in the data and weighting by population preserves the expected results. The results weighted by population increase the steepness of the slope dramatically, suggesting that high population jurisdictions may be more likely to be located near the border, where the gradient is steepest. Specification 6 interacts all the state fixed effects and all the control variables with a polynomial in distance and allows the coefficients on these interactions to vary on the high-, low- and same-tax side of the border. Such a specification removes any possibility of coincidental correlation with the distance function and allows each state to have its own tax gradient. The results increase in magnitude and in significance. Column 8 includes state fixed effects and state-border-pair fixed effects, such that all the identifying variation comes from variation in local taxes within only one border region in a state. Such a specification controls for the level of all state controls and controls for the possibility that the east border of a state may be very different from the west border (i.e., the presence of mountains or rivers, etc.). The last three columns of Table 7 restrict the sample to towns within 150, 98, and 40 miles of the border. The restriction of 98 miles is the optimal bandwidth of the local linear regressions above. In these specifications I re-select the order of the polynomial for each restricted sample by the cross-validation method above. Notice when the sample is restricted to a local region around the border, the tax gradient becomes steepest and the gradient on the high-tax side becomes insignificant. From Table 7, it can be seen that as the estimating area becomes larger, the steepness of the tax gradient becomes smaller. This suggests that the mean derivatives are strongest in a local region of the border – where cross-border shopping is likely to be most salient.

Many of the coefficients for the high- and low-tax side are similar in magnitude and sign. Because of the similar estimates on both sides of the border, I must consider the possibility

[34] Column 2 indicates the results are robust to a binary treatment. The results are also robust to excluding some states where local taxes are not extensively utilized (column 6), to using local taxes only as the dependent variable (column 9), and to using county plus local plus district taxes as the dependent variable, thus avoiding the need to instrument for county tax rates (column 10).

that the coefficients identify something fundamental about borders, but do not identify the effect of tax discontinuities. While such a border effect cannot be dismissed with certainty, a variety of robustness checks suggest that the results are not driven by a pure border effect. I will show no significant effect at same-tax state borders. In the following sections, I will show that the effect varies with the size of the discontinuity and for both county and state borders. Thus, if the results are not driven by tax differentials at state borders, they must be driven by a policy that changes discontinuously at the border and is correlated with the tax differential and with distance at both state and county borders. In addition, the tax gradient would be the same on both sides of the border, if a pure border effect were operating. I can reject the null hypothesis that the slopes on the high- and the low-tax side of the border are identical in the baseline specification ($t = 3.90$ with a $p = .048$).

Previously, I have estimated a gradient effect that is common to all states. Table 8 displays the mean derivatives by border-type in every state that allows for LOST and highlights substantial variation in the gradients. Out of the twenty-eight states that have a high-tax neighbor and allow for LOST, twenty states have a negative gradient consistent with the theory. Out of the eight states with positive gradients, only three states – Colorado, Oklahoma, and West Virginia – have statistically significant gradients that imply local taxes increase away from the border. The negative gradient is steepest in Louisiana and Arkansas. Of the twenty-two states with a low-tax neighbor, eight states have positive gradients consistent with the theory. Of these states, only North Dakota and Oklahoma have statistically significant gradients that imply taxes increase away from the nearest low-tax neighbor.

5.3 Is the Tax Gradient Steepest Near the Border?

Consumers who live further away from the border have less incentive to cross state lines to avoid paying the sales tax, because of transportation costs. As a result, jurisdictions in a local region of the border will adjust tax rates the most rapidly, either to attract cross-state shoppers to the interior of the state or to undercut their higher tax local neighbors. In fact, in the n town model in the Appendix, the tax gradient is steepest near the border. Using the unrestricted sample of the fixed effect IV model from Table 5, I evaluate the marginal effects conditional on one-mile intervals. With the quintic polynomial, Figure 9 indicates the marginal effects are steepest within a thirty mile radius of the neighboring high-tax state border. In this region, the marginal effects are almost five times as large as the average marginal effect for the full sample. These results are significant at the 95 percent confidence level. In a local region of the border on the low-tax side, towns rapidly adjust local tax rates downward the closer to the border. On the high-tax side of the border, the marginal effects are approximately zero for all distances, except in a vicinity of the border.

As a falsification test, it is useful to compare these results to towns where the neighboring state has the same state tax rate. Figure 10 plots the marginal effects conditional on various distances for these towns. As expected, if the state tax rates are uniform, the local tax rates are uniform but highly volatile, because of the small number of such towns in the sample.

Figure 11 presents the marginal effects conditional on distance, when the optimal bandwidth is selected to restrict the sample to towns within 98 miles of the border. I expect the marginal effects to increase in absolute value (note the different scale of the vertical axis), because the sample no longer contains towns at far distances, where the tax gradient is most likely to be flattest. Again, the figure indicates that, for low-tax states, the marginal effects are steepest in the vicinity of the border. On the high-tax side, in a very local region of the border, taxes increase with distance from the border in a manner consistent with the theory.

The tax gradient may be heterogeneous not only in distance from the border, but also in the size of the tax discontinuity. Consumers may decide to cross-border shop both because they live closer to the border and because of a large difference in tax rates.

5.4 Is the Tax Gradient Steepest for Large Tax Differentials?

Figure 12 presents changes in the marginal effects conditional on both distance and the size of the discontinuity in tax rates. Standard errors are omitted for simplicity, but the standard errors unconditional on distance can be read from the columns of Table 9. The theory predicts that the tax gradient should be steepest for larger state tax rate differences. Figure 12 indicates that the theory is correct, especially in a local region of the border. In the region of zero to forty miles from the border, on the low-tax side, an increase in the size of the discontinuity from two to six percentage points increases the marginal effects by a factor of 1.5. On the high-tax side, the tax gradient slopes shift upward, implying that larger discontinuities create more incentives for localities to act as the theory predicts. Such a pattern begins to suggest the causal nature of the estimates; the existence of a discontinuous omitted variable at state borders that is also correlated with the difference in state tax rates and distance is less likely.

Figure 13 displays the predicted values of the regression equation, and thus converts the marginal effects into level terms conditional on the average size of the discontinuity and on various tax differentials. The level graphs have slopes that are consistent with the marginal effects above. The level of local option taxes on the low-tax side of the border shifts up as the discontinuity increases in absolute value. On the high-tax side of the border, the level of local taxes shifts down. In other words, as state tax rates increase, local tax rates decrease holding fixed the neighboring tax rate. This confirms the results of the RD design regarding the level of tax rates – and generalizes the results to a treatment that is heterogeneous.

Looking at Table 9, the average marginal effect of distance is almost perfectly monotonic in the size of the discontinuity. A significant decreasing gradient only emerges when the discontinuity is greater than 1.25 percentage points for towns in a low-tax state. Towns behave as if the neighboring state has assessed the same tax rate, when the discontinuity in state tax rates is small. On the high-tax side, the tax gradient is significant (but of the unexpected sign) over most relevant ranges of the discontinuity. However, an insignificant gradient begins to emerge if the size of the discontinuity is greater than 5 percentage points.

5.5 Extension: Second Closest State Borders and County Borders

Up until now, the empirical specifications have assumed a one-dimensional response: towns only respond to one border and one level of higher government. The existence of critical towns in the theory suggests that the process is actually multi-dimensional – and that towns respond based on their proximity to multiple borders. My theory does not account for a tax gradient near county borders, because I do not consider multiple levels of government.

To address the concern that towns may be responding to two state borders, I calculate the distance from the second closest intersection of a major road and a state border.[35] For computational feasibility, I use the "as the crow-flies" distance instead of driving distance. Column 1 of Table 10 is analogous to the baseline specification in Equation 5. The only difference is the use of the "crow-flies" distance instead of driving distance. Marginal effects are nearly identical, but are not always significant. In column 2, I add a polynomial in distance from the second closest border along with its interaction with the size of the difference in state tax rates at that border and dummies H and S. After controlling for multiple-state borders and their relevant discontinuities, the tax gradient increases in absolute value.

The second concern is that towns can both reduce the tax differential at state borders through local option taxes, and reduce the tax differential at county borders through local sales taxes. To account for this, I calculate the driving distance from every population weighted centroid to the nearest intersection of a major road and a county border. I then regress town and district taxes (without county taxes) on a polynomial in distance from the county border, plus controls and interactions. Column 3 shows the marginal effects of distance from the state border while controlling for the second state border and the nearest county border. The results in column 3 remain unbiased estimates of the marginal effects of

[35] The closest border intersection is always with respect to a contiguous state by definition. However, the second closest state border is often, but not always, a contiguous state.

the distance from the state border because of the inclusion of state fixed effects. Note that the sign of the gradient on the low-tax side of the border flips, and becomes insignificant.

In columns 4 and 5, I present the marginal effects of towns with respect to county borders – as discontinuities at county borders are equivalent in spirit to discontinuities at state borders. The results are of the same sign but are much larger than the state effects. Intuitively, this arises because counties are smaller than states and localities have pressure to adjust their tax rates much more rapidly over shorter distances. Due to the exclusion of county fixed effects, the presence of institutional differences that vary systematically across counties within a state will bias the estimates. These results suggest that the addition of multiple levels of government to the model would not change the interpretation of the results, because accounting for multiple borders does not qualitatively alter my findings.

5.6 Extension: Who Adopts Local Taxes Within a State?

The emergence of the tax gradient in the data may be a result of towns always setting positive tax rates conditional on distance from the border. But, the tax gradient will also appear if towns near the border are either more or less likely to assess a non-zero tax rate. To test if distance is a determinant to setting a non-zero tax rate, I run the following binary choice probit regression:

$$\begin{aligned} z_{lc} = \beta_0 + \beta_1 H_{lc} + \beta_2 S_{lc} + \beta_3 R_{lc} + \beta_4 R_{lc} H_{lc} + X_{lc}\varphi + \\ G(d_{lc})\rho + R_{lc}G(d_{lc})\gamma + H_{lc}G(d_{lc})\delta + R_{lc}H_{lc}G(d_{lc})\alpha + \\ S_{lc}G(d_{lc})\theta + \lambda \mathrm{T}_{lc} + \zeta_s + \varepsilon_{lc}, \end{aligned} \tag{8}$$

where all of the variables are defined as above with the exception of z_{lc}, which takes on the value of one if a locality assesses a non-zero town or district (sub-town) tax. The variable z_{lc} takes on a value of zero if both the town and district sales tax are zero.[36] I again instrument for the county tax rates. The last three columns of Table 9 present the marginal effects from the probit regression and Figure 14 presents the results conditional on distance.

The results indicate that towns near the high- and low-tax side of the border are more likely to assess a local option tax. For example, in low-tax states, the average marginal effect

[36] The probit specification above might be suggestive of the need for a two-tier hurdle model in the previous sections. In the previous sections, I assume that the choice of going from a 0% to 1% tax rate is equivalent to going from 1% to 2%. Given the background section on local option taxes in Section 2.2 this is likely to be the case. Each time a jurisdiction passes a sales tax, it requires a council vote or a town-wide referendum – each of which are equally likely to draw public opposition. Additionally, most local taxes are remitted to the state government and then forwarded to the town, suggesting the passage of a local option tax imposes few administrative costs (at start-up) on the local government. The results of the probit are also consistent with the results for Equation 5.

is -0.47. If this effect were constant, a town 100 miles from the border is 47 percent less likely to have a local option tax compared to an identical town on the border. For the high-tax state, the effect is 44 percent. The negative effect on the low-tax side is consistent with the tax gradient decreasing away from the border. Towns near the border realize they can export some of the town's tax burden to residents of the neighboring state and substitute to a local option sales tax – perhaps as a mechanism to reduce the property tax. On the high-tax side, towns near the border are more likely to have local option taxes as well, which is inconsistent with the theory and may explain why no tax gradient emerges in the tax rates. However, as the size of the discontinuity increases, the marginal effect on the probability of assessing a local option tax is decreasing.

