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Abstract

State borders create a discontinuous tax treatment of retail sales. In a Nash game, local tax rates will be higher on the low-state-tax side of a border. Local taxes will decrease from the nearest high-tax border and increase from the low-tax border. Using driving time from state borders and all local sales tax rates, local tax rates on the low-tax side of the border are 1.25 percentage points higher, reducing the differential in state tax rates by over three-quarters. A ten minute increase in driving time from the nearest high-tax state lowers a border town's local tax rate by 6%.

JEL-Code: H200, H250, H730, H770, R510.

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Differences in sales tax rates may lead consumers to cross-border shop and firms 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 state border. This motivates my main question of interest: do localities assess local sales taxes as a function of distance from the nearest state border?

In a theoretical model that expands Kanbur and Keen (1993) and Nielsen (2001), I demonstrate that from the local government's perspective, the equilibrium tax rates in a decentralized system depend on the distance of each jurisdiction to a neighboring state. The existing tax competition literature focuses on the role of jurisdiction size as a determinant of tax rates and ignores distance.[1] The model in this paper provides a novel insight: the spatial location within a federation is an important factor determining tax rates. A broad uniform tax rate within the federation will not occur in equilibrium if states set different tax rates – even if all of the sub-federal governments are identical in every respect except proximity to a 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 – to empirically test the spatial reach of tax competition within a federation.[2] Use of an exhaustive cross-section of municipal tax rates allows me to generalize my findings as well as exploit distance to geographic borders to identify fiscal competition. In order to measure how towns set tax rates away from the border, I create a data set of the distance to borders. I find the shortest driving time from the population centroid of each town in the country to a state-border major road crossing. This distance measure minimizes measurement error in the actual distance a consumer would travel and improves upon the linear approximation of distance previously used.[3] One implication of this paper is that calculating driving times is computationally feasible in large data sets.

The first testable prediction of the theory is a *level effect*: at a border between a high-state tax state and a low-state tax state, the local taxes in municipalities "near" the border on the low-tax

[1] Haufler (1996) , Kanbur and Keen (1993), Mintz and Tulkens (1986), Trandel (1994), and Nielsen (2001) often focus on various asymmetries such as country size, population, or public good preferences as an explanation for variation in tax rates and find that larger jurisdictions set higher rates. The paper also relates to papers such as Hoyt (2001), Janeba and Osterloh (2013), and Keen and Kotsogiannis (2002) that discuss tax competition and sales taxation in a federation or region.

[2] Up until this point, tests of local sales tax competition have been constrained by data limitations to studying particular states. For example, Luna (2003), Sjoquist et al. (2007), and Burge and Piper (2012) study tax competition among localities in Tennessee, Georgia and Oklahoma.

[3] Several previous studies have focused on the role of distance to a competing jurisdiction. Lovenheim (2008), Harding, Leibtag and Lovenheim (2012), Hanson and Sullivan (2009) and Merriman (2010) study how elasticities, tax incidence, and tax evasion are a function of distance to borders. Many of these studies use the linear crow-flies distance. Eugster and Parchet (2013) exploit driving distance from cultural borders in Switzerland on to determine the effect on local tax rates.

side should be higher than local taxes in municipalities "near" the border on the high-tax side.[4] Empirically, 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 average differential in state tax rates at the border by more than three-quarters. The theoretical model provides the intuition: a border town in a low-state tax state realizes a smaller elasticity of demand than an otherwise identical town on a high-tax side of the border. The second testable prediction of the theory is a *gradient effect*: as one moves away from the border in a low-tax state, local sales taxes should fall and the tax gradient is negative; as one moves away from the border in a high-tax state, local taxes should rise and the tax gradient is positive. The empirical evidence on the tax gradient is mixed; the gradient on the low-tax side of the border is robustly negative, but the gradient on the high-side depends on the empirical specification. For towns near the border, a ten minute increase in driving time in low-tax states lowers local tax rates by 6% of the average local rate. This is an economically meaningful effect considering that individuals often travel more than ten minutes to shop. These tax gradient effects dissipate after traveling over thirty minutes from the state border, which suggests the spatial reach of tax competition in response to state policy differentials is limited to towns near the border.

The methodology outlined in the paper is applicable to research on how jurisdictions (or smaller entities such as firms) respond to policies that vary discontinuously at a border. Studying open economy public finance also consists of analyzing competition over spending policies, regulatory policies, zoning restrictions, or even labor laws – and in a federalist system of governance, the response of municipalities to state policy discontinuities may occur across multiple policy instruments. Consider the case of environmental regulations, which may differ across states making one side of the state border more attractive on the basis of lower costs to a firm. Localities may adjust their zoning regulations or commercial property taxes to make themselves more attractive to firms despite being in a high-regulation state. A similar argument applies to minimum wage differentials or right-to-work laws across states. Towns on the less business friendly side of the border may adjust local policies to "compensate" the business for the stringent state based regulations. Although businesses may be less mobile, Holmes (1998) finds strong evidence of bunching on the favored side of the border; the strategic bunching of firms implies that localities have incentives to respond to the mobility of firms due to state policy differentials. In each of these examples, a firm has a preferred location in the absence of any policy differentials. In the presence of state policy differentials, that firm may want to locate as close to its preferred location (to have access to a productive amenity such as a particular labor pool), but it may deviate from it if the tax or regulatory

[4] Throughout this paper, for simplicity, I use the phrase "low-tax side of the border" to refer to the side of the border in a state that has the lower *state* tax rate (thus, the nearest state border is a "high-tax border"). The "high-tax side of the border" is the side with the higher *state* sales tax rate (thus, the nearest state border is a "low-tax border"). It is conceivable that a municipality on the low-tax side of the border could have a higher aggregate tax rate (state plus local) than an adjacent municipality on the high-tax side of the state border.

savings outweigh the cost of choosing a distorted location decision. Local policies that lower the cost to the firm may draw the firm back toward its preferred location. Firms may also respond to state policy differentials just like municipalities and alter their prices (rather than their location decision) or wages in an effort to overcome higher state taxes or more costly state regulations in order attract price-sensitive mobile consumers.

The results of this study are of interest to a literature much broader than the tax competition literature. The implications of the analysis are important for studying the behavioral response to taxation. The results shed light on the extent to which competition for sales tax dollars influences retail trade and consumer shopping patterns. However, a researcher will mismeasure the "true" policy differential if ignoring local policies. Given that local tax rates are higher in a low-tax state, a researcher looking only at state sales tax rate differentials will inaccurately over-estimate the incentives for cross-border shopping resulting in incorrect elasticity estimates.

Furthermore, tax differentials at state borders induce discontinuities in the choice set of agents known as a "notch." Although notches are abundant in tax policy and in a federalist system, they have not been exploited in the fiscal competition literature. Notches arise because an incremental change in where a consumer purchases a good induces a discontinuous change is the sales taxes due. Several recent studies have focused on how discontinuous changes in the tax system influence individual behavior (Sallee and Slemrod (2012), Ramnath (2013), and Kleven and Waseem (2013)). Many of these studies have found that individuals and firms respond by changing their behavior to be on the tax-favored side of the notch. In the context of the tax competition literature, such a result is akin to the evidence that individuals will engage in cross-border shopping in the presence of large salient discontinuities. Unlike notches in the income tax code, border discontinuities may have responses on two margins: (1) the response of consumers and (2) a response by sub-state jurisdictions to mitigate the notch or to take advantage of it via tax exporting.

This paper exploits notches for causal identification with spatial data. Recent work (McMillen (2010); Gibbons and Overman (2012)) has highlighted the limitations of spatial econometric models in terms of causal identification. This paper represents one of the first attempts within spatial public finance to overcome these weaknesses by exploiting plausibly exogenous variation resulting from institutional aspects of the tax system. I move away from the direct approach of studying fiscal competition via reaction functions (Devereux, Lockwood and Redoano 2007 and Jacobs, Ligthart and Vrijburg 2010) and instead exploit institutional and spatial aspects of the federalist tax system to construct a quasi-experimental design. Moreover, I exploit the intensity of the policy discontinuities at borders to identify causal effects.

1 Background

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%, over thirty states allow at least one local or county governments to set a LOST. Over 7,500 localities utilize this option. Among these towns, local sales taxes contribute anywhere from 1% to 52.2% of municipalities' revenues. Given that the use tax is often evaded and not easily enforced, the jurisdiction of sale rather than the jurisdiction of residence effectively determines the tax paid. Of the states that allow for LOST, the locality's degree of autonomy varies. The appendix discusses institutional differences.

2 A Theory of Local Fiscal Competition

2.1 Setup of the Model

I extend Kanbur and Keen (1993) and Nielsen (2001)'s two-state partial equilibrium models of cross-border shopping by allowing for multiple jurisdictions and multiple levels of government. The model features three states located on a circle indexed by $j = H, M, L$ for high-, medium-, and low-tax states. Each state has three identical towns indexed $i = A, B, BB$, where the towns are arranged as depicted in Figure 1.[5] "A" denotes the towns "Away" from the border. "B" and "BB" denote the towns at the state "Border." Each town is of an equal length that is x units.

[Figure 1 Here]

State governments levy a state sales tax rate, τ^j, on commodity purchases within the state. In this analysis, I assume that state tax rates are exogenous.[6] Exogenously different preferences for a state public good will imply that the state tax rates will differ across the states (Haufler 1996). 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 state tax differential. 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

[5] I model jurisdictions on a circle rather than a line segment in contrast to Ohsawa (1999) so that the only source of municipal heterogeneity is the state the municipality is in and its spatial location relative to the state's borders. On a finite line segment, the towns furthest away from the state border would have only one neighbor rather than two. In my model, all the variation in the local tax rates are a result of distance from the border and the state tax rate and not from the number of municipal neighbors.

[6] Municipal tax rates change relatively infrequently and changes in local tax rates are often uncoordinated. Most municipalities are atomistic with respect to the state. Statutory state tax rates are also rigid for fairly long periods. It seems reasonable to believe that states do not respond strategically to a single municipality. Endogenous state tax rates can be introduced into the model but would require making states asymmetric in order to induce different state tax rates.

t_i^j to maximize local tax revenue. Taxes are assessed 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 maximizing tax revenue.[7]

Firms are perfectly competitive and set price equal to marginal cost. The pre-tax price is the same in all jurisdictions and is normalized to one. Consumers are distributed uniformly across each town and the populations are identical in all towns. Each consumer will purchase one unit of the consumption good, but will have a choice over the location of purchase. The reservation value net of the producer price for each consumer, V, is assumed to be large enough so that all consumers will purchase one unit of the good. If the individual decides to purchase in the home town, she does not incur any transportation costs. The surplus she will receive from such a purchase is $V - T_i^j$. Alternatively, each consumer can purchase the consumption good from the first store over the border in a neighboring town. Let the distance to the nearest town border for any consumer be denoted ℓ and the transportation cost of traveling to the border (and back) be $\delta > 0$ per unit of travel. The surplus the consumer will receive from purchasing one unit of the private good abroad is $V - T_k^n - \delta\ell$, where $k \neq i$ indexes the tax rate in a foreign town of state n, which may or may not equal j.[8]

A consumer will purchase the private good from the neighboring town if the surplus of purchasing the good elsewhere is strictly greater than buying the good at home which implies:

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

I assume that x is sufficiently large so that towns do not have incentives to target consumers multiple towns over.

2.2 Equilibrium with Three Heterogeneous States

The revenue in 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. 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. The appendix outlines the revenue functions and derives the best response functions.

[7] The model does not consider welfare maximization or political economy arguments. The revenue maximization assumption is discussed at length in Kanbur and Keen (1993). Nielsen (2002) assumes governments maximize consumer surplus plus revenue; Agrawal (2012) considers welfare maximizing governments when states can levy geographically decentralized tax rates.

[8] All of the action is with consumers who decide where to make their "single" purchase. Firm location responds to the consumers and locate where the consumer demand is.

A unique Nash equilibrium exists when towns are sufficiently large:

$$\begin{array}{lll} t_{BB}^{H} = \kappa(\omega - 12R - 11S) & t_{A}^{H} = \kappa(\omega - 6R - 3S) & t_{B}^{H} = \kappa(\omega - 12R - S) \\ t_{BB}^{M} = \kappa(\omega + 11R - S) & t_{A}^{M} = \kappa(\omega + 3R - 3S) & t_{B}^{M} = \kappa(\omega + R - 11S) \\ t_{BB}^{L} = \kappa(\omega + R + 12S) & t_{A}^{L} = \kappa(\omega + 3R + 6S) & t_{B}^{L} = \kappa(\omega + 11R + 12S), \end{array} \tag{2}$$

where $\kappa = 1/53$ and $\omega = 53\delta x/2$. The appendix proves that the Nash equilibrium derived above is unique and outlines that a Nash equilibrium in pure strategies will exist if $x > x^*$ where x^* is a minimum size of the town. To describe the properties of the solution, I define two terms.

Definition 1. The *level effect* is the difference in local option taxes between a border town in a high-tax state and a border town in a low-tax state. The level effect is negative if the local taxes are lower in the high-tax state.

Definition 2. The *tax gradient* is the slope of local option taxes away from the border. The tax gradient is increasing in distance from the border if local option taxes increase as towns are further from the nearest state border. The tax gradient is decreasing in distance from the border if local option taxes decrease as towns are further from the nearest state border.

I characterize the spatial patterns of the Nash equilibrium in two propositions according to these definitions: a level-effect and a spatial tax gradient effect.

Proposition 1. *At a border between a high-tax state and a low-tax state, the local tax rate for a municipality near the border on the high-tax side will be lower than the local tax rate in a municipality near the border on the low-tax side.*

Corollary 1. *The magnitude of the difference in local tax rates between two municipalities on the border is proportional to the size of the state tax rate differential.*

Proof. Differencing the local tax rate on the high-tax side of the border and the local tax rate on the low-tax side of each border yields:

$$t_{BB}^{H} - t_{B}^{L} = -\rho D < 0 \quad t_{B}^{H} - t_{BB}^{M} = -\rho R < 0 \quad t_{B}^{M} - t_{BB}^{L} = -\rho S < 0, \tag{3}$$

where $\rho = 23\kappa$. The negative relationship indicates that local taxes are lower on the high-tax side of the border. If the state tax differential at each border increases, each of the above local tax differentials becomes larger in absolute value. □

Given the expressions in 3, it can easily be seen that the total tax rate (municipal plus state) will remain higher on the high-tax side of the border, but that in the presence of municipal option taxes, the differential shrinks to $\frac{30}{53}$ of what it would have been without municipal tax competition.

For example, the total tax differential $T_{BB}^{H} - T_{B}^{L} = D - \rho D = \frac{30}{53}D$.[9] This level effect is large and dramatic, reducing tax differential approximately in half. Geographic borders thus induce a level effect on municipal tax rates near the state border. Next, I study the spatial reach of this effect.

Proposition 2. *If D is sufficiently small relative to R and S, as a town is further away from the state border in a relatively high-tax [low-tax] state, local taxes will rise [fall].*

Proof. Differencing the tax rates within a state yields differences proportional to:

$$\begin{array}{ll} t_A^L - t_B^L = -4R - 3S < 0 & t_A^H - t_{BB}^H = 3R + 4S > 0 \\ t_A^M - t_{BB}^M = -4R - S < 0 & t_A^M - t_B^M = R + 4S > 0 \\ t_A^L - t_{BB}^L = R - 3S \lesseqgtr 0 & t_A^H - t_B^H = 3R - S \lesseqgtr 0 \end{array} \tag{4}$$

where the factor of proportionality is 2κ. The left column in equation 4 studies the tax gradient on the low-tax side of a border, while the right column reports the tax gradient on the high-tax side of the border. The tax gradient is decreasing at all three sides of the low-tax borders if $t_A^L - t_{BB}^L = R - 3S = R - 3S + S - S = D - 4S < 0$ and increasing on all three sides of the high-tax borders if $t_A^H - t_B^H = 3R - S = 3R - S + R - R = 4R - D > 0$, which requires $D < 4S$ and $D < 4R$. □

Corollary 2. *If D is sufficiently small relative to R and S, the tax gradient becomes steeper when the differential in state tax rates increases at the closest border holding constant the state tax differential at the other state border.*

Proof. See Appendix. □

A tax gradient emerges where on the relatively high-tax side of the border, local taxes rise as distance from the border increases. On the relatively low-tax side of borders, local taxes fall as distance from the border increases. Without conditions on the parameters, the tax gradient is theoretically ambiguous at one border in each of the highest and lowest tax states – though this is partially an artifact of having only three towns in a state. Because states are relatively small, if the state tax differential at one state border is excessively large relative to the state tax differential at the other border, the larger tax differential may be able to "pull" the third and furthest town into its tax gradient. If $D < min(4R, 4S)$ then D will not pull a third town into its gradient.[10]

If states were composed of a sufficiently large number of towns, it is likely that tax gradients always will be increasing [decreasing] in the region away from nearby low-tax [high-tax] state

[9] What intuition can be taken from the size of the proportion ρ? Simulations indicate that ρ declines slightly as the number of jurisdictions in the model increases. Intuitively, this is a result of more intense tax competition. In a variant of the theoretical model with two states that feature only one town each, the value of ρ is $2/3$ as towns are not constrained by their interior neighbors; this results in more local tax rate differentiation across the state border (Agrawal 2014).

[10] For a lengthy discussion concerning the role of the critical town where the gradient changes sign, see Agrawal (2011).

borders. Figure 2 plots a numerical solution to the model with more than 3 towns and provides some insight with regard to this. The figure demonstrates that for the given parameters, taxes rise the fastest in a local region of the border and when the tax differential is largest. Simulation results yield conjecture 1.

[Figure 2 Here]

Conjecture 1. *The tax gradient will be the steepest near the border.*

Remark. Proving this would require solving a model with a large number of towns, which is beyond the scope of this paper. The basis of the conjecture is numerical solutions to the model with a large number of towns.

The model presented in the paper is used to derive positive implications. The simple model delivers intuitive results concerning the pattern of tax levels and tax gradients in the presence of borders and the results would likely survive generalizations to richer models. The model cannot answer whether a system of decentralized tax setting within a federalist system of government will result in a higher level of revenue or welfare relative to a system without local control of tax rates. Agrawal (2012) determines that the optimal commodity tax system (from a social welfare maximizing state's perspective) is almost always geographically differentiated within a state. However, the model of Agrawal (2012) studies the optimal pattern of tax rates when a state planner can determine them. Whether decentralization of tax rates to localities is optimal remains an open question. The results in this paper suggest that the decentralization of tax rates can allow for jurisdictions to reduce large distortions resulting from state policy; but this is likely to come at a cost of intensifying competition within the state. Ogawa and Wildasin (2009) demonstrate that decentralized competition for mobile resources can result in efficiency improvements.

2.3 Intuition

The results modify the intuition of Kanbur and Keen (1993) by showing that the elasticity that pins down tax rates depends on a jurisdiction's spatial location. In Kanbur and Keen (1993), the "small" jurisdiction, 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, but what matters is the relative size of the "foreign" plus "domestic" market. The "foreign" market consists of shoppers who would cross-border shop because of state tax differences even if local taxes were the same. For a border town in a high-tax state, even if its local tax rate is zero, some residents will always shop abroad. Therefore, starting from a position where local taxes are equal, this border town perceives a relatively small (in comparison to an interior town) market of "foreign" plus "domestic" shoppers. The border town in the high-tax state perceives the relatively larger elasticity (because its market is smaller) and undercuts its interior neighbor. On the low-tax side, starting from equal local tax rates, the border town is already attracting residents from the neighboring states. Therefore, because the town has already attracted some foreign residents, it perceives the "foreign" plus "domestic" market as larger than that of its interior neighbor. The interior town perceives itself as small and undercuts the border town. Thus, if local taxes are equal, the town with the largest market in the presence of the state differentials will always want to set higher rates relative to the town with a smaller market. The same intuition applies to the intuition of the level effect.

[Figure 3 Here]

Figure 3 emphasizes the intuition underlying the model in the region of the border between State L and State H. The figure shows the size of the tax bases when all local tax rates are equal. In such a world, the tax base of the border town on the low-tax side of the border is especially large because the town captures $\frac{\tau^H - \tau^L}{\delta}$ shoppers due to differences in the state tax rates. Thus, the border town's tax base in the low-tax state is large relative to both its interior neighbor and the border town in the neighboring state. The difference in the size of the tax base with the town in the neighboring state is especially large given that this town is in a disadvantaged position a loses cross-border shoppers. The results is that there will be a large and dramatic level effect exactly at the border (large differences in bases) and a smaller (smaller differences in bases), but important tax gradient effect moving away from the border. When the tax base is large, a revenue maximizing government realizes a small elasticity demand; following an inverse elasticity rule that town will adjust its tax rate upward relative to its neighbors. The towns with the smaller tax base will do the reverse and lower their tax rates relative to their neighbors until the elasticities are equalized across the jurisdictions. The implication for the empirical analysis is clear – if towns respond according to the theory, this will be powerful evidence that municipalities are engaging in rational tax competition by appropriately responding to the effect of state tax rates on their elasticity of demand.

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 decrease as towns are further from a high-tax border and increase as towns are further from a low-tax border. Third, the tax gradient flattens further from the border. Fourth, the the larger the discontinuity in state tax rates, the steeper the tax gradient and the more dramatic the level effect at the border. Translating the theoretical model to the empirical model, I can define a jurisdiction as being treated if the town is on the relatively high-tax side of the border. The strength of the municipal response to this treatment will depend on the intensity of the treatment (the size of the discontinuity at the border) and on the municipality's proximity to the border.

3 Data and Evidence

3.1 Data

Do localities on the high-tax side of a border set lower local taxes than localities on the low-tax side? Is there a tax gradient that is a function of distance from the border? The data on tax rates come from Pro Sales Tax's national database.[11] The data contain state, county, municipal, and district tax rates for April 2010. This paper represents the first scholarly use of a national cross-section of municipal sales taxes. Because I combine the tax data with Census data, I restrict the sample to municipalities that are identified Census Places, which subsequently will be referred to as localities.[12] To do this, I merge Geo-coded data provided by the American Community Survey to the tax data.[13] Because the unit of analysis is the locality, I restrict the sample to states with at least one municipality or district with a non-zero tax rate.

I substantially enhance the data used to measure distance to borders. I draw on, but substantially modify the method of Lovenheim (2008) to calculate distance from the border. Using Arc-GIS software, I estimate the minimum driving time from the population weighted centroid of a locality to the closest intersection of a major road and a state border crossing.[14] Unlike Lovenheim (2008) I calculate distance from the population weighted centroid instead of the population weighted distance, which enables me to calculate driving distance and driving time.

It is essential to have the most accurate measure of distance, because this paper analyzes taxes away from the border. Relative to the "as the crow-flies" distance (which is currently used in the literature), my measure of driving distance more accurately captures the true commuting time from the nearest state border. Driving **time** contains more information about true travel costs than other measures of distance. Although the "crow-flies distance" is correlated with driving distance, it is

[11] The data are proprietary, but was provided to me. For a complete description of the data, see http://www.prosalestax.com/.

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

[13] 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; in this case Places are matched based on where there is more population. It is possible that some matches that would be correct remain unmatched.

[14] 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 residential roads.

not a very accurate measure of true commuting costs except in a local region of the border and can match towns to the incorrect border. The appendix describes how I calculate driving time. I only use observations that are less than 5 hours from a state border.

International borders are used in the analysis even though crossing a national border is more difficult and may restrict cross-border shopping. In the empirical analysis, I include a dummy variable that equals one if the border is an international border in order to mitigate differences between state and international borders.

[Table 1 Here]

Table 1 presents summary statistics at the local level. The average town in the sample realizes a 1.88 percentage point state tax differential at the closest state border and the average local plus district plus county tax is 2.25 and 1.08 on the low- and high-tax side of the border respectively.

4 Empirical Analysis

4.1 Methodology: The Tax Level Effect

Are local tax rates on the low-tax side of the border higher relative to localities on the high-tax side of the border? I conduct a regression discontinuity (RD) design following the local linear regression and bandwidth selection methodology of Imbens and Kalyanaraman (2012). 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. Jurisdictions on the high-tax side of a border are referred to as being treated.