5.7 Discussion

In summary, in a local region of the border, towns in low-tax states keep their local tax rates relatively high in order to export a large fraction of their tax burden to cross-border shoppers. This is especially salient when the size of the tax gap is largest – and when the town is most likely to attract cross-border shoppers who will bear some of the burden of the tax. As towns get further from the border, tax rates fall, and they fall the fastest the closest to the border – suggesting that towns undercut their neighbor in an effort to attract cross-border shoppers. However, towns farther away from the border need a much lower tax rate to attract residents from the low-tax state or from the border towns in their state. The empirical evidence here suggests that for towns beyond fifty miles from the border, tax rates are relatively constant with respect to distance and even slightly increasing.

On the high-tax side, the results do not line up with the theory, except in the case of very large state tax rate differences. An explanation for these effects is that the local tax rates on the high-tax side are much lower on average. Localities on the high-tax side of the border may not be constrained when assessing local option taxes because they do not anticipate further cross-border shopping problems. If the state tax rate is high, localities may anticipate that any remaining consumers have a low elasticity – leading the jurisdiction to raise the rate without fear of losing shoppers. An alternative explanation is suggested by Harding, Leibtag and Lovenheim (Forthcoming) who find that the incidence of the tax varies with distance from neighboring low-tax states. If firms near the border pass on less of the tax to consumers, the firms may be already smoothing the post-tax price in the same manner the localities would. If towns know that firms near the border bear more of the burden of the tax, the jurisdiction will have incentives to raise taxes near the border. These authors find no evidence that the incidence varies with distance on the low-tax side of borders. If incidence effects do not vary with distance in low-tax states, then the towns will adjust the local tax rate as a function of distance because the local government cannot rely on firms to vary the incidence of the tax with distance. A final explanation is yardstick competition by municipalities. If jurisdictions engage in yardstick competition, governments observe the tax rate levels of nearby jurisdictions and mimic the tax rate. For border localities on the high-tax side of the border, some of the local neighbors are on the low-tax side of the border. Because these neighbors in the low-tax state set relatively high tax rates, border jurisdictions on the high-tax side may look to their neighbors in the opposing state and set a relatively high tax rate compared to a town interior to their state.

The level of local tax rates is substantially higher for border towns on the low-tax side of the border. And the existence of an economically and statistically significant tax gradient implies that discontinuities at state borders continue to affect the elasticity of demand in local jurisdictions away from the border by inducing a unique form of tax competition where jurisdictions account for this discontinuity.

6 Conclusion

Identical local governments within a state will have incentives to differentiate their taxes to smooth the discontinuity in the total tax rate at the border, even when the state government prefers a higher or lower state tax rate than its neighbors. Discontinuities at state borders make identical jurisdictions heterogeneous based on the jurisdiction's location within a state and its ability to attract cross-border shoppers.

The discontinuity in the tax system at state borders induces welfare distortions with respect to consumption as some residents cross borders to purchase lower-tax goods. It is also likely to create horizontal inequities – where individuals with the same ability to pay actually pay different taxes – if some residents cross-border shop while others do not. A continuous tax system will reduce these welfare distortions, but will still have horizontal inequities if some individuals purchase goods a few neighboring jurisdictions away.

Moreover, as in Kleven and Slemrod (2009), "tax-driven product innovations" will distort the location of the firm. Such innovations require no technological innovations, but distort the characteristics of the goods – where the characteristic is the location of sale – to avoid taxes. In the context of the retail sales tax, this innovation arises as firms distort the locational characteristics of the good to the tax favorable side of the border in order to capture cross-border shoppers.[37] Absent the tax differential, the firm may have decided to locate on the

[37] The model presented in this paper did not allow for firms to choose their location decisions. However, shopping patterns must be linked with retail locations.

other side of the border. Instead, the locational characteristics become inefficient because of the firm's decision. I uncover a local tax gradient, which reduces these production and consumption distortions at state borders.

Even if the first-best tax system – as set by a global welfare maximizer who is constrained by varying state tax rates – is a perfectly continuous function of distance from the border, it is likely that this system is administratively infeasible. However, as in the model presented above, smoothing the size of the discontinuity through discrete steps in the tax system (that are a function of distance) is likely to happen as a result of tax competition over local tax rates – approximating a continuous policy. Although the discrete steps will induce additional notches within the tax system, the reduction in the larger distortion across the state will almost certainly be welfare improving. The new distortions at local borders are virtually guaranteed in any tax system given the infeasibility of an infinite number of differentiated tax rates.

Whether the tax gradient is optimal from a state government's perspective or if it is optimal for a state to allow localities to adopt LOST raise different questions than the global planner's decision. Agrawal (2011*a*) shows in a model where states maximize social welfare that the optimal pattern for the state depends critically on the elasticity of cross-border shopping, the inequality in consumption profiles, and the relative magnitudes of the tax base and exporting effects. If the elasticity of cross-border shopping is below a critical value, then it is advantageous to have higher tax rates – as empirically found in this paper – in the border region of a low-tax state. For it to be optimal to set higher rates in the border region of a high-tax state, the within-state inequalities in consumption induced by cross-border shopping must be sufficiently large such that the social planner would want to eliminate these inequalities by raising the border region's rate. It may be welfare enhancing from the state government's perspective to allow localities to assess local sales taxes.

This paper shows that federalism is a partial solution to the administrative difficulty of centrally implementing a tax system where tax rates are a continuous function of distance from the border. If local jurisdictions can set additional retail sales taxes, the salience of the state border would directly influence localities close to that border. On the other hand, jurisdictions located far from the border worry less about the notches because these jurisdictions do not have in-flows or out-flows of cross-border shoppers.

Empirically, I show that conditional on a set of observables, distance is a significant factor in the pattern of local option taxes. Jurisdictions on the low-tax side of the border that are relatively close to the border have higher tax rates than identical jurisdictions farther away from the border. These jurisdictions have a smaller elasticity of demand and export the tax burden to cross-border shoppers from the neighboring state. Although local tax rates gradually offset border differences on the low-tax side, the results have an unexpected sign on the high-tax side. Identical towns on opposite sides of the border also differ in the level of local tax rates with local taxes substantially lower on the high-tax side of the border. Although a discrete tax gradient is not the first-best outcome of a perfectly continuous tax gradient, the empirical evidence suggests that local option taxes will gradually smooth tax differentials over longer distances on the low-tax side.

The methodologies I develop in the paper are broadly applicable to analyzing how local governments respond to any policies that vary discontinuously at a border. For example, suppose states implement varying environmental restrictions on firms. At the margin, firms may choose to relocate to the side of the border with lower emission standards. Localities may adopt local regulations as a function of distance to the border in order to discourage firms from relocating and to reduce the regulatory differential at the border. More generally, "notched" or discontinuous policies are widespread and often are heterogeneous in magnitude. The methodologies developed in this paper account for this heterogeneity. Researchers can apply the theoretical and empirical methodologies introduced in this paper to test if "notched" policies induce jurisdictions to implement policies that vary with distance from the discontinuity.

7 Appendix

7.1 Proof of Uniqueness of the Equilibrium

In the paper, I derive conditions under which an equilibrium will exist. Existence follows from concavity and continuity of the best response functions, plus certain additional conditions outlined in the text. Once existence is shown, I prove below that any equilibrium in this model will be unique for the case of a multiple state, n town model. The solution to a three state model with n towns is characterized by the equation $\mathbf{At} = \mathbf{b}$. The proof generalizes to a multi-state model simply by changing the dimensions of the vectors and the elements of

b. This system can be written as:

$$\begin{bmatrix} 1 & -\frac{1}{4} & 0 & & \cdots & & 0 & -\frac{1}{4} \\ -\frac{1}{4} & \ddots & \ddots & \ddots & & & & 0 \\ 0 & \ddots & \ddots & \ddots & & & & \\ & \ddots & \ddots & 1 & -\frac{1}{4} & & & \vdots \\ \vdots & & & -\frac{1}{4} & 1 & \ddots & \ddots & \\ & & & & \ddots & \ddots & \ddots & 0 \\ 0 & & & & \ddots & \ddots & \ddots & -\frac{1}{4} \\ -\frac{1}{4} & 0 & & \cdots & & 0 & -\frac{1}{4} & 1 \end{bmatrix} \begin{bmatrix} t_{BB}^{H} \\ \vdots \\ \vdots \\ t_{B}^{H} \\ t_{BB}^{M} \\ \vdots \\ \vdots \\ t_{B}^{M} \\ t_{BB}^{L} \\ \vdots \\ \vdots \\ t_{B}^{L} \end{bmatrix} = \frac{1}{4} \begin{bmatrix} \delta x - D \\ \delta x \\ \vdots \\ \delta x \\ \delta x - R \\ \delta x + R \\ \delta x \\ \vdots \\ \delta x \\ \delta x - S \\ \delta x + S \\ \delta x \\ \vdots \\ \delta x \\ \delta x + D \end{bmatrix}. \tag{9}$$

Proof. Matrix **A** is a strictly diagonally dominant matrix because the sum of the diagonal element in every row is greater than the sum of all the off-diagonal elements in absolute value. By the Levy–Desplanques theorem, a strictly diagonally dominant matrix is non-singular – has an inverse. For a given number of towns and parameters in the model, therefore, $\mathbf{A}^{-1}\mathbf{b}$ is unique. When a Nash equilibrium exists, it is guaranteed to be the unique Nash equilibrium and is characterized by $\mathbf{A}^{-1}\mathbf{b}$. □

7.2 Characterizing the Solution to an n Town Model

In this section, I generalize the solutions in the text for a model with three states and n total towns. Recall that the solution to an n town model – where n is defined as the total number of towns in the model such that each state has $\frac{n}{3}$ towns – can be obtained by solving Equation 9, where the solution is given by $\mathbf{t}^{*}=\mathbf{A}^{-1}\mathbf{b}$.[38] Define $\mathbf{A}^{-1}$ as $\boldsymbol{\Xi}$. Then, letting

[38] Adding additional states would just change the position of the elements of **t** and **b**. Similarly, making states heterogeneous with respect to the number of towns would change the position of the elements.

$\ell = -\frac{1}{4}$, the determinant of $\boldsymbol{\Xi}$ is given by:

$$\det(\boldsymbol{\Xi}) = 1 + \sum_{k=1}^{\lfloor \frac{n-1}{2} \rfloor} \frac{(-1)^k n(n-k-1)!\ell^{2k}}{(n-2k)!k!} + 2\ell^n \mathbf{1}(n \text{ is odd}) - 4\ell^n \mathbf{1}(n \text{ is even} \,\&\, \frac{n}{2} \text{ is odd}), \tag{10}$$

where $\mathbf{1}(\bullet)$ is an indicator function that takes on the value one if $\bullet$ is true and takes on the value zero otherwise. Then, I can decompose $\boldsymbol{\Xi}$ such that $\boldsymbol{\Xi} = \frac{1}{\det(\boldsymbol{\Xi})}\boldsymbol{\Psi}$. Letting i index rows (the town) and j index columns (the town's neighbors' positions on the circle), the elements of $\boldsymbol{\Psi}$ are given by $\psi_{i,j}$. If n is even, the elements of the first row in $\boldsymbol{\Psi}$ can be solved for as:

$$\psi_{1,j} = \begin{cases} \phi_j & \text{for } j = 1, ..., \frac{n}{2} \\ -2\ell\phi_{\frac{n}{2}} & \text{for } j = \frac{n}{2} + 1 \\ \phi_{2+n-j} & \text{for } j = \frac{n}{2} + 2, ..., n, \end{cases} \tag{11}$$

while if n is odd, the elements are given by:

$$\psi_{1,j} = \begin{cases} \phi_j & \text{for } j = 1 \\ \phi_j + \xi_j & \text{for } j = 2, ..., \frac{n-1}{2} + 1 \\ \phi_{2+n-j} + \xi_{2+n-j} & \text{for } j = \frac{n-1}{2} + 2, ..., n, \end{cases} \tag{12}$$

where

$$\phi_j = \sum_{k=0}^{\lfloor \frac{n-j}{2} \rfloor} \frac{(-1)^k (n-j-k)!\ell^{2k+j-1}}{(n-j-2k)!k!}, \tag{13}$$

and

$$\xi_j = \sum_{k=0}^{\lfloor \frac{j-2}{2} \rfloor} \frac{(-1)^{j+k-2}(j-2+k)!\ell^{n-j+2k-1}}{(j-2)!k!}. \tag{14}$$

Note that as they are written above, equations 11 and 13 only yield the elements of the matrix's first row. Each of the subsequent rows will shift the elements of the previous row one place over, where the final element of the row will become the first element of the row. Therefore, for $i > 1$:

$$\psi_{i,j} = \psi_{1,r} \;\text{ where } r \equiv (j + n - r + 1)(\bmod n), \tag{15}$$

and $(j+n-r+1)(\bmod n) = j+n-r+1-n\left\lfloor \frac{j+n-r+1}{n} \right\rfloor$.