To implement the regression discontinuity design, I conduct local linear regression for the local tax rates where the running variable is driving time to the border. I include the same set of controls at the place and county level as listed in the summary statistics table and allow them to vary locally. The bandwidth is selected optimally and a triangle kernel is used in order to smooth the data by giving the most weight to observations nearest to a particular distance.

4.2 Result: Are Local Taxes Higher in Low-Tax States?

Figure 4 graphically presents the results of the regression discontinuity design for the full sample and for large tax differentials. Tables 2 and 3 shows the RD results for state borders. Specifications 1-4 present the results for various types of local tax rates at state borders. Note that whether the running variable is driving time or driving distance does not influence the RD results, because in a local region of the border they are highly correlated. Specification 2 is most preferred; it demonstrates how much the tax differential at state borders falls after **all** (county plus town plus district) local option taxes are assessed. The results from the RD design using the total local rate yield an estimate of -1.23: a town (located precisely near the border) on the high-tax side has a local sales tax rate that is 1.23 percentage points lower than a similar border town on the low-tax side. The next two specifications suggest that counties close the gap by more than municipalities.

[Figure 4 Here]

[Table 2 Here]

For the average town in the sample, the nearest state tax rate differential is 1.88 percentage points, but this is not informative of the state tax differential as distance approaches zero. Specification five conducts the RD using the state tax rate; in a local region of the border, the average size of the state tax differential between high-tax and low-tax states is 1.40 percentage points. Thus, combining this with the local tax rate results results suggests that local taxes reduce tax differentials at state borders to 0.17 percentage points. Thus, local sales taxes reduce state policy differences by 85%. Even after state and local option sales taxes are accounted for, as in column 6, the total tax rate (state plus all local) remains statistically higher in high-tax states. Columns 5 and 6 provide powerful evidence that differences in state tax rates are almost completely dissipated by local tax autonomy; small but statistically significant differences remain at state borders. In terms of the theory, this result sheds light on the empirical value of ρ and suggests that the value of ρ is approximately 0.85 – closer to one than theory suggests.

Although the control variables are mostly continuous at state borders, other confounding policies may not be. The interpretation of the results would be causal only if no other state policies that are discontinuous at borders are correlated with being a high- or low-tax state. Put differently, the results should not necessarily lead readers to conclude that an exogenous increase in a state's tax rate would cause local option sales tax rates to fall by the magnitudes suggested by the RD. If state tax rate changes could be observed, it would be possible to study how the change in tax differentials at borders induces municipal responses. Given I only have a cross-section of tax rates, the results at state borders should only be interpreted as causal if no other unobserved variables or policies that are correlated with state tax rates change discretely at state borders. However, to convince the reader that the results are in fact being driven by tax differentials, I conduct two robustness checks. First, I run the regression discontinuity separately for various state tax rate differentials and show that the size of the difference in local taxes is most intense when the tax differential is largest as predicted by the theory. Second, I study the level effect on municipal tax rates at county borders that are not also state borders; unobservable policy differences at county borders are much more likely to be small.

To further convince the reader that the difference in local tax rates is being driven by the tax differential at state borders, I run the RD conditional on various state tax differentials (intensity of treatment). Corollary 1 predicts that when the tax differential is largest, the difference in local taxes on both sides of the border should be largest. Table 3 indicates that when the tax differential is less than 1 percentage point, local taxes close the difference by 0.31 percentage points. However, when the differential is greater than 4 percentage points, local taxes close the gap by about 2.5 percentage points.

[Table 3 Here]

Table 4 present the results at county borders. Column 2 indicates that for county borders that are not state borders, municipal tax rates close the gap by about 0.13 percentage points. This sample includes many county borders where the tax differential is very small. In a local region of the border, county tax differentials are less than one percentage point. When restricting the sample to county borders where the tax differential is greater than 1 percentage point, local taxes close the differential at county borders by more than half. The county borders results suggest that ρ is smaller at county borders than at state borders, which may be a result of salience issues (Chetty, Looney and Kroft 2009) if state tax differentials are more salient than county tax differentials.

[Table 4 Here]

The RD results powerfully show that local sales taxes reduce tax differentials at borders. This result is large in magnitude – and is largest for the biggest differentials.

4.3 Methodology: The Tax Gradient Effect

The subject of this section is the spatial reach of the effect of state tax differentials on municipal tax rates. To study the spatial reach of tax competition based on distance to the border I will estimate separate polynomials in distance to the low- and high-tax border.[15] A jurisdiction is "treated" if the jurisdiction is on the high-tax side of a border. The "intensity" of the treatment is given by the size of the difference in the state tax rates. The municipal response is allowed to vary based on driving time.

The theory, equations 3 and 4 in particular, suggest that the local tax rate will be a function of the tax differential at the state border as well as a locality's distance to the border. In addition, the equations suggest that neighboring local tax rates also play a role and should be used as an independent variable (appropriately addressing endogeneity concerns). This leads to my empirical

[15] I use a polynomial RD design rather than local linear regression in order to calculate the marginal effect of distance and to allow the municipal response to vary depending on the intensity of treatment.

identification strategy. Letting l index localities, c index counties and s index states, and all other variables to be defined in the paragraphs below, the reduced form equation testing the spatial reach of the effect of state tax rate differentials is given by:

$$\begin{aligned} t_{lc} = \beta_0 + \beta_1 h_{lc} + \beta_2 s_{lc} + \beta_3 \iota_{lc} + \beta_4 \iota_{lc} h_{lc} + \\ \sum (d_{lc})^k \varsigma_k + \iota_{lc} \sum_{k=1}^{p} (d_{lc})^k \gamma_k + h_{lc} \sum_{k=1}^{p} (d_{lc})^k \delta_k + \\ \iota_{lc} h_{lc} \sum_{k=1}^{p} (d_{lc})^k \alpha_k + s_{lc} \sum_{k=1}^{p} (d_{lc})^k \theta_k + X_{lc} \varphi + \zeta_s + \phi t_{-l} + \varepsilon_{lc}. \end{aligned} \tag{5}$$

The variable t_{lc} denotes the county plus town plus district tax rates in municipality l and t_{-l} is the spatial lag of these tax rates. Additionally, 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 ι_{lc} as the difference between the state tax rate of the home state and the tax rate in the nearest neighboring state (the intensity of the treatment).[16] The driving time from a locality to the nearest state border is d_{lc} and note it is always positive. 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.[17] The parameters γ_k, ς_k, δ_k, α_k, and θ_k are the coefficients on each term in the polynomial – linear, square, cubic, etc.

Jurisdictions are treated if they are on the high-tax side of the border, but the above specification allows the intensity of the treatment – size of the state tax rate discontinuity ι_{lc} – to play a role. The coefficients on $\sum_{k=1}^{p} d_{lc}$ will pick up the average effect of distance on local tax rates. The interactions $h_{lc} \sum_{k=1}^{p} d_{lc}$ and $s_{lc} \sum_{k=1}^{p} d_{lc}$ will allow for the effect of being at a particular distance from the border on the high-tax (and same-tax) side to be different than the effect of being at that distance on the low-tax side. The interaction of the distance term with ι_{lc} in $\iota_{lc} \sum_{k=1}^{p} d_{lc}$ allows the intensity of treatment to influence the municipal response as a function of distance. As defined, ι_{lc} is negative for towns in relatively low-tax states and positive for towns in relatively high-tax states. The coefficients on $\iota_{lc} h_{lc} \sum_{k=1}^{p} d_{lc}$ allow for a percentage point change in the intensity of the treatment to have heterogeneous effects depending on the side of the border.

The set of X_{lc} contains observable characteristics of locality l in county c. The matrix includes the Census variables listed in the footnote of Table 1 at the Census Place level **and** county level plus some other control variables generated using geographic files, a dummy for proximity to international borders, a dummy for proximity to oceans or water, and the vote share received

[16] The tax base of the state sales tax varies across states so a simple comparison of tax rates across states measures the incentive for cross-border shopping with error. One of the main differences in taxes bases across states is the treatment of food purchases, but consumers are probably less likely to engage in cross-border shopping for food.

[17] Lovenheim and Slemrod (2010) use dummy variables based on distance. Lovenheim (2008) and Harding, Leibtag and Lovenheim (2012) impose $log(d)$ as the functional form because they do not have sufficient power to use a more flexible polynomial.

by Obama in the 2008 Presidential election. I control for both place and county characteristics because t_{lc} is determined by two-levels of government. The controls include demographic variables that taken together will proxy for differences in public good preferences across jurisdictions. In expression 5, ζ_s are state fixed effects. The state dummies will help to control for variation in policies (including the state sales tax rate) and unobservables that are constant within states, such as state political climates or state business policies.

Local tax data is highly spatially correlated and equations 3 and 4 suggest that neighboring tax rates should be an independent variable in the specification. The spatial lag, t_{-l}, is defined as the average of local tax rates within a thirty mile radius of the population-weighted centroid of each jurisdiction. Neighboring local tax rates are simultaneous and by definition are endogenous. I instrument for t_{-l} using the standard instrument in the tax competition and spatial econometrics literature – the set of the spatially lagged X's and fixed effects. For example, one of the elements of X is area; thus, one of the instruments for neighboring tax rates is the average of the neighboring jurisdictions' areas. I use the entire subset of the spatially lagged x_{-l}'s and spatially lagged fixed effects as instruments. The justification of this set of instruments can be found in Brueckner (2003) and was proposed by Kelejian and Prucha (1998). Critically, Kelejian and Prucha (1998) show that using this IV procedure will render the estimates consistent even in the presence of spatial error dependence. The F-statistic for instrument strength from the first stage in the baseline specification 17.98 ($p = .00$) and remains strong in other specifications.[18]

I am interested in the marginal effect of distance. 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:

$$\frac{\partial t_{lc}}{\partial d_{lc}} = \begin{cases} \sum_{k=1}^{p} k[\varsigma_k + \delta_k + (\gamma_k + \alpha_k)\iota_{lc}](d_{lc})^{k-1} & \text{for } h_{lc} = 1 \,\&\, s_{lc} = 0 \\ \sum_{k=1}^{p} k[\varsigma_k + \gamma_k \iota_{lc}](d_{lc})^{k-1} & \text{for } h_{lc} = 0 \,\&\, s_{lc} = 0 \\ \sum_{k=1}^{p} k[\varsigma_k + \theta_k](d_{lc})^{k-1} & \text{for } h_{lc} = 0 \,\&\, s_{lc} = 1, \end{cases} \tag{6}$$

where the coefficients indicate the k^{th} order term of the fifth degree polynomial used in the analysis.[19]

From this expression, I can calculate the sample mean of the estimated derivative conditional on being in a high-, low-, or same-tax state relative to the neighbor. The mean derivative is a consistent estimate of the marginal effect for each side of the border. Standard errors for mean

[18] The choice of spatial weights is robust to using inverse distance weights. I also have used a more narrow set of instrumental variables (the area and perimeter of a jurisdiction, which are historically drawn). The results on the low-side remain unchanged, but become insignificant on the high-side. The appendix also shows the results using only the spatial lags of the X's as instruments yields similar results.

[19] The polynomial order is selected using "leave-one-out" cross-validation. 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 .575 at a polynomial order of five. See van der Klaauw (2002) for a discussion of cross-validation.

derivatives are calculated using the Delta Method and are clustered at the county level. 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 setting lower tax rates than those at the border.

4.4 Results: How Steep Is the Tax Gradient?

Tables 5 presents the mean derivatives using the full sample of towns within five hours of a border. The results in this section are informative but also include many towns that are far away from the border, for which the theory predicts the tax gradient should be relatively flat. Future sub-sections will study the tax gradient in a local region of the border. In columns 1 and 2, I estimate the tax gradient using driving distance (miles) to the state border and the crow-flies distance currently used in the literature. On average, the crow-flies distance will under-estimate the true travel time and may match to a border that is not closest based on driving. The attenuation bias from this measurement error is evident in the table. The preferred baseline specification is given by column 3; it uses driving time to state borders, which contains more information about the true cost of travel. The results using driving time are more efficient than the results using the crow-flies distance or driving distance.

[Table 5 Here]

The mean derivative on the low-tax side of the state border is significant and of the expected sign: -0.082. Moving a town one hour away from its high-tax state neighbor – assuming constant marginal effects – will decrease its local tax rate by just under one tenth of a percentage point. Interpreting this in the context of the average local tax rate, which is 2.25 percent, implies that average local taxes are about 4% lower 1 hour away from the border. The gradient for towns with a same-tax state neighbor is insignificant and almost zero, which is consistent with the theory. On the high-tax side of the border, the marginal effects are smaller but are unexpectedly negative (-.04 percentage points).[20] It is important to keep in mind that this is an average effect across the entire sample where towns more than an hour from the border are included in the estimate. The tax gradient in a local region of the border is likely to be much stronger and will be the focus of the following sub-section.

Before I focus on results near the border, how robust are the results to alternative specifications? The remaining columns of table 5 indicate the results are robust to various instruments, weight matrices and to focusing on town tax rates only. Table 6 highlights additional robustness

[20] Results of equation 5 without any controls or state fixed effects yields a significant -0.15 on the low-tax side and an insignificant 0.01 on the high-tax side.

checks.[21] The first several columns show the results are robust a variety of institutional features of LOST including localities reaching the maximum allowed local sales tax rate in some states. As an additional check, note that, taking the limit as $\iota \to 0$, level differences in local tax rates will exist because of the dummy variables h and s. Such a result is inconsistent with the theoretical predictions. To rectify this, in column 6, I impose that the coefficients on these two dummy variables as well as the vector of θ and δ coefficients are zero; this imposition guarantees that as the tax differential approaches zero, municipalities should set identical tax rates all else equal. Such a restriction comes with a loss of flexibility in the polynomial, but produces similar results, so I proceed with the more flexible form.

[Table 6 Here]

Columns 7 and 8 are critical robustness checks. The first 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 state taxes 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 border pair fixed effects help to capture the fact that certain borders may be characterized by spatially correlated unobservables. Column 8 uses only linear state borders. After visually inspecting every state border, any border that has a non-linear segment is discarded. One reason to do this is that non-linear borders are often delineated by rivers. Because of unobservable amenities or bunching of populations at rivers, one may worry that taxes are rising toward borders to account for this fact. Linear borders, on the other hand, were often arbitrarily determined along lines of latitude or longitude. These borders are more likely to be borders within a featureless plane and are much more likely to be exogenously determined. Using only linear borders preserves the sign of the tax gradient on both sides of the borders and magnifies the slope on the low-side of the border by about 50%. Both of these specifications suggest that the marginal effects are strategic reactions to tax differentials rather than to some other border characteristic.

[Table 7 Here]

In table 7, Columns 2-4 are designed to check for coincidental correlation of the control variables with the distance function. Column 2 allows the controls to have differential effects on the high- and low-tax side of borders. Specifications 3 interacts all the state fixed effects and all the control variables with a polynomial in distance and allows the coefficients on these interactions to

[21] The appendix also shows the results are robust to changing the order of the polynomial, weighting schemes, and restrictions on the sample of municipalities used.

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. Column 4 interacts the fixed effects with the distance functions. The results on the low-side of the border continue to match the theory. On the high-tax sides of borders, the marginal effect becomes positive and now matches the theory. This suggests that allowing the tax gradient to vary state-by-state may highlight important heterogeneity.[22] In these specifications – the most flexible specifications – the empirical results are entirely consistent with theory on both sides of the border.

4.5 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. Conjecture 1 suggest jurisdictions in a local region of the border will adjust tax rates the most rapidly. The tax gradient near the border is the most policy relevant given that towns an hour or more from the border are unlikely to respond much to the state tax differential. The mean derivatives in the past section mask this important heterogeneous response by distance. The tax gradient effect in a local region of the border is much more economically important because its slope provides the researcher with information about (1) the spatial reach of tax competition and (2) the consumer cost function of engaging in cross-border shopping.

[Figure 5 Here]

The last three columns of Table 7 restrict the sample to towns within about 80, 40 and 20 minutes of the border. 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 positive. 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. Additionally, using the full sample of the baseline model from Table 5, I evaluate the marginal effects at one-minute intervals. With the quintic polynomial, Figure 5 indicates the marginal effects are steepest within a thirty minute radius of the neighboring border. In a very local region of the border of the low-tax state, the marginal effects are almost five times as large as the average marginal effect for the full sample. Because the tax gradients become flat after about thirty minutes, this suggests that the spatial reach of tax competition for consumer sales extends slightly more than half an hour. As a falsification test, the results are compared to towns where the neighboring state has the same state tax rate. As expected, if the state tax rates are the same, the local tax rates are uniform but with large confidence bands.

[22] The appendix reports the tax gradients state by state.

Focusing on the towns near the border in Figure 5, the marginal effect of distance for a border town (a town with a distance near zero) in a low-tax state is -0.85. This suggest moving this town *ten minutes* away from the border will lower its local tax rate by 0.14 percentage points which is approximately 6% of the average local tax rate in a low-tax state. For towns located near state borders, the tax gradient effect is an important phenomenon. But, the tax gradient dissipates just after thirty minutes from the border at which point the tax gradient becomes flat. Because the tax gradient converges on zero for large distances, this yields the smaller mean derivatives in table 5 to 7. Given the tax gradient is steep near the border, tax competition and cross-border shopping are strong in this region.

4.6 Is the Tax Gradient Steepest for Large Differentials?

As suggested by Corollary 2, the tax gradient may be heterogeneous 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.

Looking at Table 8, the average marginal effect of distance is monotonic in the size of the discontinuity. On the low-tax side, the tax gradient ranges from -.052 to -.146 depending on the size of the tax differential. On the high-tax side, the tax gradient is significant (but of the unexpected sign) over most relevant ranges of the discontinuity. However, a positive and significant gradient begins to emerge if the size of the discontinuity is greater than or equal to 6 percentage points. Such a pattern taken in conjunction with the robustness checks above highlights 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 unlikely.

[Table 8 Here]

[Figure 6 Here]

The question then is how does the size of the discontinuity affect tax rates near state borders? Figure 6 presents changes in the marginal effects conditional on both distance and the size of the discontinuity in state tax rates. In the region of zero to thirty minutes 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. Furthermore, notice that as the state tax differential increases, the spatial reach of tax competition extends further. For towns on the low-tax side of borders, the spatial reach of tax competition is approximately thirty minutes when state tax differentials are small. When state tax differentials are large and salient, the tax gradient effects extend out almost an hour. 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. The tax gradient effect is an important economic phenomenon in the local region of borders and especially for large salient tax differentials as towns rationally adjust their tax rates in response to cross-border shopping.

4.7 Second Closest State Borders and County Borders

Up until now, the empirical specifications have assumed towns only respond to one border and one level of higher government. Jurisdictions may respond based on their proximity to multiple borders – especially in small states or in towns located in the "corner" of a state. Towns may also respond to county borders in addition to tax differentials at state borders. To address the concern that towns may be responding to two state borders, I calculate the linear distance to the second closest intersection of a major road and a different state border. The results are robust to controlling for distance to the second closest border and driving time to the nearest county border. The results for these specifications are available in an appendix.

4.8 Discussion

Towns near the border in low-tax states keep their local tax rates relatively high because they realize a relatively small elasticity of demand. This is especially salient when the size of the tax gap is largest. As towns get further from the border, tax rates fall, and they fall the fastest the closest to the border. The existence of an economically and statistically significant tax gradient implies that discontinuities at state borders continue to affect the elasticity of demand in localities up to thirty minutes from the border. The use of borders as a means of identifying strategic reaction provides a novel and new strategy to identify fiscal competition.

On the high-tax side, the results do not always line up with the theory, where the baseline specification may produce results of the unexpected sign – except in the case of very large state tax rate differences and the most flexible robustness checks. A possible explanation for this effect is that border localities on the high-tax side of the border may not anticipate further cross-border shopping problems from additional local taxes. If the state tax rate is high, localities may (incorrectly) anticipate that any remaining consumers have a low elasticity relative to neighbors at the interior of the state – leading the jurisdiction to raise the rate without fear of losing shoppers to within state neighbors and leading to a negative gradient. An alternative explanation is suggested by Harding, Leibtag and Lovenheim (2012) 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 resulting in a negative gradient. These authors find no evidence that the incidence varies with distance on the low-tax side of borders. Thus, the low-tax towns may correctly 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.

The results estimated in this paper may be consistent with a model where the median voter determines the local sales tax rate and another tax rate. On the high-tax side of a border, the median voter is more likely to be a cross-border shopper if the town is closer to the border. If the median voter's goal is to set taxes in a manner that reduces their own tax obligations, then someone who engages in large amounts of cross-border shopping may seek to raise sales taxes in order to export the tax burden to residents who do not cross-border shop. The higher sales tax rate may offset some of the tax burden for other taxes that the median voter pays. As towns are further from the border, the median voter is less likely to be a cross-border shopper. Of course, any of these modifications may have additional consequences, which suggests the need for additional theoretical modeling.

Although the evidence regarding the tax gradient on the high-tax side of borders is sometimes inconsistent with the theory, the dramatic level differences that arise at borders are unambiguous. These level effects provide powerful evidence that jurisdictions engage in "rational" decision-making. Evidence of rational tax competition is hard to identify in the literature. However, borders provide the researcher with a novel opportunity to predict how a strategically behaving jurisdiction will set tax rates.

5 Conclusion

Discontinuities in the tax system at state borders induce welfare distortions with respect to consumption, as some residents cross borders to purchase lower-tax goods. Firms distort the location characteristics of the good to the favorable tax side of the border, which results in an inefficient product mix. State tax differences 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 geographically differentiated tax system will reduce these welfare distortions, but will still have horizontal inequities if some individuals purchase goods a few neighboring jurisdictions away.

I uncover a local tax gradient and dramatic local tax level effects, 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 small 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 small distortions within a state, the reduction of a large salient distortion at the border may 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. 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.

The methodologies I develop in the paper are broadly applicable to analyzing how local governments respond to any fiscal policies that vary discontinuously across states and that distort the location decisions of firms or people near the border. Localities need not respond to policy discontinuities on one dimension; in fact, localities may respond to state regulatory differentials by changing tax or spending policies. 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 environmental standards. Localities may adopt local environmental regulations as a function of distance to the border to discourage firms from relocating; alternatively, they may respond with more favorable tax or spending policies. More generally, "notches" – resulting from discontinuous policies – are widespread and often differ in magnitude at each border. The methodologies developed in this paper exploits the magnitude of the policy differentials rather than their mere existence. Researchers can apply the theoretical and empirical methodologies to test if "notches" induce jurisdictions to implement policies that vary with distance from the discontinuity.

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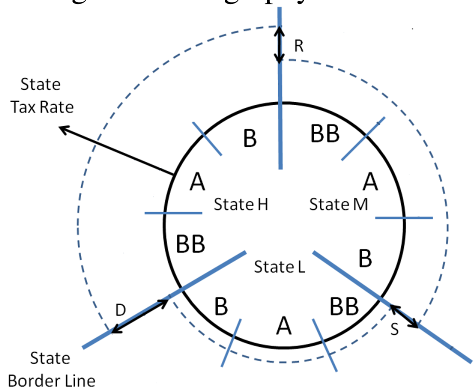
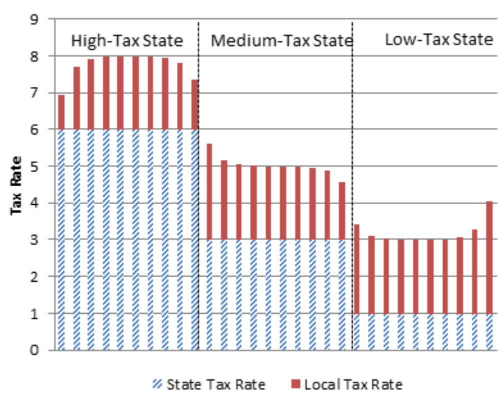
Figure 1: Geography of the Model



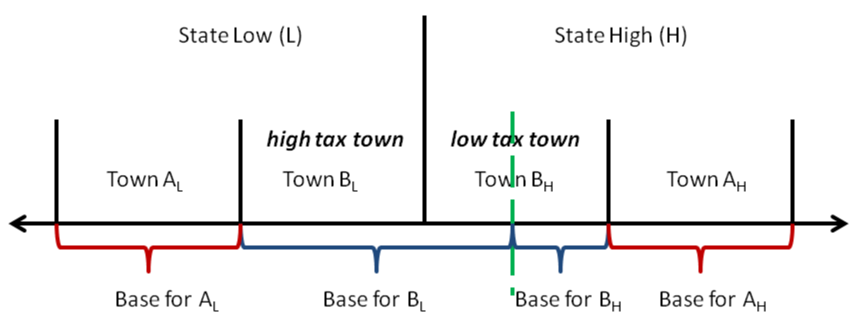
The dotted lines around the circle represent the level of the state tax rate. The large solid lines are state borders and the smaller solid lines are town borders.