The equilibrium tax rates can now be characterized as $\mathbf{t}^{*}{=}\mathbf{A}^{-1}\mathbf{b} = \boldsymbol{\Xi}\mathbf{b} = \frac{1}{\det(\boldsymbol{\Xi})}\boldsymbol{\Psi}\mathbf{b}$. It should be noted that

$$\sum_{j=1}^{n}(-\ell)\delta x\psi_{i,j} = \frac{1}{2}\delta x \;\forall i. \tag{16}$$

To complete the characterization of the solution, one must determine how the size of the discontinuities in $\mathbf{b}$ that multiply the inverted matrix enter the solution. Under the assumption that all states are uniform in size, the discontinuities $D, R,$ and S will additively enter into town i's equilibrium tax rates as $(-\ell)(\psi_{i,n}-\psi_{i,1})D$, $(-\ell)(\psi_{i,\frac{n}{3}+1}-\psi_{i,\frac{n}{3}})R$, and $(-\ell)(\psi_{i,\frac{2n}{3}+1}-\psi_{i,\frac{2n}{3}})S$. Recalling that $D = R + S$ because of the circular setup of the problem, if $x > x^*$, the equilibrium tax rates can be characterized as:

$$t_i^* = \frac{1}{2}\delta x - \frac{\ell(\psi_{i,n}-\psi_{i,1}+\psi_{i,\frac{n}{3}+1}-\psi_{i,\frac{n}{3}})R + \ell(\psi_{i,n}-\psi_{i,1}+\psi_{i,\frac{2n}{3}+1}-\psi_{i,\frac{2n}{3}})S}{\det(\Xi)} \;\forall i. \tag{17}$$

Notice that if the states were asymmetric with respect to the number of towns, the above expressions could be modified by picking the j^{th} element of $\mathbf{\Psi}$ appropriately – where the number of towns are adjusted on the j index of ψ.

7.3 Methodology for Calculating Distance from the Border

In this section, I outline the methodology for calculating distance from the border. Arc-GIS is used to calculate this variable and all base map files necessary to calculate distance from the border are available on the Arc-GIS / ESRI map CD.[39] Figure 15 shows the methodology graphically.

I sometimes use the "as the crow-flies" distance from the population weighted average centroid of a place to the nearest intersection of a major road and a state border or foreign country to calculate the distance from the border. The District of Columbia is counted as a state, but Native American reservations are treated as localities. The justification for treating reservations as localities is that with some exceptions, purchases on Native American reservations by non-tribal members are subject to state sales taxes. Furthermore, reservations are often small and although they frequently sell cigarette purchases tax free, they do not have extensive shopping outlets for many larger items. Many reservations have also begun charging tribal tax rates on general sales.

To calculate distance from the border, I execute the following steps. When calculating distance, the projection system utilized in the map files is essential to guaranteeing that the distance measure is accurate for all latitudes and longitudes. This requires that the projec-

[39] The section below utilizes jargon from mapping software, which may be unfamiliar to readers not familiar with Arc-GIS.

tion system selected preserves distance attributes and that it be the same on all maps before beginning any calculations. I select the North American Equidistant Conic Projection System. When the coordinate system is defined differently, I convert the coordinate system using the NAD 1983 to WGS 1984 _ 1 geographic transformation option. This transformation converts the coordinate system with an accuracy of plus or minus two meters.

First, in order to identify the tax rates at international crossings, I merge a detailed polygon file of the fifty states plus the District of Columbia with detailed files of Canada and Mexico. It is important to use a "detailed" file that precisely traces out the border. Smoothed files may be off several miles in many circumstances. I then convert the polygon file into a line file that explicitly identifies the geographic identification number of the "left" and "right" states. This identification will allow me to record the neighboring state's tax rate. Second, I overlay a detailed Census major roads file. Census major roads are Class 1, 2, and 3 roads, which include major highways and paved roads primarily used for transportation. These classes of roads exclude dirt roads and primarily residential roads. Then, I find the precise intersection of each state border line with a major road. This intersection is identified with a FID number, which can be used to identify the state border combination from the state line file. I drop all intersections that correspond to coastal areas or to major routes that are defined as ferry crossings.

Third, I identify the population weighted centroid as the point in which the place would balance on a scale if every person in that place were equal weight. To calculate this, I identify the population distribution within a place using the population of every Census block in the country.[40] Let b index each Census block point given by population P_b and has latitude ϕ_b and longitude λ_b. The population weighted center of place i is the latitude $\bar{\phi}$ and the longitude $\bar{\lambda}$ given by:

$$\bar{\phi}_i = \frac{\Sigma P_b \phi_b}{\Sigma P_b} \qquad \bar{\lambda}_i = \frac{\Sigma P_b \lambda_b Cos(\phi_b(\frac{\pi}{180}))}{\Sigma P_b Cos(\phi_b(\frac{\pi}{180}))}.$$

Fourth, I run a "near" command on the 25,000 population weighted centroids and the several thousand intersections that I found above. This will calculate the nearest linear distance from the intersection of the major roads and the state borders. Fifth, I conduct a spatial join on the centroids with the level of geography I wish to analyze (call it a place polygon file). I define a centroid as being within a place polygon if its point is contained entirely within the polygon. This spatial join will attach the geographic identifier of the Census place or county to the centroid.

To calculate the second closest border crossing, I follow the method outlined above, but

[40] A Census block is the smallest unit of geography. In some cases, a block may be a large area with little or no population. In other areas, a Census block may contain an entire apartment complex or building and may have a population of several hundred.

instead of executing a near command in ArcGIS, I use the near table command. This will calculate all of the nearest border crossings up to a particular threshold. I calculate 1000 of the nearest border crossings for each place centroid. This is a sufficient number for me to calculate the distance from the second closest border.

The data calculated above then can be merged based on geographic identification numbers to the Census data. However, the tax data does not contain geographic identifiers, so I must merge the data using name matching. In cases of merging by county, this is an easy process and I am able to obtain a 99.9% match rate. One county does not match because it is not in the tax data set. Census places are the closest to towns in the United States. Census places contain no county information. In some states, Census places (and towns) cross county lines. To deal with this issue, I intersect Census places and counties using a spatial join in ArcGIS. This matches each place to a county that it overlaps. I can then name match Census places to the tax data using place, county, and state names. Name matching to Census place data obtains nearly a 90% match rate.[41] I hand match any remaining observations.

Inevitably, a better measure of distance is actual driving distance. I calculate driving distance using ArcGIS' network analyst toolbox. After following the first three steps above, I use ESRI's street file to calculate driving distance. The data in the street file contains all streets in the country, but note that the final destination I use will always be a major road as above. I convert the data to a network data set so that it has street driving speeds within it. To calculate driving distance, I locate the nearest minor street to a population weighted centroid and to the major road crossings by searching within a fifty-mile radius. After doing this, I need to specify how ArcGIS will calculate driving distance. Using the centroids as origins and the border crossings as destinations, I use a time criterion to calculate distance – that is I have GIS minimize the driving time to the nearest location.[42]

In addition, I need to make assumptions on how the individual drives to the border. I assume that individuals follow a "hierarchical" method of driving – that is whenever possible, I have ArcGIS route their travel via larger roads. I also require that individuals must obey one-way streets or turn restrictions onto roads. However, I do not impose any other restrictions – that is I do not restrict individuals from using alleys, four-wheel drive roads, or ferry crossings.[43] Using the network analyst, ArcGIS returns the driving distance (in miles) and time (in minutes) for the shortest time path from each population weighted centroid to the nearest intersection of a major road and state border.

[41] Recall some Census places are not towns and some towns are not Census places.

[42] The alternative would be to use a distance criterion.

[43] I impose these restrictions and find the driving distances are almost perfectly correlated.

7.4 Online Appendices

Online appendices are at http://www-personal.umich.edu/~dagrawal/research.htm and contain two contributions. The first online appendix presents a very simple two-state model of the tax gradient. The model is much simpler than the one in the text, but demonstrates most of the intuition in a very stark manner. The second appendix presents all the figures and tables below for a regression specification with the total local plus county tax rate as the dependent variable. The results are very similar to the ones presented in the text.

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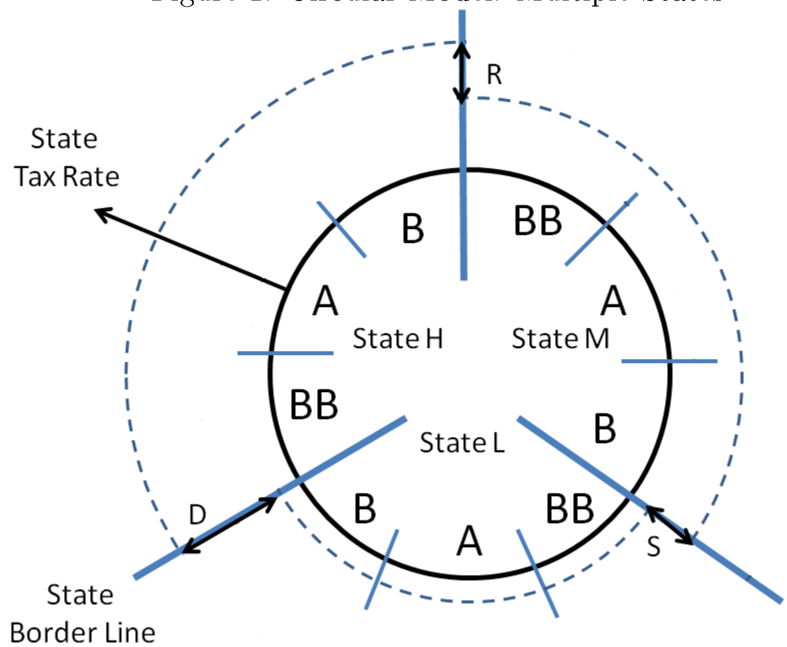
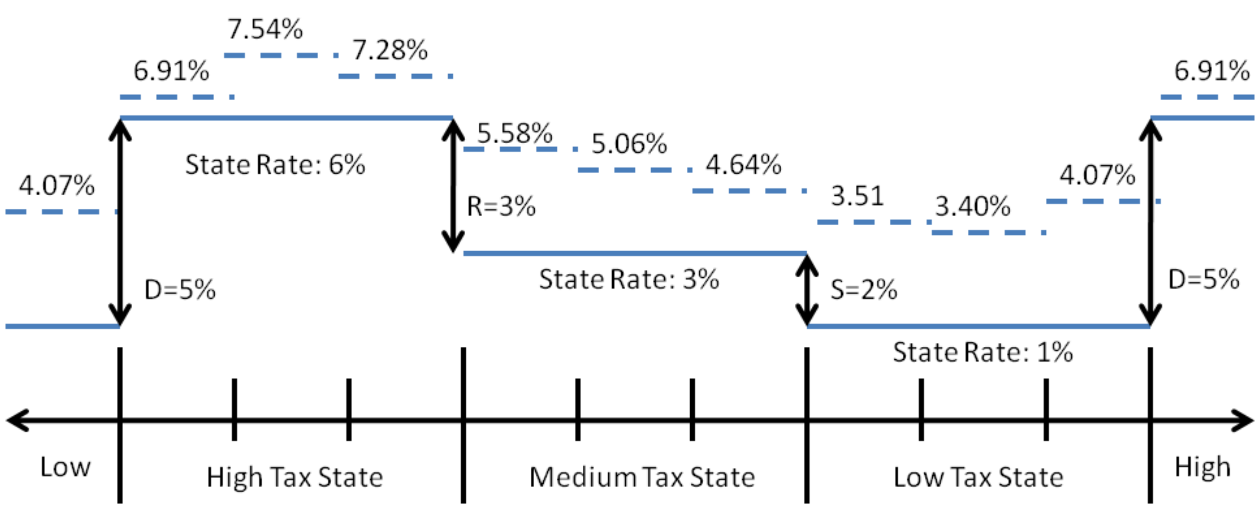
Figure 1: Circular Model: Multiple States



The dotted lines around the circle represent the level of the state tax rate. The large solid lines are state borders and the smaller solid lines are town borders.