Figure 2: Numerical Results for a Multiple Town Model



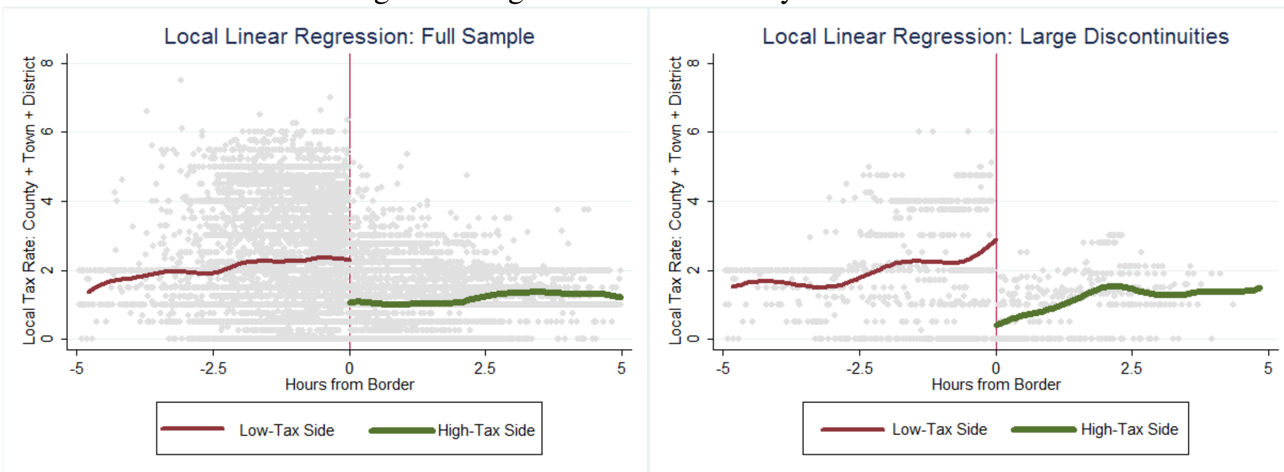
The figure above shows the Nash Equilibrium when the model has a large number of towns (thirty) and the parameters of the model are set such that $\delta x = 4$, $D = 5$, $R = 3$, and $S = 2$. Notice that local taxes (solid colors) are highest in the lowest tax state. Also note that the difference in local taxes is largest for towns closest to the largest discontinuities. Taxes are a function of distance to borders in a manner where the change near the border is most rapid and for the largest discontinuities.

Figure 3: Intuition of the Model



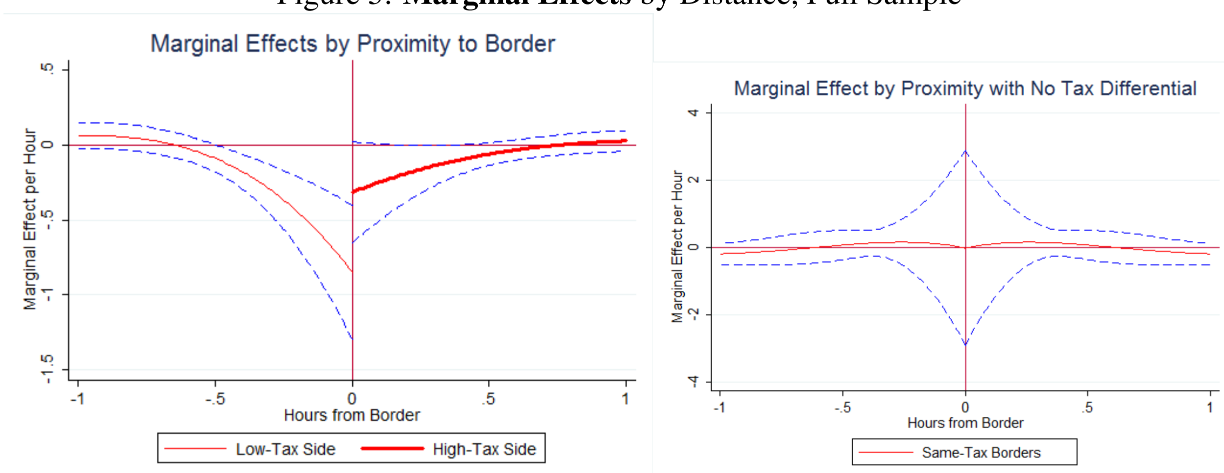
Consider what happens in the region of the border starting from a position where the local tax rates are equal, but the state tax rates are not. The size of the tax base influences the elasticity of the tax base.

Figure 4: Regression Discontinuity Results



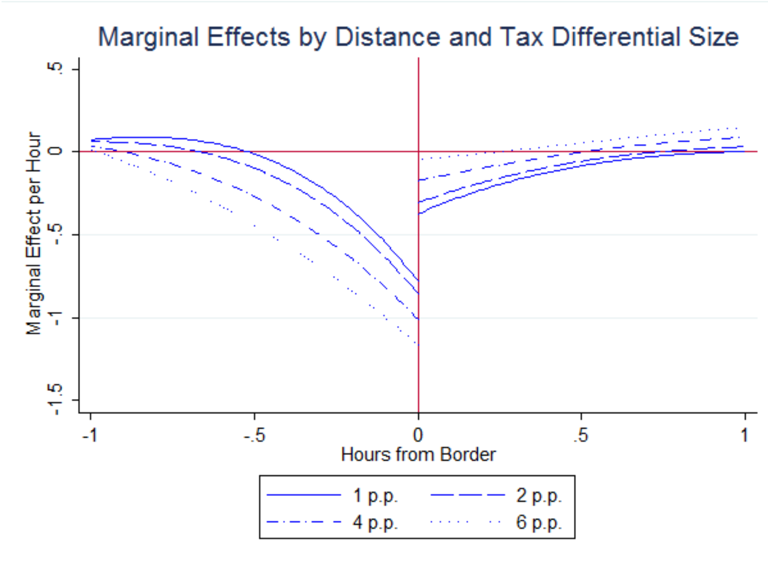
Both graphs plot the results of a local linear regression without covariates over a scatter plot of the raw data. The running variable is the time in hours from the border. The RD methodology follows Imbens and Kalyanaraman (2012) with a triangle kernel. The first graph uses the full sample, while the second graph restricts the sample to observations facing a four percentage point or larger tax differential. For the full sample, the RD results suggest that local taxes close the tax differential at state borders by 1.25 percentage points.

Figure 5: **Marginal Effects** by Distance, Full Sample



Marginal effects represent the effect of moving **away** from the border in both directions. In the first figure, the left side represents towns on the low-tax side of the border while the right side represents the high-tax side of the border. In the second figure, both sides represent what taxes would look like when there is no tax differential at state borders. The marginal effect represents how tax rates change when time from the border increases. If the marginal effect is negative, this means that moving away from the border lowers municipal tax rates. The units on the vertical axis represent the marginal effects per hour. To derive marginal effects per minute, divide the values on the vertical axis by 60. The results suggest that on the low-tax side of the border, local sales taxes decrease in driving time from the state border and that this decrease is most rapid in a local region of the border. The results of the second figure suggest that local taxes are not a function of distance when the tax differential is zero. Confidence intervals are 95%.

Figure 6: **Marginal Effects** by Distance and Size of the Discontinuity in State Rates



Marginal effects represent the effect of moving **away** from the border in both directions. The left side represents towns on the low-tax side of the border while the right side represents the high-tax side of the border. The marginal effect represents how tax rates change when time from the border increases. If the marginal effect is negative, this means that moving away from the border lowers municipal tax rates. The units on the vertical axis represent the marginal effects per hour. To derive marginal effects per minute, divide the values on the vertical axis by 60. Notice that the marginal effects are largest in absolute value for the largest tax differentials in low-tax states. Confidence intervals are omitted for simplicity.

Table 1: Summary Statistics

Averages with Standard Deviations in ( )

Variable	Low-Side	High-Side	Same-Tax
Differential in State Tax Rate (ι)	-1.89	1.87	0
	(1.67)	(1.46)	(0)
Driving Distance from State Border (miles)	55.22	63.67	50.73
	(43.09)	(52.07)	(31.43)
Travel Time from State Border (min.)	71.33	82.31	64.85
	(51.32)	(62.28)	(36.90)
Crow-Fly Distance from State Border	42.65	48.03	38.50
	(34.57)	(38.57)	(23.58)
County Rate	1.39	0.54	1.84
	(1.28)	(0.74)	(1.15)
Local + District + County Rate	2.25	1.08	3.07
	(1.56)	(0.91)	(1.44)
Spatial Lag of Local Tax Rate	2.19	1.17	3.08
	(1.41)	(0.82)	(1.22)
Sample Size	8394	6952	463

High-side means that the nearest state to the location is a low-tax state. The control variables include (at the local and county level), the number of neighbors, area, perimeter, population, %non-citizens, % on public assistance, % senior, % less than college, % work in state, % male, the ratio of private to public school students, % white, income, age, the number of rooms in a home, the average age of a home, and the Obama vote share in 2008 at the county level.

Table 2: RD Estimates: State Borders

	(1)	(2)	(3)	(4)	(5)	(6)
No Controls	-1.20***	-1.23***	-0.34***	-0.65***	1.40***	.18**
	(0.07)	(0.09)	(0.04)	(0.12)	(.03)	(.08)
Controls	-1.17***	-1.25***	-0.34***	-0.70***	1.45***	.18**
	(0.07)	(0.08)	(0.04)	(0.11)	(.03)	(.07)
Controls and State	-1.19***	-1.27***	-0.34***	-0.70***	1.45***	.17**
Dummies	(0.06)	(0.08)	(0.04)	(0.11)	(.03)	(.07)
Bandwidth	36	39	83	108	94	41
Type of Border	State	State	State	State	State	State
Tax Rate	Total Local	Total Local	Town Only	County Only	State Tax	State + Total Local
Measure of Distance	Miles	Minutes	Minutes	Minutes	Minutes	Minutes
Average Tax Differential in Sample	1.88	1.88	1.88	1.88	1.88	1.88

The results represent the effect of state tax rate differentials on the level of tax rates in border towns on the high-tax side relative to border towns on the low-tax side. Columns (1) - (4) estimate the level effect at state borders for various local tax rates – local plus district plus county rates, local only and county only. The first two columns compare the results when the running variable is driving distance and driving time. For all columns (2) to the end, the running variable is the driving time to the nearest state border intersection of a major road and the bandwidth is in minutes. Column (5) uses the state tax rate as the dependent variable to determine the size of the state tax differential in a local region of the border. Column (6) uses the state plus total local rate as the dependent variable to see if differences in state tax rates are completely dissipated by local tax autonomy.

***99%, **95%, *90%

Table 3: RD Estimates: By Size of Tax Differential

	(1)	(2)	(3)
No Controls	-0.31**	-1.63***	-2.47***
	(0.14)	(0.09)	(0.31)
Controls	-0.73***	-1.66***	-2.21***
	(0.23)	(0.08)	(0.42)
Controls and State Dummies	-0.73***	-1.66***	-2.21***
	(0.23)	(0.08)	(0.42)
Bandwidth	35	61	61
Type of Border	State	State	State
Tax Rate	Total Local	Total Local	Total Local
Sample Restriction	Small Differential	Medium Differential	Large Differential
Average Tax Differential in Sample	0.60	2.05	6.38

The results represent the effect of state tax rate differentials on the level of tax rates in border towns on the high-tax side relative to border towns on the low-tax side. Driving time is the running variable in all columns. This table restricts the RD to various sized tax differentials at state borders. In column (1) the tax differential at the border is less than or equal to 1 percentage point. Columns (2) and (3) restrict the samples to tax differentials between 1 and 4 percentage point and above 4 percentage points, respectively. ***99%, **95%, *90%

Table 4: RD Estimates: County Borders

	(1)	(2)	(2’)	(3)
No Controls	-0.28***	-0.13*	.94***	-1.22***
	(0.07)	(0.07)	(.09)	(0.28)
Controls	-0.23***	-0.11*	.87***	-0.78***
	(0.06)	(0.07)	(.08)	(0.25)
Controls and State Dummies	-0.23***	-0.12*	.86***	-0.86***
	(0.07)	(0.07)	(.08)	(0.25)
Bandwidth	14	17	11	13
Type of Border	County	County	County	County
Border Counties?	Y	N	N	N
Tax Rate	Town	Town	County	Town
Restriction	-	-	-	Large Differential
Average Tax Differential in Sample	0.99	0.81	0.81	2.17

The results represent the effect of county tax differentials on the level of tax rates in border towns from the high-tax side relative to a border towns on the low-tax side. For all columns, the running variable is the driving time to the nearest county border intersection of a major road and the bandwidth is in minutes. Column (1) uses all county borders while columns (2) to (3) use county borders that are not also state borders. Column (2’) uses the county tax rate as the dependent variable to determine the tax differential in the region of county borders. Column (3) focuses on county borders where the tax differential is larger than 1 percentage point. ***99%, **95%, *90%

Table 5: Mean Derivatives: Baseline Specifications

Mean Derivative	(1)	(2)	(3)	(4)	(5)	(6)
Low-Tax State	-.149***	-.147*	-.082***	-.081***	-.099***	-.060***
	(.069)	(.075)	(.025)	(.038)	(.031)	(.023)
High-Tax State	-.069	-.026	-.040**	-.038**	+.029	-.040**
	(.043)	(.054)	(.019)	(.019)	(.032)	(.016)
Same-Tax State	-.200	-.118	-.009	-.022	+.014	+.044
	(.167)	(.203)	(.080)	(.075)	(.098)	(.097)
Specification	Baseline Specification	Baseline Specification	Baseline Specification	Inverse Distance Spatial Weights	Spatial Lag: Geography	Town Taxes Only
Running Variable	Driving Distance	Crow-Fly Distance	Driving Time	Driving Time	Driving Time	Driving Time
Observations	15,260	15,260	15,260	15,260	15,260	15,260

The marginal effects represent a **per 100 mile** change for (1)-(2) and a **per one hour** change for (3)-(6).

In all specifications except (6), the left hand side variable is the county plus local plus district tax rate. All specifications have fixed effects. (1) is derived from Equation 5 when the running variable is driving distance. (2) is identical to the previous column except the running variable is the crow-flies distance to borders. (3) uses driving time to the nearest state border as the running variable. This variable contains more information than driving distance and better approximates the travel cost of getting to a border. All subsequent columns will use it. (4) uses inverse distance spatial weights to estimate the spatial lag and (5) uses only lagged geographic variables as instruments for the neighbors' tax rates. (6) estimates the tax gradients looking only at local tax rates (no county rates).

Standard errors are clustered at the county level and calculated using the Delta Method. ***99%, **95%, *90%.

Table 6: Mean Derivatives: Robustness Checks

Mean Derivative	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Low-Tax State	-.082***	-.092***	-.170***	-.081**	-.094***	-.078***	-.067***	-.126***
	(.025)	(.028)	(.043)	(.032)	(.026)	(.023)	(.025)	(.032)
High-Tax State	-.040**	-.017	-.002	-.077***	-.042**	-.019	-.036*	-.032
	(.019)	(.052)	(.031)	(.024)	(.019)	(.017)	(.020)	(.028)
Same-Tax State	-.009	-	-.052	-.018	-.002	-.056	-.054	.0002
	(.080)		(.158)	(.141)	(.080)	(.023)	(.070)	(.119)
Specification	Baseline Specification	Neighbor No LOST	Exclude States with Low Standard Deviation	Exclude States Max Max Out	Mexico / Canada	Coefficients Restricted	Border and State FE	Linear Borders
Observations	15,260	3385	8148	11,625	15,260	15,260	15,260	5523

The marginal effects represent a **per hour** change.

The left hand side variable is the county plus local plus district tax rate. (1) repeats the baseline specification of table 5 when the running variable is time. (2) only uses state borders that do not allow for LOST on the opposite side. (3) restricts the sample to states with a standard deviation of local taxes greater than 0.50 and (4) drops states that appear to max out. (5) interacts all the polynomial terms with separate dummy variables for the Mexican and Canadian borders. (6) restricts the polynomial to converge on both sides of the border when the tax differential converges to zero. (7) adds border pair fixed effects to the state fixed effects already present in the model. (8) addresses the concern that borders are endogenous and delineated by unobserved spatial features by restricting the sample to borders that are straight lines. Straight line borders are not delineated by rivers and often divide states through flat featureless planes based on arbitrary latitude or longitude agreements.

Standard errors are clustered at the county level and calculated using the Delta Method. ***99%, **95%, *90%.

Table 7: Mean Derivatives: Robustness Checks and Distance Restrictions

Mean Derivative	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Low-Tax State	-.082***	-.131***	-.116***	-.145***	-.120**	-.629***	-.500
	(.025)	(.023)	(.027)	(.043)	(.053)	(.157)	(.366)
High-Tax State	-.040**	-.025	+.208***	+.138***	-.027	+.184	+1.37***
	(.019)	(.017)	(.039)	(.037)	(.056)	(.154)	(.355)
Same-Tax State	-.009	+.085	.191	-.214	-.288	+.650	+.256
	(.080)	(.079)	(.167)	(.147)	(.192)	(.518)	(1.080)
Specification	Baseline Specification	X's Vary Both Sides	Interact All	Interact FE	80 Minutes Restriction	40 Minutes Restriction	20 Minutes Restriction
Observations	15,260	15,260	15,260	15,260	9073	4698	1890

The marginal effects represent a **per hour** change.

The left hand side variable is the county plus local plus district tax rate. (1) repeats the baseline specification of table 5 when the running variable is time. (2) interacts the control variables with the dummy variables for the side of the border. (3) allows for interactions of the polynomials with the state fixed effects and the controls. (4) includes an interaction of the polynomials with state fixed effects. (5) restricts the sample to observations within eighty minutes of the border. (6) and (7) restrict the sample to observations within forty and twenty minutes of the nearest border.

Standard errors are clustered at the county level (except for column 3) and calculated using the Delta Method. ***99%, **95%, *90%.

Table 8: Marginal Effects by Intensity of the Treatment

	Low-Tax Side	High-Tax Side	Same-Tax
Not Conditioned on Notch (ι)	-.081***	-.049**	-.009
	(.025)	(.019)	(.080)
5th Percentile of ι	-.052	-.077***	
$\iota_{Low} = -.25$; $\iota_{High} = .25$	(.033)	(.026)	
10th Percentile of ι	-.056*	-.077***	
$\iota_{Low} = -.50$; $\iota_{High} = .25$	(.030)	(.026)	
30th Percentile of ι	-.063**	-.058***	
$\iota_{Low} = -.875$; $\iota_{High} = 1.00$	(.028)	(.022)	
50th Percentile of R	-.079***	-.039**	
$\iota_{Low} = -1.75$; $\iota_{High} = 1.75$	(.025)	(.019)	
70th Percentile of ι	-.084***	-.032*	
$\iota_{Low} = -2.025$; $\iota_{High} = 2.00$	(.026)	(.019)	
90th Percentile of ι	-.102***	.009	
$\iota_{Low} = -3.00$; $\iota_{High} = 3.65$	(.032)	(.023)	
95th Percentile of ι	-.146**	.069*	
$\iota_{Low} = -5.40$; $\iota_{High} = 6$	(.060)	(.040)	

The marginal effects represent a **per 1 hour** change. The marginal effects presented are the derivatives calculated at the particular value of ι listed in the table. On the low-tax side, the derivative is evaluated at ι_{Low}. On the high-tax side, the derivative is evaluated at the value of ι_{High} given.

Standard Errors are clustered at the county level and calculated using the Delta Method. ***99%, **95%, *90%

A Supplementary Appendix: Theory

A.1 Deriving the Nash Equilibrium

Step one requires establishing the revenue function for all towns in the model using the cutoff rule in the text. The revenue functions for towns in State M are as follows:

$$R_i^M = \begin{cases} t_A^M(x + \frac{t_{BB}^M - t_A^M}{\delta} + \frac{t_B^M - t_A^M}{\delta}) & \text{for Town A} \\ t_{BB}^M(x + \frac{t_B^H - t_{BB}^M + R}{\delta} + \frac{t_A^M - t_{BB}^M}{\delta}) & \text{for Town BB} \\ t_B^M(x + \frac{t_{BB}^L - t_B^M - S}{\delta} + \frac{t_A^M - t_B^M}{\delta}) & \text{for Town B.} \end{cases} \tag{A.1}$$

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. Revenue functions for towns in the other two states can be similarly established.

Then in step two, differentiating the revenue functions with respect to the local tax rate in the jurisdiction yields the following best response functions:

$$\begin{array}{lll} t_{BB}^H(\cdot) = \frac{1}{4}(\delta x - (R+S) + t_A^H + t_B^L) & t_A^H(\cdot) = \frac{1}{4}(\delta x + t_{BB}^H + t_B^H) & t_B^H(\cdot) = \frac{1}{4}(\delta x - R + t_A^H + t_{BB}^M) \\ t_{BB}^M(\cdot) = \frac{1}{4}(\delta x + R + t_B^H + t_A^M) & t_A^M(\cdot) = \frac{1}{4}(\delta x + t_{BB}^M + t_B^M) & t_B^M(\cdot) = \frac{1}{4}(\delta x - S + t_A^M + t_{BB}^L) \\ t_{BB}^L(\cdot) = \frac{1}{4}(\delta x + S + t_B^M + t_A^L) & t_A^L(\cdot) = \frac{1}{4}(\delta x + t_{BB}^L + t_B^L) & t_B^L(\cdot) = \frac{1}{4}(\delta x + (R+S) + t_{BB}^H + t_A^L). \end{array} \tag{A.2}$$

In step three, the system of nine equations and nine unknowns can be solved for the municipal tax rates. This yields equation characterizing the solution in the text.

A.2 Proof of Uniqueness of the Equilibrium

I prove below that any equilibrium in this model will be unique for the case of a three state, three town model. The solution to a three state model with three towns is characterized by the equation

$\mathbf{At} = \mathbf{b}$. This system can be written as:

$$\begin{bmatrix} 1 & -\frac{1}{4} & 0 & & \cdots & & & 0 & -\frac{1}{4} \\ -\frac{1}{4} & \ddots & \ddots & \ddots & & & & & 0 \\ 0 & \ddots & \ddots & \ddots & & & & & \\ & \ddots & \ddots & 1 & -\frac{1}{4} & & & & \vdots \\ \vdots & & & -\frac{1}{4} & 1 & \ddots & \ddots & & \\ & & & & \ddots & \ddots & \ddots & 0 & \\ & & & & & \ddots & \ddots & \ddots & \\ 0 & & & \cdots & & \ddots & \ddots & \ddots & -\frac{1}{4} \\ -\frac{1}{4} & 0 & & \cdots & & & 0 & -\frac{1}{4} & 1 \end{bmatrix} \begin{bmatrix} t_{BB}^{H} \\ t_{A}^{H} \\ t_{B}^{H} \\ t_{BB}^{M} \\ t_{A}^{M} \\ t_{B}^{M} \\ t_{BB}^{L} \\ t_{A}^{L} \\ t_{B}^{L} \end{bmatrix} = \frac{1}{4} \begin{bmatrix} \delta x - D \\ \delta x \\ \delta x - R \\ \delta x + R \\ \delta x \\ \delta x - S \\ \delta x + S \\ \delta x \\ \delta x + D \end{bmatrix}. \tag{A.3}$$

Proof. The proof modifies Ohsawa (1999). Matrix $\mathbf{A}$ 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 $\mathbf{A}^{-1}\mathbf{b}$. □

A.3 Conditions for Existence

Matrix $\mathbf{A}$ has an inverse, but three conditions must be satisfied to guarantee existence of the model. First, all local taxes must be positive. Second, cross-border shopping must occur only one town over along the continuum. Third, the number of residents of each town that cross-border shop must strictly less than the total population of the town. All three conditions will be satisfied if the length of the town is sufficiently large.[23] Looking at the Nash equilibrium it easy easy to see that tax rates will be positive for a large enough length given that every tax rate contains a $\frac{\delta x}{2}$ that enters positively. The intuition in this condition for the other assumptions lies with the fact that if the length of the jurisdictions are sufficiently large, the cost of shopping two (or more) towns over $\delta(x+\ell)$ will become so large that the tax savings will never warrant such a trip. Similarly, if the town size is sufficiently large, then residents at the interior of the town will face a cost $\delta\ell$ that guarantees they will shop at home even if cross-border shopping is outward on both sides of the border. Denote the value of x that satisfies all three of these conditions as x^*. Given that matrix $\mathbf{A}$ has an inverse, then $x > x^*$ guarantees that a small deviation in the tax rate of a particular town

[23] This is equivalent to finding a value of δ that is sufficiently large given that x and δ enter multiplicatively in the Nash equilibrium.

cannot change revenues discontinuously and a Nash equilibrium will exist in pure strategies. Given that x is not restricted in the model, it is clear that such an x^* can be established.