Figure 2: Example of Equilibrium Tax Rates



The figure above flattens the circular model of Figure 1. The solid horizontal lines are the state tax rates. The dotted lines are the municipal plus state tax rates in the Nash Equilibrium when the parameters of the model are set such that $\delta x = 4$, $D = 5$, $R = 3$, and $S = 2$.

Figure 3: Driving Distance from the Nearest Border

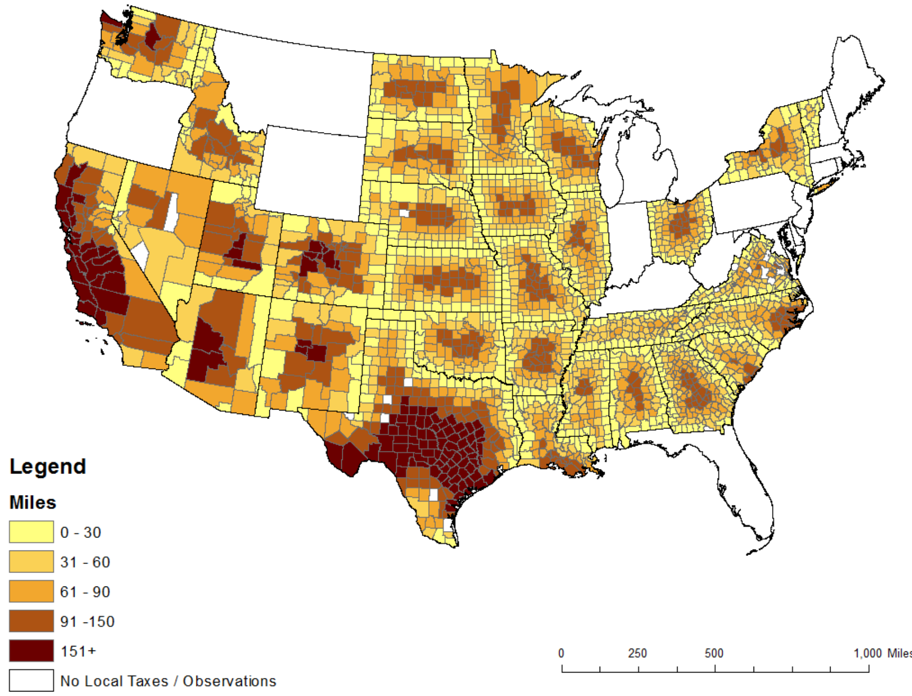


Figure 4: State Sales Tax Rates

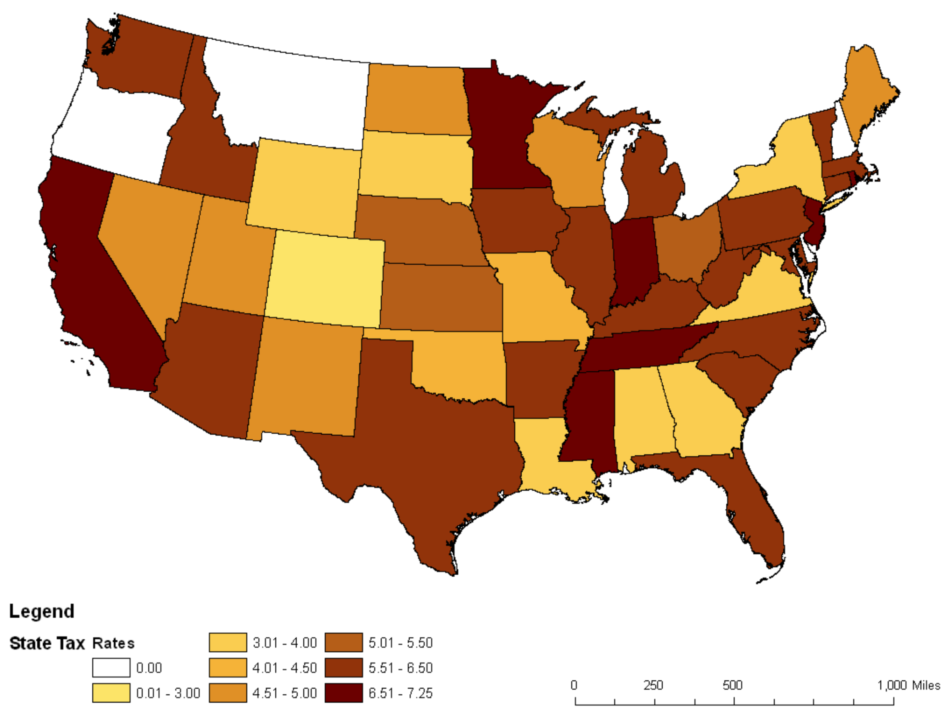


Figure 5: County Tax Rates by Whether the Nearest Border Is a High- or Low-Tax State

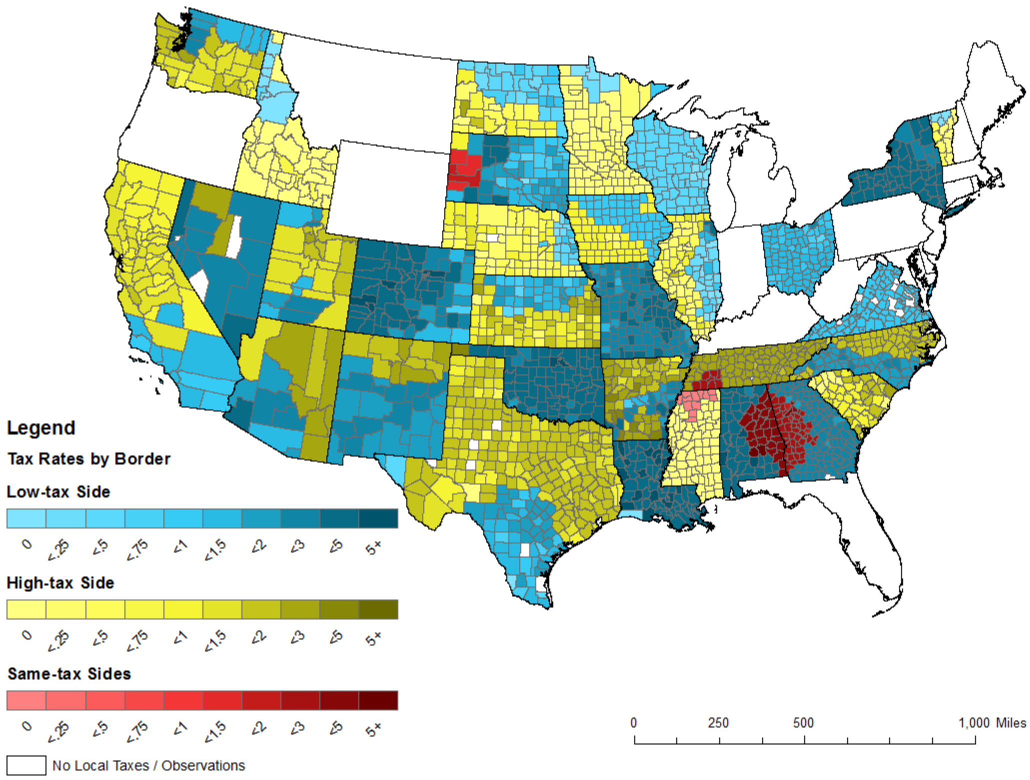


Figure 6: Missouri Example of Local Option Taxes

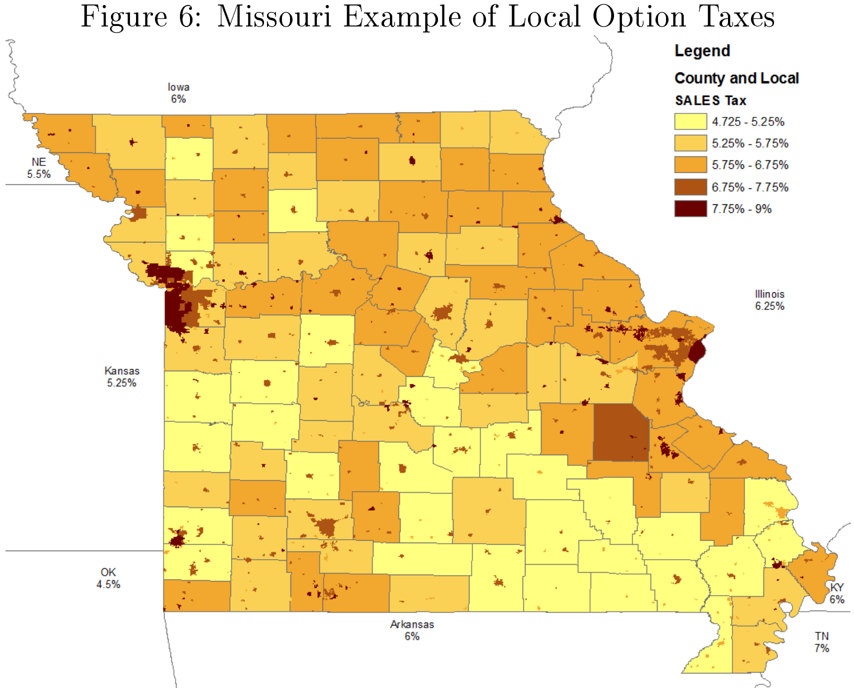
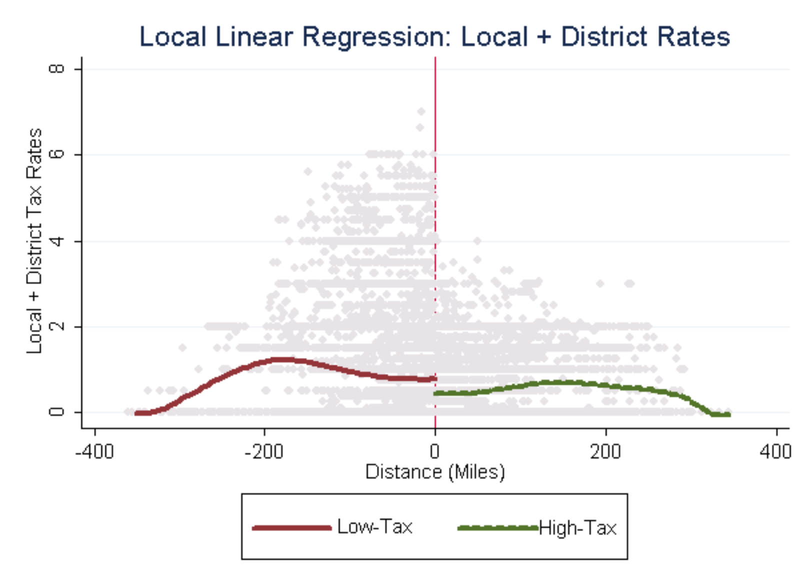
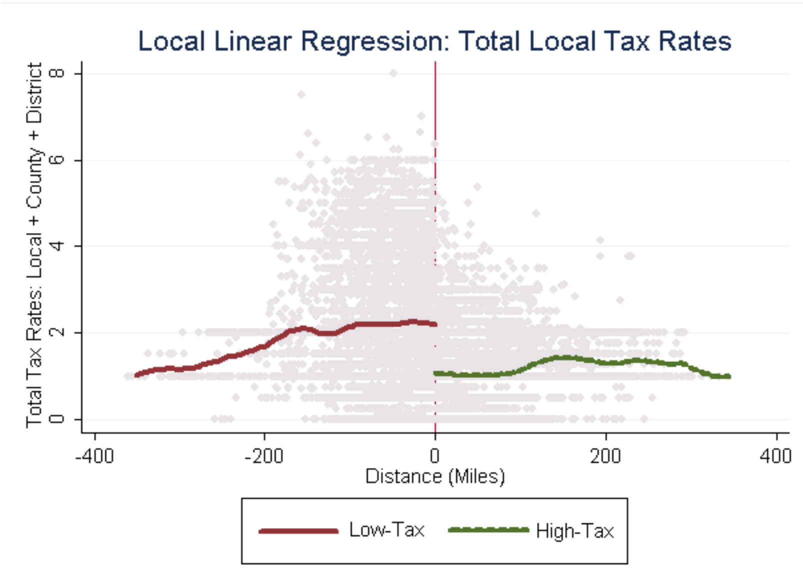