A.4 Proof of Corollary 2

Corollary. *If D is sufficiently small relative to both R and S, the tax gradient becomes steeper when the discontinuity in state tax rates increases at the closest border holding constant the state tax differential at the other state border.*

Proof. In order for D to be sufficiently small, $D < min(4R, 4S)$ and all gradients can be signed unambiguously as in the equation below. Using $S = \tau^M - \tau^L$, $R = \tau^H - \tau^M$, and $D = \tau^H - \tau^L$, the slopes of the tax gradient at each border are proportional to:

$$\begin{array}{ll} t_A^L - t_B^L = -4(\tau^H - \tau^M) - 3(\tau^M - \tau^L) < 0 & t_A^H - t_{BB}^H = 3(\tau^H - \tau^M) + 4(\tau^M - \tau^L) > 0 \\ t_A^M - t_{BB}^M = -4(\tau^H - \tau^M) - (\tau^M - \tau^L) < 0 & t_A^M - t_B^M = (\tau^H - \tau^M) + 4(\tau^M - \tau^L) > 0 \\ t_A^L - t_{BB}^L = (\tau^H - \tau^L) - 4(\tau^M - \tau^L) < 0 & t_A^H - t_B^H = 4(\tau^H - \tau^M) - (\tau^H - \tau^L) > 0 \end{array} . \tag{A.4}$$

The corollary requires that the tax differential near the border town in each of the expressions above to increase (without affecting the differential at the other border of the state). This corresponds to an *increase* in the neighboring state tax rate for the first column (towns in relatively low-tax states) and to a *decrease* in the neighboring state tax rate for towns in the second column (towns in relatively high-tax states). A small increase or decrease in the neighboring state tax rates can be easily calculated as being proportional to:

$$\begin{array}{ll} \frac{\partial(t_A^L - t_B^L)}{\partial \tau^H} = -4 < 0 & -\frac{\partial(t_A^H - t_{BB}^H)}{\partial \tau^L} = 4 > 0 \\ \frac{\partial(t_A^M - t_{BB}^M)}{\partial \tau^H} = -4 < 0 & -\frac{\partial(t_A^M - t_B^M)}{\partial \tau^L} = 4 > 0 \\ \frac{\partial(t_A^L - t_{BB}^L)}{\partial \tau^M} = -4 < 0 & -\frac{\partial(t_A^H - t_B^H)}{\partial \tau^M} = 4 > 0 \end{array} . \tag{A.5}$$

The sign of the comparative statics indicates that the decreasing tax gradients (the first column) become more negative and the increasing tax gradients (the second column) become more positive, which implies all tax gradients become more steep. □

B Supplementary Appendix: Data

B.1 Background on the Local Option Sales Tax

The institutional regulations governing local sales taxes differ by states. Some states do not allow for LOST. Of the remaining states that allow for some form of 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 or transportation districts (examples: Colorado or Missouri). 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 states, a mandatory county rate is set uniformly across the state with the option to increase the rate (example: California). As a result, some consumers face different tax rates street blocks away while others need to travel many 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, when the maximum LOST is capped, "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 states like 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. Table A.1 provides summary statistics by state. For an even more detailed institutional background, please see Agrawal (2013).

The paper includes international borders in the analysis. 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. The empirical analysis uses the federal plus provincial tax rate in the analysis. 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.

B.2 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.[24] Figure A.1 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.[25] 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 projection 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.[26] Let b

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

[25] 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.

[26] A Census block is the smallest unit of geography. In some cases, a block may be a large area with little or no

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 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. Using the distribution of Census blocks, I determine the county in which the Census place has the majority of its population. For Places that cross county lines, the Place is matched to the county in which the plurality of its population is located. This uniquely 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 matches over 2/3 of the United States population to a locality.[27] I hand match any remaining observations possible.

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

population. In other areas, a Census block may contain an entire apartment complex or building and may have a population of several hundred.

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

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.

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.[28] 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. The time to the nearest state border is the travel time by car assuming that the individual obeys all speed limits and driving restrictions on the roads.

Figure A.1 demonstrates the centroids and border crossings at the New York-New Jersey border.

B.3 Map Analysis and Summary Statistics

Figure A.2 presents the distribution of the county tax rate plus the average municipal tax rate with the county. Figure A.2 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, but counties are also significantly larger. The within state variation is dominated by the cross-state variation resulting from the level effect of state tax rates. Table A.2 presents a full set of summary statistics for the variables used in the analysis at the local level; county level controls for the Census and geographic variables are also included but not reported.

C Supplementary Appendix: Additional Empirical Results

C.1 Additional Robustness Checks

Before proceeding, recall the definition of the tax gradient.

Definition. The *tax gradient* is defined as the slope of local option taxes away from the border. The tax gradient is increasing in distance from the border if local option taxes increase as towns

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

are further from the nearest state border. The tax gradient is decreasing in distance from the border if local option taxes decrease as towns are further from the nearest state border.

Table A.3 presents additional robustness checks. Column 2 does not include the intensity of treatment interactions in case the reader is worried the tax differentials are endogenous. Column 3 seems to indicate that on the low-side of borders 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 their interior neighbors, which is consistent with a Hotelling style model where towns at the end of the line segment set higher rates. Column 4 indicates that the gradient becomes slightly steeper when excluding jurisdictions near international borders (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. Two additional columns show that the results are robust to weighting the jurisdictions by population and to giving each state equal weight in the sample. The table also shows in its final two columns that the sign of the gradients robust to the order of the polynomial although the third degree polynomial is likely not flexible enough.

C.2 Multiple Borders

I calculate the distance from the population weighted centroid of every town to the second closest county border. For computational feasibility, I use the "as the crow-flies" distance instead of driving distance for the second closest border. Distance to the closest state border is still measured as driving time. Column 2 of Table A.4 adds 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, the tax gradient remains unchanged. This suggests that the closest border is the most relevant for local governments.

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 time from every population weighted centroid to the nearest intersection of a major road and a county border. I then regress local 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. I control for the county tax rate and instrument for it with its demographic characteristics. Note that the sign of the gradient on the low-tax side of the border remains negative as predicted, and the sign becomes positive on the high-side but remains insignificant. In column 4, 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 only marginally significant at the 10% level on the high-tax side.

The above 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.

C.3 State by State Gradients

These results are important for several reasons. One, the researcher may worry that the results are being driven by pooling so many (different) large and small states or by institutional differences such as maxing out. Looking at the results state-by-state suggests that the mean derivatives in the full population are a good representation of the states on average. Two, doing this exercise highlights how types of borders, particular state institutions, or the characteristics of a particular state may influence the tax gradient. As such, it informally suggests the states (and type of states) that are prone to steeper gradients.

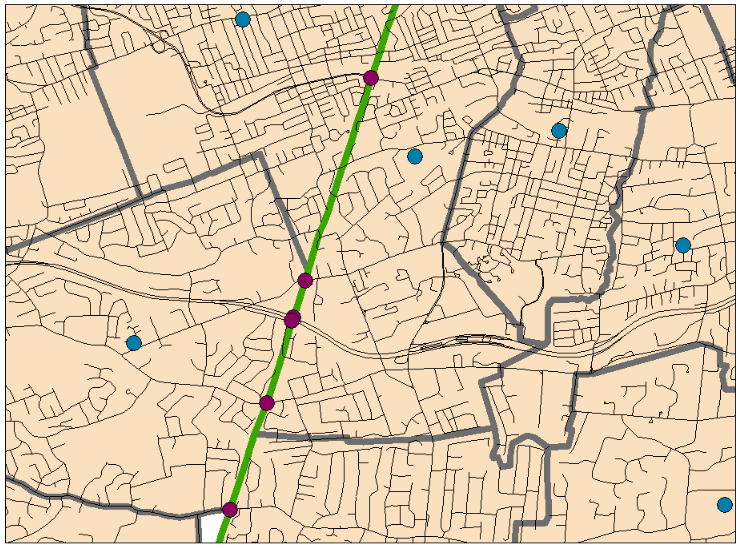
Table A.5 displays the mean derivatives in every state that allows for LOST and highlights substantial variation in the gradients. Out of the sixteen states that have a high-tax neighbor, twenty states have a negative gradient consistent with the theory. Out of the ten states with positive gradients, only three states – Alabama, Idaho, and Nevada – 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-one states with a low-tax neighbor, fifteen states have positive gradients consistent with the theory. Of these states, only seven have statistically significant gradients that imply taxes increase away from the nearest low-tax neighbor.

Table A.1: ProSales Tax Summary Statistics by State (April 2010)

	State Rate	County Taxes?	Local Taxes?	District Taxes?	Neighboring States
Alabama	4.00	Yes	Yes	Yes	FL, GA, MS, TN
Alaska	-	Yes	Yes	-	CAN
Arizona	5.60	Yes	Yes	-	CA, MEX, NM, NV, UT
Arkansas	6.00	Yes	Yes	-	LA, MO, MS, OK, TN, TX
California	7.25	Yes	Yes	Yes	AZ, MEX, NV, OR
Colorado	2.90	Yes	Yes	Yes	KS, NE, NM, OK, UT, WY
Connecticut	6.00	-	-	-	MA, NY, RI
Delaware	-	-	-	-	MD, NJ, PA
D.C.	6.00	-	-	-	MD, VA
Florida	6.00	Yes	-	-	AL, GA
Georgia	4.00	Yes	Yes	-	AL, FL, NC, SC, TN
Hawaii	4.00	Yes	-	-	-
Idaho	6.00	Yes	Yes	-	MT, NV, OR, UT, WA, WY
Illinois	6.25	Yes	Yes	Yes	IN, IA, KY, MO, WI
Indiana	7.00	-	-	-	IL, KY, MI, OH
Iowa	6.00	Yes	Yes	-	IL, MN, MO, NE, SD, WI
Kansas	5.30	Yes	Yes	Yes	CO, MO, NE, OK
Kentucky	6.00	-	-	-	IL, IN, MO, OH, TN, VA, WV
Louisiana	4.00	Yes	Yes	Yes	AR, MS, TX
Maine	5.00	-	-	-	CAN, NH
Maryland	6.00	-	-	-	DC, DE, PA, VA, WV
Massachusetts	6.25	-	-	-	CT, NH, NY, RI, VT
Michigan	6.00	-	-	-	CAN, IN, OH, WI
Minnesota	6.875	Yes	Yes	Yes	CAN, IA, ND, SD, WI
Mississippi	7.00	-	Yes	-	AL, AR, LA, TN
Missouri	4.225	Yes	Yes	Yes	AR, IA, IL, KS, KY, NE, OK, TN
Montana	-	-	-	-	CAN, ID, ND, SD, WY
Nebraska	5.50	Yes	Yes	-	CO, IA, KS, MO, SD, WY
Nevada	4.60	Yes	-	Yes	AZ, CA, ID, OR, UT
New Hampshire	-	-	-	-	CAN, MA, ME, VT
New Jersey	7.00	-	-	-	DE, NY, PA
New Mexico	4.85	Yes	Yes	-	AZ, CO, MEX, OK, TX
New York	4.00	Yes	Yes	Yes	CAN, CT, MA, NJ, PA, VT
North Carolina	5.75	Yes	-	Yes	SC, TN, VA
North Dakota	5.00	Yes	Yes	-	CAN, MN, MT, SD
Ohio	5.50	Yes	-	Yes	IN, KY, MI, PA, WV
Oklahoma	4.50	Yes	Yes	-	AR, CO, KS, MO, NM, TX
Oregon	-	-	-	-	CA, ID, NV, WA
Pennsylvania	6.00	Yes	-	-	DE, MD, NJ, NY, OH, WV
Rhode Island	7.00	-	-	-	CT, MA
South Carolina	6.00	Yes	Yes	Yes	GA, NC
South Dakota	4.00	-	Yes	Yes	IA, MN, MT, ND, NE, WY
Tennessee	7.00	Yes	Yes	-	AL, AR, GA, KY, MO, MS, NC, VA
Texas	6.25	Yes	Yes	Yes	AR, LA, MEX, NM, OK
Utah	4.70	Yes	Yes	Yes	AZ, CO, ID, NM, NV, WY
Vermont	6.00	-	Yes	-	CAN, MA, NH, NY
Virginia	4.00	Yes	-	-	DC, KY, MD, NC, WV
Washington	6.50	Yes	Yes	Yes	CAN, ID, OR
West Virginia	6.00	-	-	-	KY, MD, OH, PA, VA
Wisconsin	5.00	Yes	-	Yes	IA, IL, MI, MN
Wyoming	4.00	Yes	-	-	CO, ID, MT, NE, SD, UT