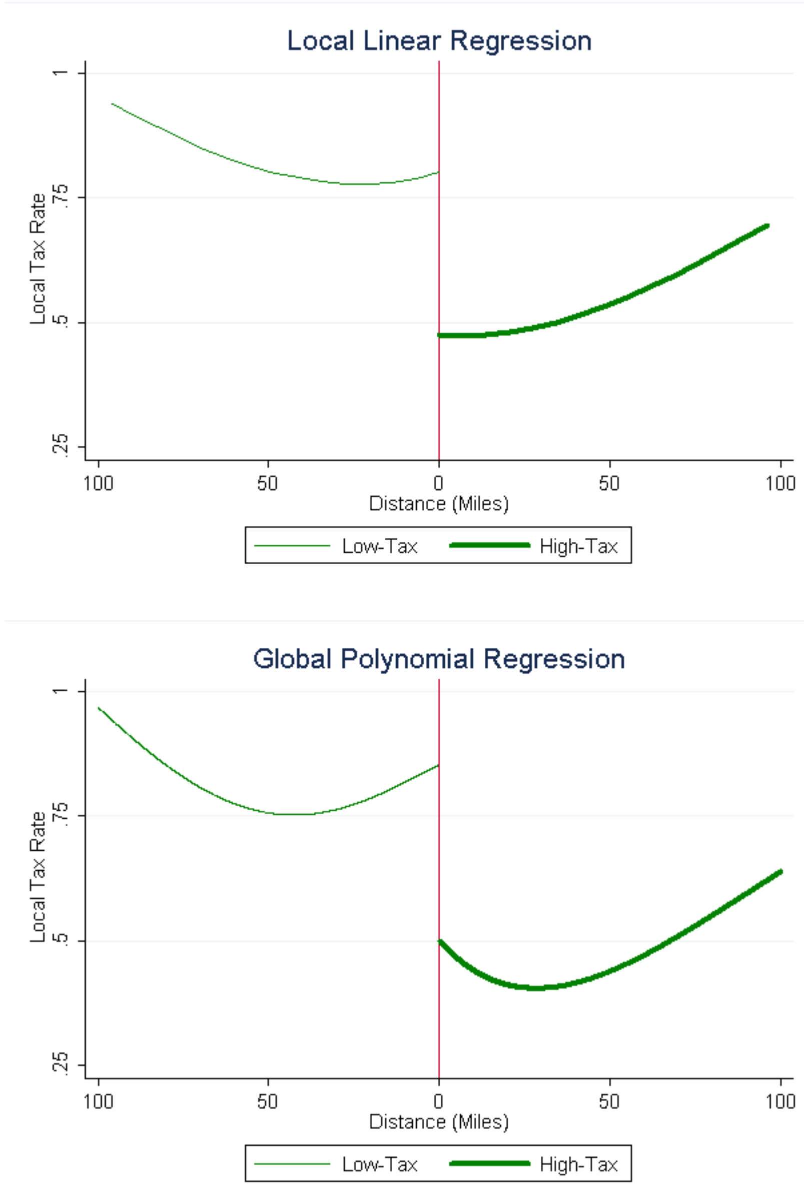
Figure 7: Regression Discontinuity Results





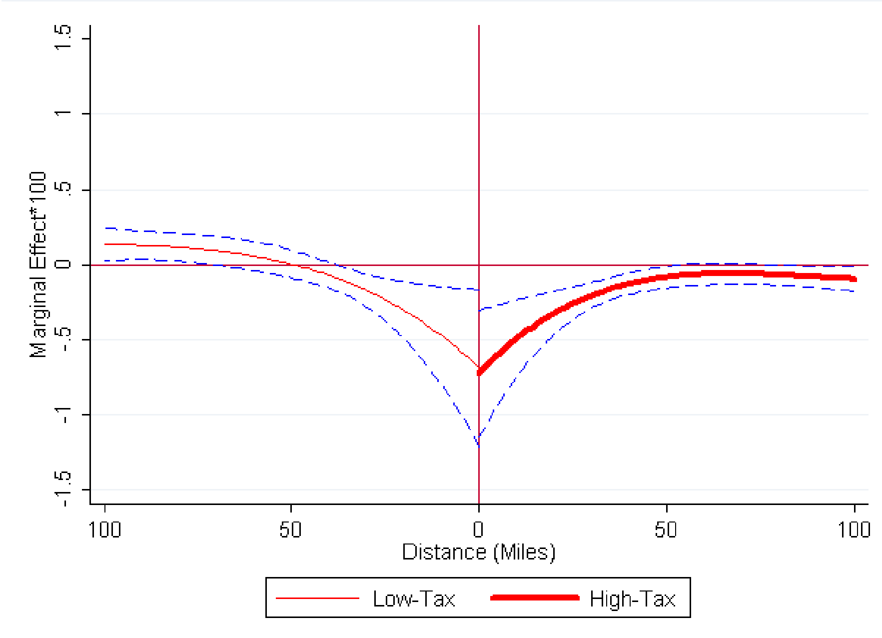
The top graph uses municipal tax rates only, while the second graph depicts the RD for the total effective local tax rate.
RD methodology follows Imbens and Kalyanaraman (Forthcoming) with a triangle kernel.
The graphs above do not include additional covariates.

Figure 8: Comparison of the Local Linear Regression with the Global Polynomial Regression



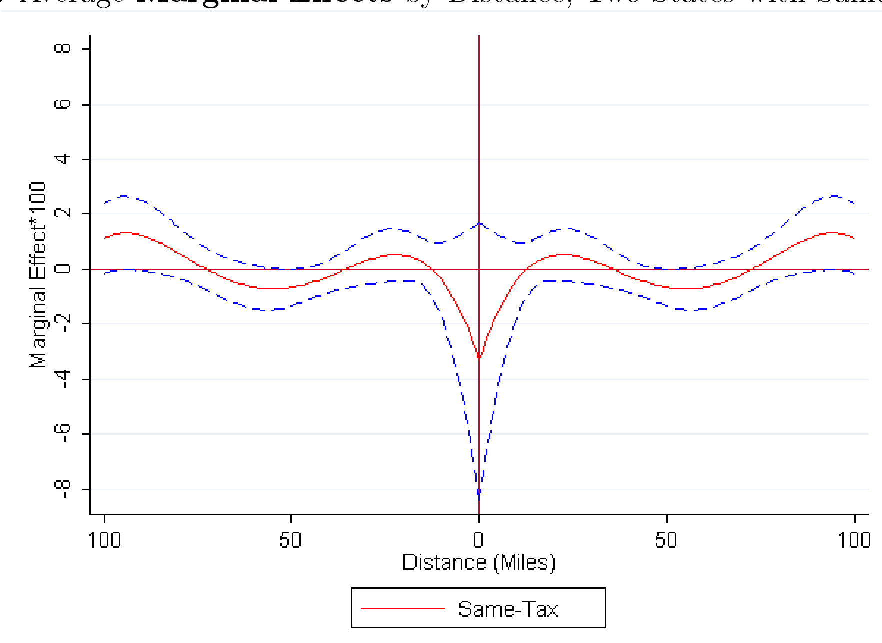
The top graph zooms in on the top graph in Figure 7. The bottom graph plots the predicted value from a fifth degree global polynomial evaluated at the average discontinuity size with no covariates.

Figure 9: Average **Marginal Effects** by Distance, Full Sample



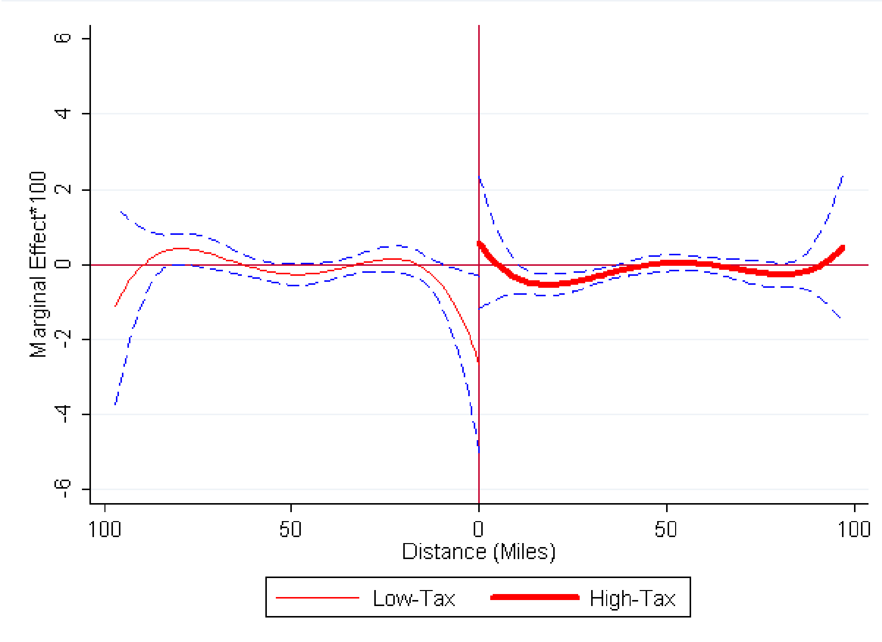
Marginal effects represent the effect of moving **away** from the border in both directions.
To derive the per mile marginal effects, divide by 100.
Confidence intervals are 95%.

Figure 10: Average **Marginal Effects** by Distance, Two States with Same Tax Rate



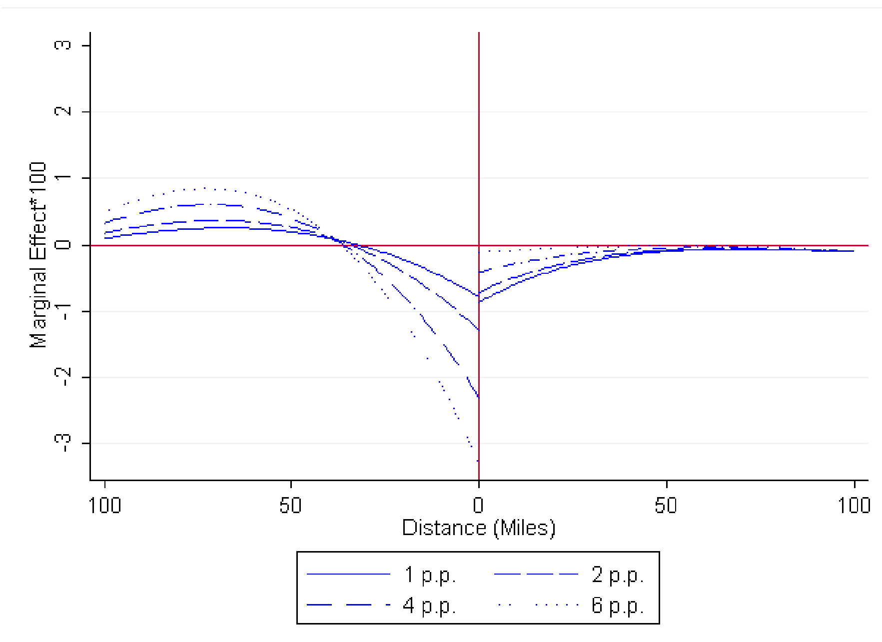
Marginal effects represent the effect of moving **away** from the border in both directions.
To derive the per mile marginal effects, divide by 100.
Confidence intervals are 95%.