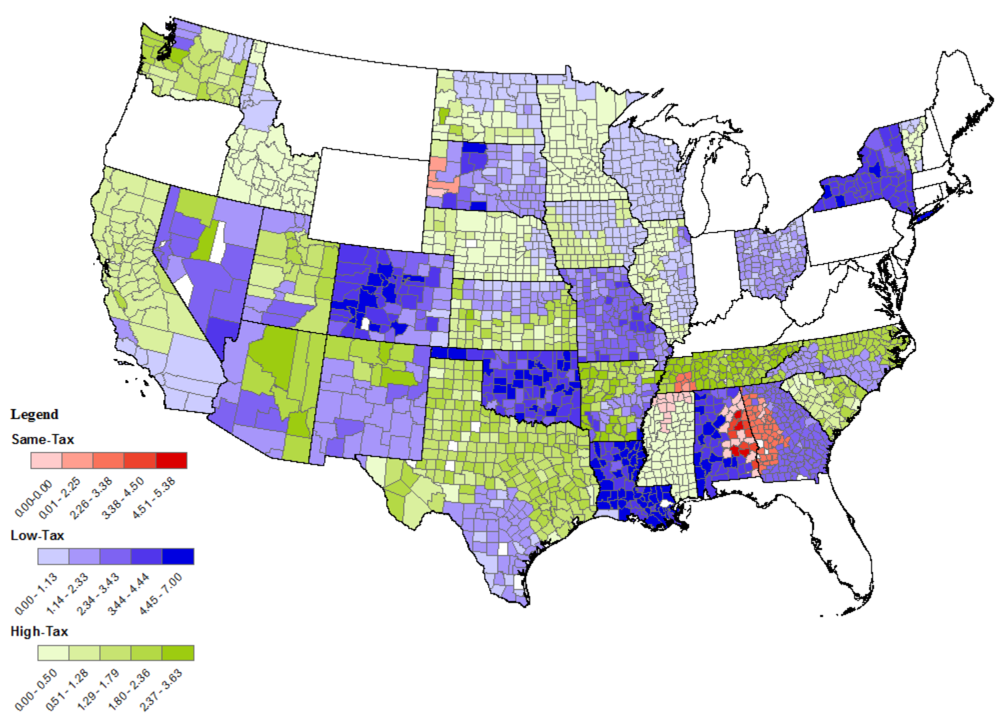
Yes means that the maximum value in the ProSales Tax dataset is non-zero.

Figure A.1: 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. Source: Author's creation using Census mapfiles.

Figure A.2: County Plus Average Town and District Tax Rates by the Type of Border



Source: Author's calculation. Red denotes places where the nearest state border has no state tax rate differential. Blue denotes places on the low-state tax side of the border. Green denotes places on the high-tax side of the state border. Darker colors are higher local tax rates.

Table A.2: Summary Statistics

Averages with Standard Deviations in ( )

Place Level Data – Full Sample

Variable	Low-Side	High-Side	Same-Tax
Differential in State Tax Rate (ι)	-1.89	1.87	0
	(1.67)	(1.46)	(0)
Driving Distance from State Border (miles)	55.22	63.67	50.73
	(43.09)	(52.07)	(31.43)
Travel Time from State Border (min.)	71.33	82.31	64.85
	(51.32)	(62.28)	(36.90)
Crow-Fly Distance from State Border	42.65	48.03	38.50
	(34.57)	(38.57)	(23.58)
Second Closest State Crow-Fly Distance	84.93	101.80	74.50
	(53.75)	(62.76)	(31.60)
Number of Neighbors	1.93	1.64	1.86
	(2.05)	(1.58)	(1.94)
Town Area	5.50	5.51	8.72
	(19.14)	(15.79)	(15.06)
Town Perimeter	13.83	14.38	25.15
	(23.68)	(23.55)	(35.00)
Population	10,790	8080	9022
	(109,942)	(42,364)	(26,672)
Senior (%)	15.85	16.17	14.27
	(7.92)	(8.10)	(6.67)
Less Than College (%)	81.12	82.18	82.63
	(14.97)	(13.69)	(12.85)
Work in State (%)	96.27	95.65	95.30
	(8.54)	(9.60)	(10.22)
Male (%)	49.14	49.00	47.95
	(5.37)	(5.26)	(5.59)
Ratio of Private to Public School Students	0.14	0.13	0.17
	(0.50)	(0.59)	(0.39)
Public Assistance (%)	2.40	2.42	1.85
	(3.49)	(3.34)	(2.83)
Non-Citizen (%)	2.77	3.02	3.05
	(5.21)	(5.43)	(5.87)
White (%)	84.91	85.20	66.49
	(20.15)	(19.47)	(26.62)
Mean Income	58,174	56,173	50,723
	(33,968)	(30,006)	(19,236)
Median Age	39.20	39.52	37.76
	(7.81)	(8.01)	(7.01)
Obama Vote Share	45.19	42.56	40.71
	(13.20)	(13.86)	(16.69)
Number of Rooms in Home	5.61	5.57	5.49
	(0.75)	(0.74)	(0.57)
Average Age of Home	45.85	43.58	35.30
	(15.84)	(15.73)	(11.71)
County Rate	1.39	0.54	1.84
	(1.28)	(0.74)	(1.15)
Local + District Rate	0.86	0.51	1.23
	(1.32)	(0.74)	(1.61)
Local + District + County Rate	2.25	1.08	3.07
	(1.56)	(0.91)	(1.44)
Spatial Lag of Local Tax Rate	2.19	1.17	3.08
	(1.41)	(0.82)	(1.22)
Sample Size	8394	6952	463

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

Table A.3: Mean Derivatives: Robustness Checks

Mean Derivative	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Low-Tax State	-.082***	-.082***	-.096***	-.087***	-.095***	-.089***	-.239***	-.026	-.093***	-.111***
	(.025)	(.026)	(.029)	(.028)	(.032)	(.030)	(.042)	(.021)	(.029)	(.027)
High-Tax State	-.040**	-.023	-.038*	-.034*	-.044**	-.054**	-.035	-.016	-.031*	.044*
	(.019)	(.019)	(.022)	(.019)	(.021)	(.026)	(.025)	(.018)	(.019)	(.026)
Same-Tax State	-.009	-.025	-.006	+.016	-.040	.017	-.081	-.021	-.040	.034
	(.080)	(.080)	(.078)	(.078)	(.185)	(.080)	(.202)	(.053)	(.088)	(.097)
Restriction	Time	Binary	No Ocean	No Internat.	MS, NC, NV, WI, OH	State Weights	Pop. Weights	Degree 3	Degree 7	Only Spatial Lag X's
Observations	15,260	15,260	13,045	14,259	12,869	15,260	15,260	15,260	15,260	15,260

The marginal effects represent a **per hour** change.

(1) repeats the baseline specification from the text when the running variable is time. (2) only uses a binary treatment indicator. (3) eliminates towns where the closest border would be an ocean or Great Lake. (4) drops jurisdictions where the closest border is Canada or Mexico. (5) drops states where town taxes are infrequent and the main form of taxes are district and county taxes. (6) weights each state equally in the regression. (7) weights by the population of the locality. (8) uses a cubic polynomial. (9) uses an order seven polynomial. (10) uses only the spatially lagged X's as instruments.

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

Table A.4: Mean Derivatives for Multiple Borders

Mean Derivative	(1)	(2)	(3)	(4)
Low-Tax State	-.082***	-.084***	-.092***	-.069
	(.025)	(.027)	(.029)	(.179)
High-Tax State	-.040**	-.037*	+.032	-.275*
	(.019)	(.021)	(.022)	(.146)
Same-Tax State	-.009	-.086	-.062	-.176*
	(.080)	(.079)	(.079)	(.071)
Marginal Effects	State	State	State	County
1st State	Y	Y	Y	N
2nd State	N	Y	Y	N
County Border	N	N	Y	Y
Border Counties?	Y	Y	Y	N
Observations	15,260	14,039	14,039	13,788

The marginal effects represent a **per hour** change.

(1) is the baseline specification. (2) adds a polynomial in distance from the second border plus appropriate interactions with the tax differential. The second closest border is measured using the crow-flies distance. (3) uses polynomials in driving time from the closest state border, the crow-flies distance to the second closest state border and the driving time to the closest county border plus the appropriate interactions. (4) includes a polynomial to the closest county border and drops state border counties. No polynomial in distance to the state border is included.

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

Table A.5: State by State Marginal Effects

State	Low Side	High Side	Same Side
Alabama	.065***		-.750**
	(.014)		(.319)
Arizona	-.137	.243	
	(.202)	(.375)	
Arkansas	-.608***	.810***	
	(.155)	(.247)	
California	.384	-.038	
	(.216)	(.039)	
Colorado	.111		
	(.146)		
Georgia	.011		.030
	(.059)		(.117)
Idaho	.310**	-.041	
	(.128)	(.079)	
Illinois	.167	.275**	
	(.482)	(.134)	
Iowa	-.097***	.116**	
	(.038)	(.049)	
Kansas	-.271	-.218	
	(.169)	(.175)	
Louisiana	-.478***		
	(.097)		
Minnesota	-.048*	.091	
	(.028)	(.062)	
Mississippi		.752***	.999***
		(.147)	(.262)
Missouri	-.041		
	(.139)		
Nebraska	-.177	.031	
	(.153)	(.073)	
Nevada	.112***	.986***	
	(.027)	(.173)	
New Mexico	.147	-.332**	
	(.125)	(.134)	
New York	-.377*		
	(.199)		
North Carolina	-.102	-.102*	
	(.086)	(.055)	
North Dakota	-.355***	-.011*	
	(.120)	(.125)	
Ohio	-.232**		
	(.091)		
Oklahoma	-.403***	2.396***	
	(.147)	(.657)	
South Carolina		.328*	
		(.170)	
South Dakota	-.007	.056	-.490***
	(.194)	(.727)	(.168)
Tennessee		.094	-.108
		(.091)	(.221)
Texas	-.474***	.052	
	(.109)	(.044)	
Utah	.179	.121	
	(.199)	(.097)	
Vermont	-.637	.078	
	(1.547)	(.407)	
Washington	-.175***	-.003	
	(.068)	(.065)	
Wisconsin	.045		
	(.049)		

The marginal effects represent a **per 1 hour** change. The regression specification allows for state fixed effects to be interacted with a cubic distance function and measures of the tax differential such that the gradient is allowed to vary by state.

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