Figure 11: Average **Marginal Effects** by Distance with 98 Mile Sample Restriction



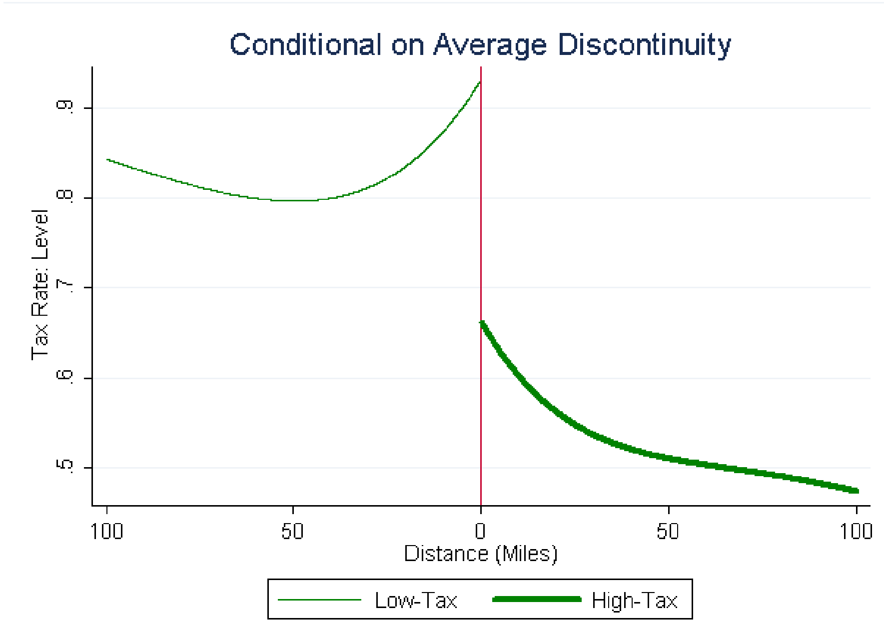
Marginal effects represent the effect of moving **away** from the border in both directions. Confidence intervals are 95%.

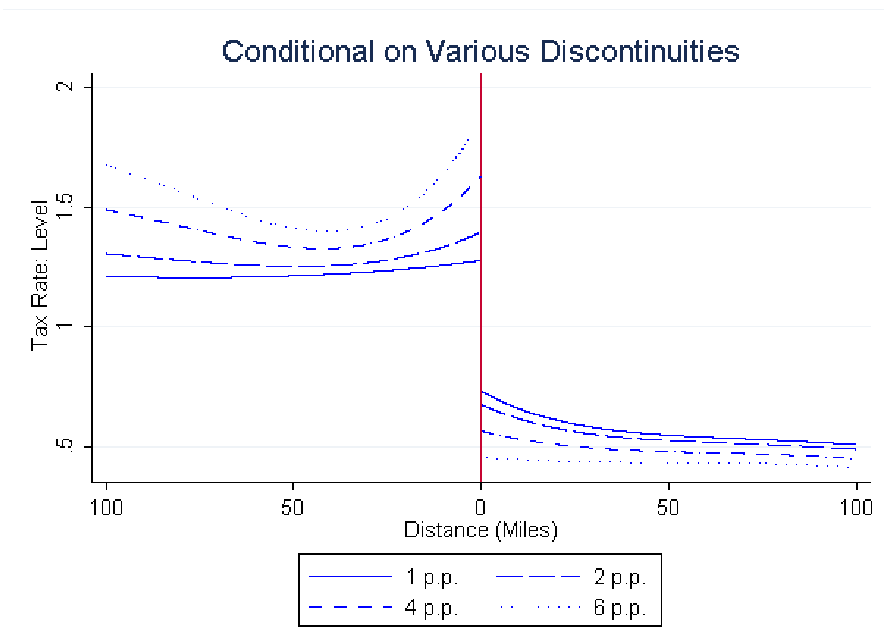
Figure 12: Average **Marginal Effects** by Distance and Size of the Discontinuity in State Rates



Left side is the relatively low-tax state. Right side is the relatively high-tax state. Marginal effects represent the effect of moving **away** from the border in both directions.

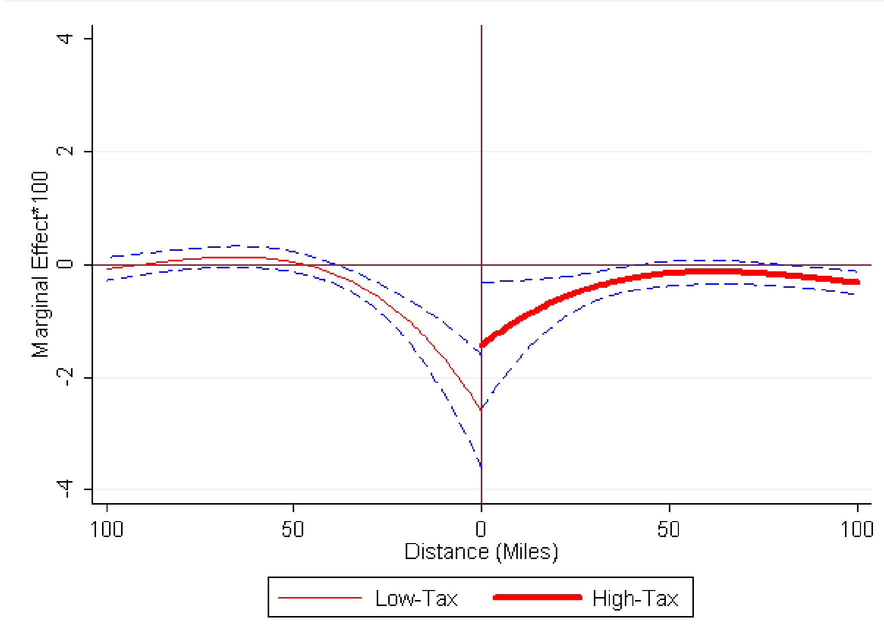
Figure 13: Predicted Values of Local Rates from a Global Polynomial Regression





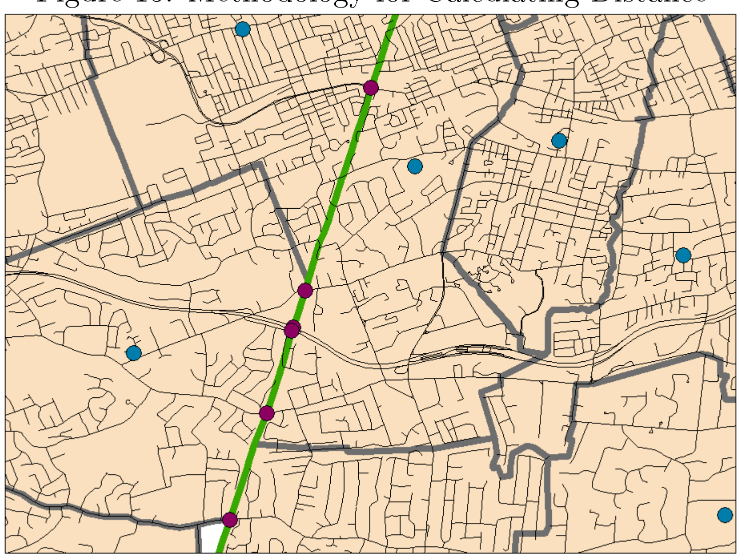
These graphs plot the predicted values of local tax rates from a global polynomial regression including state fixed effects and covariates. The top graph evaluates the predicted value conditional on the average discontinuity and the set of covariates. The bottom graph conditions on various discontinuity sizes. The marginal effects in Figures 9 and 12 correspond to the slopes of the lines above, respectively.

Figure 14: Average **Marginal Effects** of the Probability a Town Has a Local Tax Rate



Left side is the relatively low-tax state. Right side is the relatively high-tax state.
Marginal effects represent the effect of moving **away** from the border in both directions.
To derive the per mile marginal effects, divide by 100.

Figure 15: Methodology for Calculating Distance



To calculate driving distances: (1) Find the population weighted centroid. These are the dots at the center of the polygons in the file above. (2) Calculate major road crossings at state borders. These are the dots along the straight line. (3) Plot a street network data set. Allow GIS to optimize over the shortest route. Notice some routes require significant side road travel, while others can follow one main road to the border. This yields a better approximation of travel distance relative to the "as the crow-flies" distance.

Table 1: Sales Tax Summary Statistics by State (April 2010)

Mean Rates Listed as a Percent

	State Rate†	County Rate‡	Local Rate	District Taxes?	Total Rate	N	Neighboring States
Alabama	4.00	1.74	2.20	Yes	8.05	483	FL, GA, MS, TN
Alaska	-	.43	1.07	No	1.50	330	CAN
Arizona	5.60	1.09	1.17	No	7.27	179	CA, MEX, NM, NV, UT
Arkansas	6.00	1.39	0.68	No	8.07	560	LA, MO, MS, OK, TN, TX
California	7.25	1.00	0.04	Yes	8.82	897	AZ, MEX, NV, OR
Colorado	2.90	0.99	2.05	Yes	6.20	308	KS, NE, NM, OK, UT, WY
Connecticut	6.00	-	-	No	6.00	172	MA, NY, RI
Delaware	-	-	-	No	0.00	58	MD, NJ, PA
D.C.	6.00	-	-	No	6.00	1	MD, VA
Florida	6.00	0.74	-	No	6.74	562	AL, GA
Georgia	4.00	2.94	0.001	No	6.94	571	AL, FL, NC, SC, TN
Hawaii	4.00	0.13	-	No	4.13	66	-
Idaho	6.00	0.02	0.02	No	6.04	199	MT, NV, OR, UT, WA, WY
Illinois	6.25	0.34	0.13	Yes	6.90	1528	IN, IA, KY, MO, WI
Indiana	7.00	-	-	No	7.00	651	IL, KY, MI, OH
Iowa	6.00	0.93	0.01	No	6.94	980	IL, MN, MO, NE, SD, WI
Kansas	5.30	0.97	0.31	Yes	6.58	656	CO, MO, NE, OK
Kentucky	6.00	-	-	No	6.00	486	IL, IN, MO, OH, TN, VA, WV
Louisiana	4.00	1.71	2.66	Yes	8.66	367	AR, MS, TX
Maine	5.00	-	-	No	5.00	426	CAN, NH
Maryland	6.00	-	-	No	6.00	297	DC, DE, PA, VA, WV
Massachusetts	6.25	-	-	No	6.25	397	CT, NH, NY, RI, VT
Michigan	6.00	-	-	No	6.00	708	CAN, IN, OH, WI
Minnesota	6.875	0.01	0.01	Yes	6.93	1048	CAN, IA, ND, SD, WI
Mississippi	7.00	-	0.01	No	7.00	309	AL, AR, LA, TN
Missouri	4.225	1.40	0.97	Yes	6.81	977	AR, IA, IL, KS, KY, NE, OK, TN
Montana	-	-	-	No	0.00	236	CAN, ID, ND, SD, WY
Nebraska	5.50	0.00	0.26	No	5.77	629	CO, IA, KS, MO, SD, WY
Nevada	4.60	2.72	-	Yes	7.36	74	AZ, CA, ID, OR, UT
New Hampshire	-	-	-	No	0.00	221	CAN, MA, ME, VT
New Jersey	7.00	-	-	No	7.00	528	DE, NY, PA
New Mexico	4.85	0.62	1.29	No	6.77	167	AZ, CO, MEX, OK, TX
New York	4.00	3.93	0.05	Yes	8.10	1310	CAN, CT, MA, NJ, PA, VT
North Carolina	5.75	2.03	-	Yes	7.78	632	SC, TN, VA
North Dakota	5.00	0.04	0.28	No	5.32	421	CAN, MN, MT, SD
Ohio	5.50	1.28	-	Yes	6.78	1043	IN, KY, MI, PA, WV
Oklahoma	4.50	1.08	2.33	No	7.91	544	AR, CO, KS, MO, NM, TX
Oregon	-	-	-	No	0.00	306	CA, ID, NV, WA
Pennsylvania	6.00	0.06	-	No	6.06	1418	DE, MD, NJ, NY, OH, WV
Rhode Island	7.00	-	-	No	7.00	46	CT, MA
South Carolina	6.00	0.13	0.43	Yes	7.11	344	GA, NC
South Dakota	4.00	-	1.16	Yes	5.16	359	IA, MN, MT, ND, NE, WY
Tennessee	7.00	2.47	0.03	No	9.50	426	AL, AR, GA, KY, MO, MS, NC, VA
Texas	6.25	0.23	1.17	Yes	7.75	1386	AR, LA, MEX, NM, OK
Utah	4.70	1.14	0.25	Yes	6.37	253	AZ, CO, ID, NM, NV, WY
Vermont	6.00	-	0.04	No	6.04	252	CAN, MA, NH, NY
Virginia	4.00	0.93	0.07	No	5.00	335	DC, KY, MD, NC, WV
Washington	6.50	0.31	1.33	Yes	8.25	367	CAN, ID, OR
West Virginia	6.00	-	-	No	6.00	270	KY, MD, OH, PA, VA
Wisconsin	5.00	0.43	-	Yes	5.45	788	IA, IL, MI, MN
Wyoming	4.00	1.10	-	No	5.10	150	CO, ID, MT, NE, SD, UT
United States	5.31	0.81	0.38	Yes	6.61	25,721	CAN, MEX

†Denotes the state statutory rate. Excludes Indian reservations. U.S. values are the mean weighted by number of localities in the state.

‡Weighted by the number of jurisdictions in the county.

Table 2: Summary Statistics

Averages with Standard Deviations in ( )
Place Level Data – Full Sample

Variable	Full	Low-Side	High-Side	Same-Tax
Differential in State Tax Rate (R)	-.26	-1.90	1.93	0
	(2.42)	(1.65)	(1.43)	(-)
Differential in County Tax Rate	-.01	-.08	.10	-.09
	(1.03)	(1.13)	(.88)	(.87)
Driving Distance from State Border	60.21	56.33	66.15	50.44
(miles)	(50.44)	(46.55)	(55.71)	(31.20)
Travel Time from State Border (min.)	77.88	72.89	85.57	64.33
	(62.62)	(59.19)	(67.59)	(36.52)
Driving Distance from County Border	7.29	7.30	7.41	5.62
	(6.97)	(7.28)	(6.70)	(3.97)
Crow-Fly Distance from State Border	45.59	43.18	49.36	38.41
	(37.51)	(36.03)	(39.88)	(23.59)
Second Closest State Crow-Fly Distance	92.83	85.34	104.23	74.94
	(59.96)	(55.35)	(65.37)	(31.19)
Number of Neighbors	1.86	1.96	1.71	2.00
	(2.09)	(2.25)	(1.83)	(2.37)
Town Area	6.35	6.22	6.26	9.93
	(23.04)	(24.44)	(21.36)	(33.98)
Town Perimeter	15.41	14.70	15.47	27.32
	(28.66)	(27.37)	(29.05)	(40.80)
Population	10,244	11,264	8,919	9.642
	(90,367)	(109,828)	(58,781)	(33,976)
Senior	15.83	15.75	16.04	14.55
	(7.63)	(7.55)	(7.85)	(5.67)
College	21.97	22.40	21.57	19.55
	(13.93)	(14.44)	(13.31)	(12.24)
Income	37,312	37,920	36,780	33,501
	(18,048)	(18,833)	(17,250)	(12,571)
Work in County (%)	67.62	67.69	68.12	59.69
	(20.43)	(20.60)	(20.06)	(20.66)
Work in State (%)	96.20	96.26	96.12	95.57
	(8.68)	(8.52)	(20.06)	(10.26)
Obama Vote Share	43.99	45.22	42.62	40.22
	(13.66)	(13.16)	(13.90)	(16.44)
Local Rate	0.62	0.73	0.44	1.20
	(1.08)	(1.24)	(0.70)	(1.53)
Local + District Rate	0.71	0.83	0.51	1.27
	(1.13)	(1.30)	(0.75)	(1.64)
Local + District + County Rate	1.76	2.19	1.09	3.14
	(1.45)	(1.55)	(0.91)	(1.44)
Sample Size	16,799	9331	6952	516

High-side means that the nearest state to the location is a low-tax state.

Table 3: Average Tax Rates by Driving Distance

Miles to Nearest State	Low-Tax Side 100+	75-100	50-75	25-50	0-25	High-Tax Side 0-25	25-50	50-75	75-100	100+
Total Tax	7.56	6.77	6.33	6.26	6.25	7.04	6.97	7.11	7.23	8.01
	(2.42)	(2.71)	(2.36)	(2.28)	(2.25)	(1.31)	(1.24)	(1.40)	(1.57)	(1.61)
State Tax	5.64	4.88	4.90	4.85	4.79	6.20	6.24	6.21	6.17	6.68
	(1.55)	(1.08)	(.97)	(.97)	(.92)	(.60)	(.61)	(.63)	(.72)	(1.11)
County Tax	.91	1.28	1.39	1.49	1.44	.59	.60	.55	.40	.48
	(.97)	(1.30)	(1.30)	(1.32)	(1.19)	(.81)	(.84)	(.78)	(.60)	(.55)
Local Tax	.91	.91	.68	.64	.66	.38	.33	.41	.49	.64
	(1.29)	(1.44)	(1.27)	(1.17)	(1.15)	(.67)	(.62)	(.65)	(.72)	(.80)
District Tax	.10	.08	.07	.12	.13	.08	.07	.08	.09	.05
	(.36)	(.36)	(.30)	(.41)	(.38)	(.26)	(.24)	(.26)	(.28)	(.21)
Local + District	1.01	.99	.75	.76	.79	.46	.38	.49	.57	.68
	(1.35)	(1.52)	(1.29)	(1.23)	(1.21)	(1.05)	(.66)	(.73)	(.78)	(.83)
County + Local + District	1.95	2.27	2.14	2.32	2.23	1.06	1.00	1.04	1.01	1.32
	(1.40)	(1.70)	(1.60)	(1.59)	(1.48)	(1.01)	(.96)	(.93)	(.87)	(.69)
Sample Size	1368	1250	1675	2334	2704	1793	1614	1191	868	1486

Sample only includes states that allow for Local Option Taxes.

Table 4: RD Estimates

	(1) Local Tax Rates	(2) Local + District Tax Rates	(3) County Tax Rates	(4) Total Local Rates (L+D+C)	(5) Local Tax Rates	(6) Local + District Tax Rates
No Controls	-.531***	-.352***	-.521***	-1.130***	-.176**	-.043
	(.055)	(.034)	(.124)	(.068)	(0.075)	(.092)
Controls	-.505***	-.328***	-.634***	-1.242***	-.205***	-.123
	(.055)	(.034)	(.179)	(.068)	(.074)	(.090)
Controls and State Dummies	-.434***	-.324***	-.650***	-1.247***	-.154**	-.105
	(.055)	(.034)	(.178)	(.066)	(.073)	(.087)
Optimal Bandwidth	46.12	97.75	65.30	38.90	12.21	7.26
Type of Border	State	State	State	State	County	County
Unit of Observation	Locality	Locality	County	Locality	Locality	Locality
Border Counties Included?	Yes	Yes	Yes	Yes	No	No

Results represent the effect on the level of local tax rates in a border town from the high-tax side relative to an identical border town on the low-tax side. Columns (1) - (4) estimate the level effect at state borders for various local tax rates – local only, local plus district, county only, and local plus district plus county rates. The running variable is the driving distance from the locality to the state border with the exception of column (3), where the running variable is the driving distance from the county centroid to the state border. Columns (5) and (6) estimate the level effect of local tax rates and local plus district tax rates at county borders, where the county borders specifications exclude counties along state borders. ***99%, **95%, *90%

Table 5: Regression Coefficients for the Estimating Equation

Variable	(1)	(2)	(3)	(4)
Same (S)	.560	.640*	.403**	.350**
	(.403)	(.375)	(.162)	(.145)
High (H)	.066	.240***	.226***	.209***
	(.095)	(.089)	(.060)	(.062)
Notch (R)	-.174***	-.347***	-.095***	-.118***
	(.039)	(.038)	(.025)	(.025)
$H \cdot R$	.129***	.302***	.027	.063**
	(.045)	(.043)	(.030)	(.030)
Distance (d)	1.346**	1.394**	-.227	.279
	(.643)	(.628)	(.384)	(.414)
$S \cdot d$	-.8168	-8.445	-4.541	-3.626
	(-7.033)	(6.497)	(2.878)	(2.599)
$H \cdot d$	-1.436*	-.578	-.810	-1.294**
	(.843)	(.800)	(.532)	(.554)
$R \cdot d$	.888***	.766***	.443***	.508***
	(.295)	(.285)	(.168)	(.166)
$H \cdot R \cdot d$	-1.246***	-1.283***	-.344	.358*
	(.355)	(.343)	(.215)	(.211)
d^2	-4.137**	-3.051*	.228	-.705
	(1.709)	(1.698)	(1.040)	(1.087)
$S \cdot d^2$	61.003	62.433*	28.903*	22.476
	(37.526)	(34.504)	(15.979)	(14.447)
$H \cdot d^2$	2.853	-.081	1.277	2.592*
	(-2.298)	(2.197)	(1.455)	(1.501)
$R \cdot d^2$	-2.077***	-1.457**	-.895**	-.993**
	(.719)	(.715)	(.429)	(.425)
$H \cdot R \cdot d^2$	3.733***	3.383***	.991*	.711
	(.891)	(.870)	(.549)	(.542)
d^3	5.295***	3.079*	-.082	.404
	(1.811)	(1.843)	(1.131)	(1.152)
$S \cdot d^3$	-158.815*	-158.969**	-66.955*	-54.118*
	(81.579)	(74.585)	(35.64)	(32.082)
$H \cdot d^3$	-3.493	.165	-1.09	-2.193
	(2.492)	(2.395)	(1.582)	(1.611)
$R \cdot d^3$	2.059***	.993	.679	.652
	(.726)	(.742)	(.454)	(.449)
$H \cdot R \cdot d^3$	-3.747***	-2.837***	-.870	-.371
	(.913)	(.898)	(.573)	(.572)
d^4	-2.491***	-1.170	.055	.010
	(.802)	(.844)	(.517)	(.519)
$S \cdot d^4$	168.433**	164.557**	64.788*	54.247*
	(76.777)	(69.842)	(34.107)	(30.510)
$H \cdot d^4$	1.923*	.053	.387	.769
	(1.132)	(1.096)	(.722)	(.730)
$R \cdot d^4$	-.850***	-.273	-.203	-.147
	(.315)	.332	(.205)	(.203)
$H \cdot R \cdot d^4$	1.425***	.910	.281	.012
	(.400)	(.398)	(.255)	(.257)

Table 5 Continued

Variable	(1)	(2)	(3)	(4)
d^5	.366***	.134	-.016	-.028
	(.125)	(.136)	(.083)	(.083)
$S \cdot d^5$	-61.463**	-58.759**	-22.133*	-18.966*
	(26.006)	(23.557)	(11.668)	(10.362)
$H \cdot d^5$	-.331*	-.017	-.046	-.093
	(.180)	(.176)	(.116)	(.117)
$R \cdot d^5$	.117**	.021	.020	.007
	(.048)	(.053)	(.033)	(.032)
$H \cdot R \cdot d^5$	.178***	-.093	-.029	.017
	(.062)	(.063)	(.040)	(.041)
Number of Neighbors		.070***	.034***	.054***
		(.008)	(.005)	(.006)
Area		-.540***	-.446***	-.493***
		(.115)	(.077)	(.063)
Perimeter		.724***	.479**	.413***
		(.093)	(.057)	(.053)
Population		-.031	.014	-.004
		(.036)	(.019)	(.011)
Senior		-.012***	-.001	.001
		(.001)	(.001)	(.001)
College		.006***	.007***	.006***
		(.001)	(.001)	(.001)
Income		-.783***	-.215***	-.286***
		(.077)	(.054)	(.058)
International		-1.450***	-.429***	-.567***
		(.068)	(.087)	(.090)
Ocean		-1.370***	.163***	.220***
		(.029)	(.019)	(.022)
County Worker		.005***	.001***	.001***
		(.001)	(.000)	(.000)
State Worker		-.004***	.005***	.005***
		(.001)	(.001)	(.001)
Obama Vote		-.015***	.004***	.007***
		(.001)	(.001)	(.001)
County Tax (IV)				-.562***
				(.098)
Constant		1.127***	1.470***	2.345***
		(.123)	(.106)	(.179)
Observations	16,799	16,781	16,781	16,781
R^2	.054	.170	.625	.659
State FE	N	N	Y	Y
Border FE	N	N	N	N
IV?	N	N	N	Y
Marginal Effect:	.088	.291***	-.153***	-.102**
Low Side	(.059)	(.060)	(.043)	(.044)
Marginal Effect:	.046	.125***	-.209***	-.197***
High Side	(.035)	(.042)	(.032)	(.032)
Marginal Effect:	.559	.589	-.171	-.199
Same Side	(.491)	(.449)	(.195)	(.165)

The dependent variable is the local plus district tax rate. Standard errors are robust. ***99%, **95%, *90%

Table 6: Mean Derivatives for Several Specifications

Mean Derivative	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Low-Tax State	-.103**	-.116***	-.133**	-.240***	-.055***	-.094**	-.086	-.286***	-.135**	-.077*
	(.044)	(.042)	(.058)	(.058)	(.015)	(.049)	(.070)	(.054)	(.064)	(.041)
High-Tax State	-.197***	-.181***	-.198***	-.211***	-.102***	-.209***	-.239***	+.097*	-.113***	-.179***
	(.032)	(.030)	(.033)	(.039)	(.014)	(.035)	(.041)	(.058)	(.034)	(.032)
Same-Tax State	-.199	-.227	-.198	-.186	-.045	-.185	-.204	-.126	-.221	-.107
	(.165)	(.162)	(.164)	(.167)	(.069)	(.174)	(.210)	(.123)	(.198)	(.144)
Variable†	L+D	L+D	L+D	L+D	L+D	L+D	L+D	L+D	L	L+D+C
Bandwidth	N	N	N	N	N	N	N	N	N	N
Restriction	N	Binary Treat-ment	No Intern.	No Ocean	Time	MS, NC, NV, WI	Nbr. LOST	Nbr. No LOST	N	N
Observations	16,781	16,781	15,642	14,255	16,781	15243	12,516	3126	14,563	16,781

The marginal effects represent a **per 100 mile** change (i.e., per mile, the units are basis points), except for (5), which is per hour.

(1) is derived from column 4 of Table 5. (2) uses a binary treatment. (3) eliminates towns where the closest border is an international one. (4) eliminates towns proximate to the ocean. (5) uses driving time instead of driving distance. (6) drops states where the primary local taxes are district taxes. (7) utilizes only towns where the nearest neighboring state allows for LOST. (8) includes observations where the nearest neighbor is a state that does not allow LOST. (9) uses local taxes as the left side variable. (10) uses city plus district plus county taxes as the left-side variable and controls for the county X's. †L is local taxes, D is district taxes, and C is county taxes.

Standard errors are robust and calculated using the Delta Method. ***99%, **95%, *90%.

Table 7: Mean Derivatives for Several Specifications

Mean Derivative	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Low-Tax State	-.103**	-.049	-.083**	-.051	-.704***	-.203***	-.203***	-.118**	-.180**	-.695*
	(.044)	(.030)	(.046)	(.045)	(.152)	(.072)	(.070)	(.054)	(.094)	(.398)
High-Tax State	-.197***	-.150***	-.181***	-.169***	-.230***	-.129**	-.490***	-.190***	-.194***	-.490
	(.032)	(.024)	(.031)	(.031)	(.061)	(.058)	(.149)	(.041)	(.072)	(.330)
Same-Tax State	-.199	-.012	-.212	-.204	-.513	-.486*	-.380**	-.199	-.395	-.051
	(.165)	(.128)	(.149)	(.161)	(.460)	(.251)	(.179)	(.167)	(.342)	(2.616)
Variable†	L+D	L+D	L+D	L+D	L+D	L+D	L+D	L+D	L+D	L+D
Bandwidth	N	N	N	N	N	N	N	152	97.75	40
Restrict?	No	Degree 3	Degree 7	State Weights	Pop. Weights	Interact All	Border & St. FE	N	N	N
Observations	16,781	16,781	16,781	16,781	16,781	16,781	16,781	16,124	13,739	7236

The marginal effects represent a **per 100 mile** change (i.e., per mile, the units are basis points).

(1) is derived from column 4 of Table 5. (2) uses a cubic polynomial. (3) uses an order seven polynomial. (4) weights each state equally in the regression. (5) weights by the population of the locality. (6) interacts the control variables and state fixed effects with a polynomial in distance along with a full set of interactions with the high- and same-side dummies. (7) includes state fixed effects and state-border-pair fixed effects. (8) restricts the sample to observations within 150 miles of the nearest border. (9) restricts the sample to observations within the optimal bandwidth from the local linear regression. (10) restricts the sample to observations within forty miles of the nearest border. †L is local taxes, D is district taxes, and C is county taxes.

Standard errors are robust and calculated using the Delta Method. ***99%, **95%, *90%

Table 8: State by State Marginal Effects

State	Low Side	High Side	Same Side
Alabama	.001		-.056
	(.001)		(.366)
Arizona	-.563	-.014	
	(.366)	(.436)	
Arkansas	-.981***	-.544**	
	(.303)	(.249)	
California	-.016	.002	
	(.027)	(.019)	
Colorado	1.358***		
	(.210)		
Georgia	.006		-.084
	(.008)		(.162)
Idaho	.025	.058	
	(.017)	(.074)	
Illinois	-.434***	-.517***	
	(.154)	(.093)	
Iowa	-.042**	-.001	
	(.019)	(.038)	
Kansas	.038	-.555***	
	(.136)	(.136)	
Louisiana	-1.189***		
	(.382)		
Minnesota	-.199***	-.041**	
	(.057)	(.021)	
Mississippi		.012	-.131
		(.010)	(.224)
Missouri	.051		
	(.190)		
Nebraska	-.880***	-.200	
	(.312)	(.164)	
Nevada	-.008***	-.108***	
	(.002)	(.016)	
New Mexico	-.012	-1.244*	
	(.391)	(.676)	
New York	-.378***		
	(.081)		
North Carolina	-.139***	-.171***	
	(.032)	(.020)	
North Dakota	-.636**	.564*	
	(.278)	(.308)	
Ohio	-.026		
	(.024)		
Oklahoma	.905***	7.936*	
	(.183)	(4.198)	
South Carolina		-.085	
		(.218)	
South Dakota	-.528	-.265	-.591
	(.325)	(1.342)	(.513)
Tennessee		.027	-.003
		(.026)	(.069)
Texas	-.103	.027	
	(.086)	(.036)	
Utah	-.310	-.137	
	(.369)	(.106)	
Vermont	-.017	1.235**	
	(.055)	(.561)	
Virginia	-.117		
	(.122)		
West Virginia	.311***	.114	
	(.103)	(.085)	
Wisconsin	-.095***		
	(.018)		

The marginal effects represent a **per 100 mile** change (i.e., per mile, the units are basis points). The regression specification allows for state fixed effects to be interacted with the distance function such that the gradient is allowed to vary by state.

Standard errors are robust and calculated using the Delta Method. ***99%, **95%, *90%

Table 9: Average Marginal Effects by Size of the Treatment/Discontinuity

Specification	IV Regression of Rates			Probit Binary Variable		
	Low-Tax Side	High-Tax Side	Same-Tax	Low-Tax Side	High-Tax Side	Same-Tax
Not Conditioned on Notch	-.103**	-.197***	-.199	-.469***	-.435***	-.135
(R)	(.044)	(.032)	(.165)	(.087)	(.092)	(.467)
5th Percentile of R	-.029	-.234***		-.348***	-.663***	
$R_{Low} = -.25$; $R_{High} = .25$	(.059)	(.049)		(.126)	(.119)	
10th Percentile of R	-.041	-.234***		-.365***	-.663***	
$R_{Low} = -.50$; $R_{High} = .25$	(.055)	(.049)		(.118)	(.119)	
20th Percentile of R	-.054	-.217***		-.382***	-.571***	
$R_{Low} = -.75$; $R_{High} = .875$	(.051)	(.041)		(.110)	(.102)	
30th Percentile of R	-.060	-.206***		-.391***	-.516***	
$R_{Low} = -.875$; $R_{High} = 1.25$	(.050)	(.037)		(.106)	(.096)	
40th Percentile of R	-.079*	-.192***		-.416***	-.443***	
$R_{Low} = -1.25$; $R_{High} = 1.75$	(.046)	(.033)		(.097)	(.095)	
50th Percentile of R	-.105**	-.192***		-.450***	-.443***	
$R_{Low} = -1.75$; $R_{High} = 1.75$	(.044)	(.033)		(.090)	(.095)	
60th Percentile R	-.117***	-.189***		-.467***	-.424***	
$R_{Low} = -2$; $R_{High} = 1.875$	(.045)	(.032)		(.088)	(.096)	
70th Percentile of R	-.117***	-.185***		-.467***	-.402***	
$R_{Low} = -2$; $R_{High} = 2.025$	(.045)	(.032)		(.088)	(.097)	
80th Percentile of R	-.155***	-.178***		-.518***	-.369***	
$R_{Low} = -2.75$; $R_{High} = 2.25$	(.052)	(.032)		(.095)	(.101)	
90th Percentile of R	-.168***	-.139***		-.534***	-.163	
$R_{Low} = -3$; $R_{High} = 3.65$	(.056)	(.040)		(.101)	(.146)	
95th Percentile of R	-.275***	-.073		-.678***	.183	
$R_{Low} = -5.125$; $R_{High} = 6$	(.102)	(.073)		(.179)	(.256)	

The marginal effects represent a **per 100 mile** change (i.e., per mile, the units are basis points).

Standard Errors are robust and calculated using the Delta Method. ***99%, **95%, *90%

Table 10: Mean Derivatives for Multiple Borders

Mean Derivative	(1)	(2)	(3)	(4)	(5)
Low-Tax State	-.069	-.127**	.029	-.461	-.396
	(.065)	(.065)	(.067)	(.458)	(.462)
High-Tax State	-.181***	-.189***	-.129**	-1.060**	-1.206***
	(.043)	(.044)	(.061)	(.417)	(.410)
Same-Tax State	-.111	-.162	.010	-1.003***	-.935***
	(0.192)	(.193)	(.192)	(.174)	(.173)
Marginal Effects	State	State	State	County	County
1st State	Y	Y	Y	N	Y
2nd State	N	Y	Y	N	Y
County Border	N	N	Y	Y	Y
Border Counties?	Y	Y	Y	N	Y

The marginal effects represent a **per 100 mile** change (i.e., per mile, the units are basis points).

(1) is derived from column (4) of Table 5 but uses the "as the crow-flies" distance. (2) adds a polynomial in distance from the second border plus interactions. (3) uses polynomials in distance from the closest state border, the second closest state border and the closest county border plus the appropriate interactions. (4) includes a polynomial to the closest county border and drops state border counties. (5) is the same as (3) but calculates marginal effects from the county border.

Standard errors are robust and calculated using the Delta Method. ***99%, **95%, *90%